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Aquaculture Country Profile

by Stephen Lindsay

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for the Secretariat of the Pacific Community,
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Figure 1. Map of the Federated States of Micronesia.
Source: http://www.lib.utexas.edu/maps

ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
AusAID	Australian Agency for International Development
CBD	Convention on Biological Diversity
CITES	Convention on the International Trade in Endangered Species
COM	College of Micronesia — FSM
CSP	Conservation Society of Pohnpei
CTSA	Center for Tropical and Subtropical Agriculture
EEZ	exclusive economic zone
ENSO	El Niño/Southern Oscillation Phenomenon
FAO	United Nations Food and Agriculture Organization
FSM	Federated States of Micronesia
FY	fiscal year
GDP	gross domestic product
JICA	Japanese International Cooperation Agency
NAC	National Aquaculture Center
NBSAP	National Biodiversity Strategy and Action Plan
NEMS	FSM Nationwide Environmental Management Strategies
NGO	non-governmental organization
NORMA	National Oceanic Resource Management Authority
NZAID	New Zealand Agency for International Development
OFCF	Overseas Fisheries Cooperative Foundation
PATS	Pohnpei Agriculture Training School
SPC	Secretariat of the Pacific Community
SPREP	South Pacific Regional Environment Programme
TTPI	Trust Territory of the Pacific Islands
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USP	University of the South Pacific

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DEFINITION OF TERMS

The following definitions have been used throughout this document.

Aquaculture: The farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms that are harvested by an individual or corporate body that has owned them throughout their rearing period contribute to aquaculture, while aquatic organisms that are exploitable by the public as common property resources, with or without appropriate licenses, are considered harvest of fisheries.

Freshwater culture: The cultivation of aquatic organisms where the end product is raised in freshwater; earlier stages of the life cycle of these species may be spent in brackish or marine waters.

Mariculture: The cultivation of aquatic organisms where the end product takes place is raised in sea water; earlier stages in the life cycle of these aquatic organisms may be spent in brackish water or freshwater.

Brackish water culture: The cultivation of aquatic organisms where the end product is raised in brackish water; earlier stages of the life cycle of these species may be spent in fresh or marine waters. Brackish waters are characterized by large seasonal fluctuations in salinity.

Extensive aquaculture: Organisms cultured at low densities, dependent on natural productivity for food but possibly assisted by fertilization of the substrate. Characterized by small-scale fish farming in individual ponds that are commonly rain-fed or supplied with running water. Requires low management input and is usually focused on subsistence.

Semi-intensive aquaculture: Organisms cultured at higher densities than are found in extensive culture; dependent on both increased productivity, using fertilizers and waste resources, and supplemental artificial feed. Characterized by production in earthen ponds with increased management inputs (e.g., manipulating water flow to provide oxygen and maintain water quality) and the supplementing of natural foods with artificial feeds; usually focused on crops of higher value, possibly to target local market demand.

Intensive aquaculture: Organisms cultured at high densities and dependent on artificial feed for their nutritional requirements.

1. EXECUTIVE SUMMARY

The Federated States of Micronesia (FSM) National Aquaculture Profile provides detailed information on the status of aquaculture development within FSM over the past decade. Data on state- specific programs and species culture are provided.

Aquaculture has been the focus of technical development attention in the FSM for well over a decade. Programs have been designed to provide either a means of economic development and/or increase natural stocks through restocking programs. Most programs have been supported through regional and international donor agencies and managed through government and educational institutions. The majority of aquaculture programs have been undertaken in the marine environment with only limited activities utilising brackish and freshwater.

The national and state governments have highlighted aquaculture as having the potential to provide economic benefits to the nation, including local job creation and increased exports. Other potential benefits include an increase in domestic protein sources stock populations. These various benefits have not not yet been realized. Private sector aquaculture development during the past decade has been minimal. To date no economically sustainable commercial aquaculture programs have been established within FSM.

Aquaculture has been categorized into three broad areas, all of which have been undertaken over the past decade. These include subsistence, commercial and restocking. FSM has diverse marine and freshwater ecosystems that provide a range of suitable environments conducive to the culture of a wide range species. The majority of past programs have been based on the biological parameters for culture; social and commercial issues have been poorly addressed. Actual aquaculture opportunities within FSM are considerably different than perceived opportunities documented over the last decade.

Nevertheless, the potential to develop selected aquaculture commodities within FSM does exist; however, such development requires the investment of time and revenue from the private sector and support, guidance and legislation from the national and state governments. It is expected that the future development of aquaculture within the FSM will focus on high value non- perishable export products.

Constraints and development issues are discussed. Improvement in communication and coordination between the agencies involved in aquaculture is a necessary step that would adopted to allow the coordination and harmonization of projects for the mutual benefit of all stakeholders.

Aquaculture statistics are included for all species cultured over the past decade.

2. BACKGROUND

The Federated States of Micronesia (FSM) is a young independent nation. It was a United Nations Trust Territory of the Pacific Islands (TTPI) administered by the United States of America until the two nations signed a Compact of Free Association in 1986 leading to termination of the the trusteeship in the same year. FSM became a member of the United Nations (UN) in 1991. The Compact treaty established a special relationship between FSM and the United States, with the latter providing economic assistance. At this writing (October 2002) the funding provisions established under the original compact are being renegotiated.

FSM is the largest and most diverse nation within Micronesian, and is comprised of four States: Yap, Chuuk, Pohnpei and Kosrae (Fig. 1). All but Kosrae State include more than one island; each state has considerable autonomy within the federation.

The total landmass of FSM is 438 sq mi (702 sq km), with a declared exclusive economic zone (EEZ) of more than one million square miles (1.6 million sq km). FSM is comprisesd 607 islands

(including both atolls and high volcanic islands), located between 1°–10° N and 138°–163° E (Fig. 1); land elevation ranges from sea level to 2,500 feet (791 m). FSM's climate is tropical and heavily influenced by the northeast trade winds. Strong trade winds prevail from December through April, with periods of weaker winds and doldrums occurring from May to November. Rainfall is high on the high volcanic islands of Kosrae, Pohnpei and Chuuk and can exceed 400 inches (1,016 cm) per year (SPREP, 1993; Lindsay and Edward 2000). The region is affected by storms and typhoons (generally more severe in the western islands), and by periods of drought and excessive rainfall associated with the "El Niño" (ENSO) phenomena. The drought of 1997—1998 was especially severe and resulted in groundwater sources being greatly reduced, damage to agricultural systems and coral bleaching (Falanruw, 2001).

The indigenous population is Micronesian; most of the people reside on the four main islands where the state capitals are located. The birth rate is high for the region; a census undertaken in July 2000 determined FSM's population to be 107,000, with 50% below 20 years of age. The past decade has witnessed both internal migration and emigration. All states have experienced a steady movement of population from outlying atoll and island communities towards the state capitals. This has resulted in the loss of traditional values and culture, increased urbanization, pressure on infrastructure and essential services, and increased utilization of the limited resources required for subsistence lifestyles. The increased number of people in the major centers has not stimulated an increase in job availability; as a result unemployment, especially in unskilled sectors, is high. The lack of secure employment has stimulated an ever-increasing outward emigration of citizens to Guam, Hawaii and the United States mainland in search of improved employment and educational opportunities.

Traditional, social and cultural institutions remain strong. Micronesian society is based on the extended family, which is responsible for the family's welfare, especially in relation to customary family land. Ownership patterns of land and marine areas varies between the states. In Kosrae and Pohnpei, land is both privately and state owned, while marine areas are managed by the state as public trusts. In Chuuk and Yap, the majority of land and marine areas are privately owned or managed by individual estates, and are acquired through inheritance, gift or, (recently) by purchase. Land cannot be sold to non-citizens of FSM (Falanruw 2001; URS 2001 FSM Government 2002). These land and marine ownership patterns greatly influence and complicate access for the development of aquaculture.

FSM's legislative and institutional framework includes both national and individual state constitutions; the national constitution is the basis for all legal authority and decision making. Eeach of the four states functions as a semi-autonomous government (Mace 1999). This structure makes gives of each state the prerogative to enact legislation in line with their powers (as defined in the FSM Constitution) addressing concerns and issues relating to the management of the state's natural resources and development (Mace 1999). Each state has made efforts to control development and manage natural resources through the creation of land use plans, coastal zone plans, legislation and regulations. The national government provides guidance and technical assistance to the states, when needed and requested, on matters related to planning, economic development, natural resources, fisheries, and the environment (Mace 1999).

The economy of FSM is small and is largely dependent on US aid provided through the Compact of Free Association (SPREP 1993). The US dollar is FSM's currency. Estimates of gross domestic product (GDP) performance indicate that since FY1987 the FSM economy has grown by an average annual rate of 2.5 per cent (FSM Government 2000a). The economic performance of each state varied over the period of from FY1987–FY1999, with GDP growing at an annual rate of 0.3 per cent for Chuuk State, 2.5 per cent for Kosrae State and 3.6 per cent for the Pohnpei and Yap States. While real GDP grew by annual average of 2.5 per cent during this period, this was nearly matched by the rate of population growth, resulting in only a very small increase in the level of real per capita income in the FSM (FSM Government 2000a).

The primary economic activities within FSM are subsistence farming and fishing, agricultural production, commercial offshore fishing, wholesale and retail sales and government services. The government services dominate the economy. The agriculture, fisheries, and tourism sectors are recognized as providing long-term growth potential and a comparative advantage to FSM. The major economic challenge facing FSM is to assist in building and developing an environment conducive to private sector growth (FSM Government 2000a 2000b and 2002). FSM public sector wages are currently almost double those of the private sector. The contribution of aquaculture to the nation's GDP is negligible.

The commercial tuna fishery (international and domestic) is the nation's second highest revenue earner with annual revenues between USD 10,000,000 and USD 15,000,000 million dollars (FSM Government 1999a). Fifty thousand tourists entered FSM in 2000 (Kosrae received 12%, Pohnpei 37 %, Chuuk 36 %, and Yap 15 %), contributing small revenue earnings to the economy of the country.

2.1 Coastal Resources

FSM's coastal marine resources are essential and vital to both the culture livelihood of the nation's people, and marine resources remain central to subsistence livelihoods. The majority of FSM's protein requirements are derived from these resources; more recently, coastal marine resources have been utilised for artisanal (small-scale commercial) activities and have contributed to economic development (FSM Government 1999b, 2000a and 2002). The sustainable management, utilization and conservation of coastal marine resources are high priorities.

The diversity of marine organisms and their ecological assemblages is high. Species richness and diversity for all inshore marine biomes decreases from west to east. Due to the small geographic scale of shallow water marine areas, marine ecosystem habitats and associated species compositions function on small spatial scales, providing a wide range of habitats within a small geographical location (Lindsay and Edward 2000).

Coral reefs and their associated ecosystems and biomes are the dominant shallow water marine feature. All major types of coral reefs are found within FSM, including barriers reefs, fringing reefs, atolls and submerged reefs. Common habitats include lagoon reefs (pinnacles and patches), passes, channels, shallow reef flats, terraces, submerged reefs, slopes, reef holes, embayments, quasi estuaries, seagrass beds, mangroves, and mud and sand flats (Lindsay and Edward 2000). Mangrove forests and sea grass beds are well developed, especially along the fringes of high islands and some atolls, and they are essential habitats for a wide range of marine organisms (Lindsay and Edward 2000).

The condition of coral reefs and inshore marine environments within FSM is generally good, with natural processes controlling reef condition; however, coastal resources, especially those close to urban centers, are becoming over exploited. Human activities such as inappropriate and unsustainable fishing practices, sand mining, marine dredging and pollution have greatly accelerated resource depletion and habitat alteration, degradation and in some cases destruction (Lindsay and Edward 2000; FSM Government 2000a, 2002).

Coastal marine resource utilization includes inshore fisheries, nearshore fisheries for large pelagic species, and demersal fisheries. Subsistence fishers make the greatest use of inshore resources, while artisanal (small-scale commercial) fishers concentrate on nearshore and bottom resources (FSM Government 2000). In the main islands of each state small-scale fishers sell catch in excess of their own requirements. These fisheries are essentially extensions of the subsistence fishery and rely primarily on inshore species (FSM Government 2000a, 2002).

All waters located within twelve nautical miles (22.2 km) of land are considered territorial seas, and fall under the jurisdiction of the respective state governments; all forms of foreign

commercial fishing are excluded in these areas. These inshore resources, which include all coral reefs and associated lagoon and coastal ecosystems, are managed, conserved and developed by the respective state governments in association with resource owners (FSM Government 1999a).

Each state has initiated programs to develop and establish marine conservation areas and marine management plans that allow for both the preservation and sustainable development of coastal resources. The development of appropriate responsible aquaculture programs in conjunction with marine management plans may provide the opportunity for states to increase their respective fisheries sector production while the ecological integrity of the environment.

FSM has acknowledged the need to address six inshore/coastal fisheries sector policy issues in order to allow the sustainable development of these valuable resources. These issues were discussed at the 2nd FSM Economic Summit (held in Pohnpei, September 1999) and fully endorsedment at the FSM Coastal Fisheries Consortium Meeting (held in December 2000). The policy issues comprised the following:

- ensure sustainable development of inshore marine resources and preservation of the inshore marine environment
- reform laws and regulations to enhance sustainable fisheries development and management
- human resource development
- promotion of value added investments
- control of fisheries access
- promotion e of public awareness of marine resource conservation.

Outside its territorial seas FSM has an EEZ covering over one million sq mi (1.6 million sq km). The management of the EEZ falls under the jurisdiction of FSM's national government. The conservation, management and sustainable development of all commercial fisheries within this area are mandated to the National Oceanic Resource Management Authority (NORMA). The tuna fishery within the EEZ constitutes the largest commercial exploitation of natural resources within FSM. This fishery has generated annual revenues between USD 10,000,000 and USD 15,000,000; average annual catch rates range from 80,000 to 250,000 metric tonnes. The tuna fishery utilizes three gear types; (purse seine, long line and pole and line) targeting three main species of tuna: skipjack *(Katsuwonus pelamis)*, yellowfin *(Thunnus albacares)* and bigeye *T(Thunnus obesus)*. In addition, other pelagic fish (swordfish, marlin and shark species) are also caught as a byproduct of this fishery (FSM Government 1999a).

3. AQUACULTURE

Aquaculture has been the focus of technical development attention in FSM for well over a decade, with each state undertaking numerous aquaculture programs. These programs have been designed to promote economic development through increased local private-sector employment opportunities, and increased natural stocks of certain species through nationwide restocking programs. The majority of past and current aquaculture programs have been developed and undertaken with funding support from a range of regional and international donor agencies, and managed through both government and educational institutions. Private-sector aquaculture development during this period has been limited, and has not proven economically sustainable or profitable. Unfortunately, despite the long-term commitment from government and educational agencies no economically sustainable aquaculture programs have been established within FSM to date.

Aquaculture has nevertheless been highlighted by the national and state governments as having the potential to provide significant benefits to FSM, including local job creation, increased domestic protein sources, increased stock populations and increased economic exports (FSM Government 2000). High population growth rates and uncertainty regarding the stability of

FSM's economy will result in increased pressure on marine and coastal resources, for both subsistence and commercial activities. Aquaculture products may play a role in supplying FSM's protein requirements, and may assist in reducing fishing pressure on natural resources, particularly inshore marine resources.

The national and state governments acknowledge that they have a leading role in promoting the development of a sustainable aquaculture industry (endorsed at the 2000 and 2002 Coastal Fisheries Consortiums). The role of government is to ensure that polices are in place to allow and promote an aquaculture industry, and to provide a legal mechanism to effectively regulate the industry. Debate continues regarding the infrastructure and monetary investment respective governments should make in developing a viable industry (defined as one that produces economic returns and creates long-term employment).

The national and state governments clearly acknowledged that there are three broad categories within which aquaculture can be undertaken; efforts have made in each area during the past decade. These include:

- subsistence
- commercial
- restocking/reseeding

The diverse marine and freshwater habitats and ecosystems of FSM provides a range of suitable environments conducive to the culture of a variety of native and introduced species. Before new aquaculture program development is initiated consideration must be given to economic, social and traditional parameters, however, as these restrict the potential viability of farming many species. Communication and coordination between agencies involved in aquaculture must be further improved to allow the coordination and harmonization of projects for the mutual benefit of all stakeholders. Actual aquaculture opportunities within the nation are considerably different than perceived opportunities documented over the last decade.

3.1 History of Aquaculture

Historically the islands that today make up FSM practiced only limited types of aquaculture. Traditionally, several species of marine organisms (e.g. giant clams, milkfish, rabbit fish, mullet) were held captive (and in some cases fed); they were used for special occasions, or provided a reserve food supply in times of poor weather, when inhibit other fishing methods could not be used. These practices are still in use today in the more remote communities and atolls.

The majority of aquaculture projects undertaken within FSM have been designed and implemented by the government and public sector educational institutions. External funding assistance has been provided by a variety of sources; the majority comes from the special relationship between FSM and the United States, and from technical assistance programs from Japan. Funding assistance has focused on technology transfer, and has provided international expertise to develop land and water based infrastructures (e.g. hatcheries and grow out farms). Technical information transfer, training and advice (primarily to government employees) and participation in regional information exchange programs and attend workshops and conferences have also been funded. The majority of these activities have been based on known technology developed outside the region, which that has been adopted and altered through applied research and extension to suit FSM's specific environmental and social requirements.

Most aquaculture programs undertaken within FSM have been marine based; very limited brackish and freshwater aquaculture programs have been undertaken focusing solely on milkfish and aquarium fish, respectively.

Private sector involvement in aquaculture in the past has been minimal, limited to small-s-scale government sponsored grow-out nursery farms (e.g. giant clams). Several commercial operations have initiated programs to culture a variety of marine based organisms; unfortunately almost all of these ventures either failed or have yet to become economically viable.

Aquaculture reseeding programs (e.g. giant clams and trochus) undertaken in FSM have generally the not attained their original objectives. Kosrae is the only state in which limited success has been achieved with giant clam reseeding. A "spin off" of these programs is improved public and community awareness of marine resource management and conservation practices, which have lead to the development of marine protected areas and sanctuaries (e.g. trochus).

Figures for annual aquaculture seed production and economic value are almost non-existent for the majority of aquaculture commodities at present , as most commodities are not produced on a commercial scale. The few aquaculture commodities that are commercially cultured are small Table 1 provides a summary of all species that have been cultured and their current operational status for each of FSM's the four states.

Table 1. List of government and private aquaculture activities undertaken within FSM and their current status.

Species Cultured	Pohnpei	Kosrae	Chuuk	Yap
Commercial (Private)				
Milkfish (*Chanos chanos*)	Yes*			
Marine shrimp (*Panaeus vannamei*)	Yes*			
Giant clams (*Tridacna* sp.)	Yes	Yes	Yes	Yes
Pearl oyster (*Pinctada margaritifera*)			Yes	
Wool sponges (*Hippospongia* sp.)	Yes			
Freshwater aquarium fish	Yes			
Government (Public)				
Giant clams (*Tridacna* sp.)	Yes	Yes	Yes	Yes
Trochus (*Trochus niloticus*)	Yes*	Yes*		
Green snail (*Turbo marmoratus*)		Yes		
Wool sponges (*Hippospongia* sp.)	Yes		Yes	Yes*
Pearl oyster (*Pinctada margaritifera*)	Yes			
Rabbit fish (*Siganus* sp.)	Yes*		Yes*	Yes*
Seaweed	Yes*	?	?	?
Hard coral (various genera)	Yes	Yes		
Soft coral (various genera)	Yes	Yes		

* Program not currently operating.

scale at best; and data have been included below.

Each state was provided with a list of potential aquaculture species suitable for tropical aquaculture (see Appendix 12). States were requested, through stakeholder consultation, to select those aquaculture species on which they would like to focus in the foreseeable future; they were requested to consider the economic potential of various species, and if culture was environmentally sustainable. The evaluation included subsistence, commercial and reseeding programs.

Development of some species has already begun, whilse on others it is yet to be initiated. In addition, evaluation protocols (see Appendix 1) were provided to each state to highlight specific aquaculture requirements that should be considered when evaluating each species. Table 2 provides an estimate of the area under cultivation of all species in each state for the year 2002.

Table 2. Estimated Total Culture Area (sq km) of species cultured in 2002 for each state.

Species Cultured	Pohnpei	Kosrae	Chuuk	Yap
Giant clams (*Tridacna* sp.)	Less than 0.1	0.6	Less than 0.1	Less than 0.1
Pearl oyster (*P. margaritifera*)	1.5	0	0.2	0
Wool sponge (*Hippospongia* sp.)	Less than 0.1	0	Less than 0.1	Less than 0.1
Freshwater aquarium fish	Tanks only	0	0	0
Green snail (*Turbo marmoratus*)	0	Less than 0.1	0	0

To provide a detailed account of past and current aquaculture activities, this report provides the information by state. Some replication between the states has occurred as several programs (e.g. the FSM government giant clam restocking program) have been a nation wide initiative. Appendix 3 provides a species-specific summary of aquaculture programs that have been undertaken in each of the sStates. Appendix 4 provides contact details of relevant government agencies, educational institutions, NGOs and private agencies within FSM that are associated with aquaculture. Appendix 5 provides a list of donor agencies that provide assistance for the development of aquaculture programs within FSM.

The state aquaculture lists below function, as a guide to assist with future development of aquaculture; all funding assistance programs should target these priority species.

4. KOSRAE STATE AQUACULTURE PROGRAMS

The state of Kosrae has one marine hatchery (owned by the national government), several government-owned ocean nursery giant clam grow-out farms and several private sector (assisted by government) grow-out farms on a small scale. No commercial aquaculture ventures are currently operating in the state.

The FSM National Aquaculture Center (NAC) is based in Kosrae with a mission of developing an integrated aquaculture program for the nation. The administration and financial support for the NAC falls under the responsibility of the National Fisheries Section of the Department of Economic Affairs, which is based in Pohnpei at the national government (SPC, 2001a). The NAC facility has propagated giant clams for a nationwide reseeding program, and more recently (1999 onwards) for export to international marine aquarium markets. The later effort is still in its infancy. In addition, the center has assisted the Kosrae State Fisheries Division to culture several marine gastropod species (trochus and turbo) for a Kosrae state reseeding program.

NAC regularly undertakes training programs on giant clam cultivation techniques, both within Kosrae and in the other states. Farmers are taught the necessary protocols for ocean nursery culture and are provided (free of charge) clams and equipment (wire mesh) to on-grow clams in their home states. In general, 4000 8–12 month old juvenile *T. derasa* are provided to each farmer. This program has been undertaken since the inception of the facility in 1991.

The private sector has had very minimal involvement in aquaculture in Kosrae. Private involvement to date has been limited to several small-scale giant clam grow-out nursery farms that have not yet reached fruition. These farms are extension farms of NAC and all farmers have received equipment, advice and assistance as described above.

4.1 Giant Clams

Giant clams are the primary organisms cultured in Kosrae for aquaculture. NAC has produced giant clams since 1991 for the dual purpose of producing giant clams for restocking depleted reefs and to develop commercial clam farming within FSM. Some success has been realized in the former effort, especially in Kosrae, but unfortunately very little commercial development has occurred. The NAC facility has produced well over one million yearling clams since its inception and has reseeded several hundred thousand juvenile clams to the reefs of Kosrae and the other states.

Four species of giant clams can be produced at this facility: *Tridacna maxima*, *T. derasa*, *T. gigas* and *Hippopus hippopus*. The three latter species are all derived from imported stocks, although they are endemic to the region. The majority of clams currently cultivated at the NAC facility are *T. derasa*.

Giant clam restocking programs have been successful in Kosrae State, but limited success has occurred in the other states, and the majority of clams distributed to the other states during the past decade have perished. The demise of these clams has been attributed to poor site selection, inclement weather conditions (tropical storms), predators and neglect.

Juvenile *T. derasa* and H. *hippopus* clams have been found on the reef flats of Kosrae, confirming that natural reproduction and recruitment is occurring from the original introduced clams and cultured (F2 generation) clams stocks held at the NAC ocean nursery site (Stephen Lindsay pers obs; Mr. Timothy, NAC manager, pers comm).

NAC's main ocean nursery site has approximately 30,000 mature clams and covers an area of about 500 sq meters. The majority of clams held at this site are F2 generated culture stocks derived from F1 cultured stock from Palau (*T. derasa*, *H. hippopus*, *T. gigas*), Marshal Islands (*H. hippopus*, *T. gigas*), Pohnpei (*H. hippopus*) and Kosrae (*T. maxima*). The majority of clams at this site are *T. derasa* and *H. hippopus;* all animals are used as broodstock.

Five small-scale private clam farms have been recently commissioned to attempt to develop commercial clam farming in Kosrae, and 2000 one-year old *T. derasa* clams have been supplied to each farm. These farms have been set up following the original format used over the past decade. Marketing options for these new farms have not changed significantly from the original programs. Appendix 6 provides a copy of a Memorandum Of Understanding that is recommended to be used between potential farmers and NAC.

4.2 Trochus

Adult trochus were introduced into Kosrae in the 1950's and distributed on the reefs to allow populations to establish themselves and in time provide a valuable community resource; the meat that can be consumed and the shell sold. Original populations of this animal have survived and have contributed sporadically to the domestic income of Kosraeans through the sale of the button industry.

During the past decade the Kosrae State Fisheries Division has operated a trochus (*Trochus niloticus*) reseeding program. These animals have been cultured at the NAC facility (with assistance from Japanese volunteers) and have been reseeded on the reefs of Kosrae.

The program ceased culturing trochus in 1999 and has focused on recruitment and survival of the original released trochus. High mortalities have been experienced (Mr. Robert Taulung, pers comm). Adult stocks from different sections of the reefs have been translocated in an effort to increase natural stocks of trochus around the island of Kosrae. Several trochus sanctuaries have been created and are enforced through legislation.

4.3 Green Snail

The green snail *(Turbo maormoratus)* was introduced to Kosrae in 1999 from cultured stocks (F1 generation) from Tonga. The goal is to provide a source of protein and, more importantly, a source of income from the sale of the shell. In total, 300 individuals were introduced and held

in quarantine at NAC before the majority of individuals were released onto the reefs of Kosrae. The introduction was undertaken jointly by the FSM National Fisheries Section and the Kosrae Department of Agriculture, Lands and Fisheries (Fisheries Development Section) with funds and technical assistance provided by the FAO-South Pacific Aquaculture Development Program (SPC 2001a). It will be several more years before offspring of the originally introduced animals can be found on the reefs.

The Kosrae Fisheries Development Section is monitoring the growth and survival of remaining stocks and several attempts to culture hatchery -kept stocks have been undertaken. Unfortunately, these animals have not produced viable female gametes to date. Nutritional limitations and the age of the individuals are suggested as possible causes. The propagation program is ongoing.

4.4 Other species

Over the past decade several small-scale government sponsored demonstration projects have been initiated in Kosrae to culture a variety of marine organisms. These include seaweed, hard and soft corals and rabbit fish. All projects have been on a very small scale (most have been brief training workshops), and none have initiated any further activities in the public or private sectors.

An aquaculture evaluation of the Utwe—Walung Marine Park was undertaken in 2001. with Tthe mangrove crab (*Scylla serrata*) was documented as the to be best community based aquaculture option (Lindsay, 2001). To date no farming has commenced, although community and individual interest is high (Mr. Robert Taulung, personal communicationpers comms).

4.5 Future Priority Activities

The following aquaculture species have been identified by Kosrae State for future consideration.

Molluscs	
bivalves	giant clams, pearl oysters
gastropods	trochus, green snail
Crustaceans	mangrove crabs, shrimp (marine and freshwater)
Finfish	milkfish, mullet, rabbit fish, grouper, aquarium species (freshwater and marine)
Anthozoa	soft corals
Seaweed	edible (*Caulerpa* sp., *Gracilaria* sp.) and carrageen producing (*Euchema* sp.)
Sponges	wool sponges
Holothurians	sea cucumbers (commercial)

5. POHNPEI STATE AQUACULTURE PROGRAMS

The state of Pohnpei has one government-owned marine hatchery located on Lenger Island, a small offshore island in Pohnpei lagoon, several government-owned ocean nursery giant clam grow-out farms and several private sector (government assisted) small-scale giant clam grow-out farms. Three educational institutions operate small research -oriented marine mollusc hatcheries and grow-out farms, which currently focus on the production of black lip pearl oysters destined for pilot training programs.

During the past decade private sector involvement in aquaculture has varied and a range of species have been trialed. Currently private aquaculture activities are limited to sponge farming and giant clams. Nukuoro Atoll (located 300 miles or 480 km south of Pohnpei) currently oper-

ates a community -owned black lip pearl oyster farm. None of these operations are presently economically sustainabe.

5.1 Giant Clams

Giant clams have been cultured within the state for well over a decade: the Pohnpei Division of Marine Resource Development has operated the Lenger Island hatchery since 1989, culturing clams and trochus sporadically.

The goals of the hatchery facility are similar to NAC. Over the past five years it has been jointly funded and operated through technical assistance from Japan's Overseas Fisheries Cooperative Foundation (OFCF) and the Pohnpei state government. Clams have been produced for reef restocking programs and community based commercial farming. Very limited success has been achieved within the state from reseeded clams. Over the past several years colorful hatchery produced *T. maxima* clams have stimulated a small commercial industry targeting the international aquarium market. However, the majority of clams sold to this market, at least in the past, were wild collected rather than not hatchery produced.

The Lenger island hatchery has produced over a quarter of a million six-month old clams since its inception and has reseed 30 per cent of these. Four species of giant clams can be produced at this facility: *Tridacna maxima*, *T. derasa*, *T. squamosa* and *Hippopus hippopus*. The latter two species have not been produced in large numbers. All species except *T. derasa* originate from native stocks; *T derasa* have been imported from Palau and Kosrae. The majority of clams currently cultivated at the Lenger island hatchery are *T. maxima*; most clams are kept within the hatchery facility until provided to the clam farms. The ocean nursery site for the facility houses only a small number of broodstock clams of all species destined for use in the hatchery.

Pohnpei state is part NAC's integrated aquaculture program, and has received both giant clams and technical training from this program over the past decade (SPCii 2000). All clams received have been held in the Lenger Island hatchery and on-grown in community or private ocean nursery giant clams farms. All government-raised clams are destined for reseeding purposes while both reseeding and commercial options are undertaken by the commercial and private farmers. Two species of giant clam (*T. derasa* and *H. hippopus*) have been received from the (*T. derasa* and *H. hippopus*) over the past decade. It is not known if juvenile clams have reestablished themselves onto the reefs within Pohnpei from mature reseeded stocks. High mortality rates have been reported for all clams introduced for ocean nursery culture in Pohnpei Sstate, which has been attributed to limited site locations, inclement weather conditions, predators and neglect.

Five small-scale private clam farms have been jointly commissioned by the state government and NAC to attempt to develop commercial clam farming in Pohnpei. These farms have been set up following the original format used over the past decade by NAC (described above under §4.0); each farm has been provided with 2000 one-year old *T. derasa* clams.

5.2 Educational Facilities

Three educational facilities located within Pohnpei state are actively involved with training, extension, and applied research on a range of aquaculture species, including giant clams, pearl oysters, wool sponges, and hard and soft corals.

The College of Micronesia (COM)
COM provides courses in aquaculture and marine science as part of its academic curriculum, and has an aquaculture research section. Recent topics include marine water quality evaluation and butterfly fish reproductive seasonality programs. A small salt-water multi purpose laboratory is currently under construction to assist in all activities related to marine science and aquaculture programs. COM has campuses in each state and all activities are nationwide.

The College of Micronesia - Land Grant Programs
The Land Grant program has been actively involved aquaculture training and extension activities in all states for well over a decade. The Land Grant program was the host agency for a regional aquaculture extension agent, who covered all US -affiliated Pacific Island country from 1998-2002. This position provided technical assistance on a wide range of aquaculture activities. Since 2001 a small-scale mollusc hatchery (funded by the US) has produced black lip pearl oyster spat for a small-scale pilot research program to develop black lip pearl oyster farming techniques in Pohnpei. This project is being conducted in conjunction with the government of Pohnpei, and has two small ocean nursery grow-out farms. The Land Grant program has affiliated programs in each state, but the majority of their aquaculture activities are confined to Pohnpei state.

The Pohnpei Agriculture Training School (PATS)
PATS is a high school that provides vocational training courses in aquaculture and marine science as part of the academic curricula for their senior students. The program provides theory and hands on practical skills. A small hatchery and several small ocean nursery farms are used as a training tool for the students. Species cultured include wool sponges, pearl oysters, clams and hard and soft corals. In addition the school undertakes small-scale applied research programs in aquaculture.

5.3 Sponge

Sponge farming has been undertaken for well over a decade in Pohnpei state. A US-funded program government was initiated in 1990 to undertake a series of applied research activities to develop farming techniques for the Pohnpean wool sponge, to provide related technical assistance and extension services to local communities and the private sector. Numerous small-scale demonstration and community-based farms have been developed within Pohnpei, as well as the other three states. Unfortunately, most have been left unattended since funding assistance for these programs ended. The Conservation Society of Pohnpei (CSP), PATS and a private company currently operate small farms that produce sponges for sale in local markets. CSP and PATS receive external funding for equipment, technical skills to farms maintenance .

5.4 Pearl Oyster

Pearl oyster (*Pinctada margaritifera*) has been cultured in Pohnpei since 1994 on the remote outer atoll of Nukuoro. The farm is community based (owned and operated by the municipal council) and has received funding support since its inception. The farm relies on the collection of wild spat (through the deployment of spat collectors) to supply the farm. The farm has received technical assistance since its inception; to date it has produced three small batches of black pearls. The farm has not yet achieved a positive cash flow. Farm management practices need to be further developed; the remoteness of the atoll from Pohnpei (300 miles) has impeded the delivery of supplies and technical personal.

COM's Land Grant program and PATs' two educational facilities have focused on basic technical development to provide information to the nation on hatchery breed spat and farm grow-out techniques. Both facilities received funding assistance from US government agencies to operate these programs. The Land Grant program currently has two small demonstration grow -out farms, one located within Pohnpei lagoon, and the other within an atoll.

Although much interest and funding money has been allocated to pearl oyster farming there has been no domestic or foreign private sector investment in this industry to date.

5.5 Trochus

Adult trochus were introduced into Pohnpei and several outer atolls in the 1950s. Original populations of this animal have survived and have contributed sporadically to the domestic incomes of Pohnpei through the sale of shell for the button industry.

During the past decade the Pohnpei state government has operated a trochus (*Trochus niloticus*) reseeding program. These animals have been cultured at the Lenger Island hatchery with the assistance from Japanese volunteers and have been reseeded on the reefs of Pohnpei. Currently the state is not culturing trochus. Very high mortalities have been experienced from animals reseeded (Donald David, pers comm). Translocations of adult stocks from different sections of the reefs and several outer islands have been undertaken in an effort to increase natural population stocks of trochus around the island of Pohnpei. Several trochus sanctuaries have been created, and related enforcement legislation enacted.

5.6 Private sector

The private sector has been actively involved in aquaculture in Pohnpei State. Several commercial companies have been or are currently operating within the state, and involve both local Micronesian citizens and foreign investors.

Pacific Water Resources
Based in Pohnpei, Pacific Water Resources began operations in 1997, and focused production on milkfish (*Chanos chanos*) to be used as bait for the domestic tuna longline fleets. The company has imported milkfish fry, on grown them in land based nursery tanks, with final grow-out stages undertaken in brackish water earthen and made man ponds (old dredge sites). In addition the company has experimented with penaeid shrimps (*Panaeus vannamei*) in their land-based facility, and has evaluated the culture potential of mangrove crabs, tilapia and grouper. At the writing of this report the facility was not operating, but the owner indicated the operation will be recommence in the near future.

Pohnpei Natural Products
The main focus is the culture of the Pohnpean wool sponge for domestic and regional markets. This company has been in existence since 1990 and has produced and marketed sponges since this time. The operation is small but has a constant production. In addition, the company has experimented with the culture of hard and soft corals and giant clams at their marine sites, and cultures freshwater aquarium fish. Currently only sponges are sold.

Micronesian Aquaculture and Marine Consultant Services
A private company, they provide professional aquaculture and coral reef marine management services to FSM and the Pacific region. The company is based in Pohnpei. The director has been involved with many of the aquaculture projects mentioned in this report.

5.7 Other species

Over the past decade numerous small-scale demonstration projects have been initiated in Pohnpei on a wide range of marine and freshwater organisms. Funded by the government and educational institutions, these include programs that focused on cultivation techniques for seaweed, hard and soft corals and rabbit fish. All projects undertaken have provided technical assistance, training programs and equipment. All were designed to provide information for local communities (and in some cases the private sector) to participate and in time take on these potential economic activities. Unfortunately, none of these programs have resulted in a profitable economic business. Most programs operated between one and two years and were small in scale.

5.8 Future Priority Activities

The following aquaculture species have been identified by Pohnpei State for future consideration.

Molluscs	
bivalves	giant clams, pearl oysters
gastropods	trochus
Crustaceans	mangrove crabs, shrimp (freshwater)
Finfish	mullet, rabbit fish
Seaweed	carrageen producing (*Euchema* sp. and *Kappaphycus* sp.)
Sponges	wool sponges
Holothurians	sea cucumbers (commercial)

6. CHUUK STATE AQUACULTURE PROGRAMS

Chuuk has no government -owned or operated aquaculture hatchery, none has operated within the state during the past decade. The state has several government ocean nursery giant clam grow-out farms, and several semi private (government assisted) small-scale giant clam grow-out farms. There are several commercial aquaculture ventures, including a privately owned and operated marine mollusc hatchery, which has produced trochus and pearl oyster spat. Several privately -owned ocean nursery grow-out operations target clams, sponges, and hard and soft corals. Information is not presently available to provide direct evidence if these commercial facilities and companies are economically self supporting and sustainable.

6.1 Giant Clams

Giant clams are Chuuk's primary aquaculture species. Chuuk state is part NAC's integrated aquaculture program and has received both giant clams and technical training from this program over the past decade (SPC 2001b). All clams received have been cultured in government-owned and semi-private and community- based ocean nursery giant clam farms with all government clams destined for reseeding purposes whilst the latter group of farmers undertakes both reseeding and commercial options.

Chuuk state has received two species of giant clam from NAC (*T. derasa* and *H. hippopus*) over the past decade. It is not known if juvenile clams have reestablished themselves onto the reefs within Chuuk from these imported stocks. High mortality rates have been reported for all clams introduced for culture in Chuuk state, which has been attributed to poor site selection, inclement weather conditions, predators and neglect. The exception is a semi government ocean nursery farm located in the waters off Tonans Island within Chuuk lagoon. This farm has been in operation since 1994 and has received technical assistance and clams regularly from NAC. Mature clams are present at this farm.

Five small-scale private clam farms have been jointly commissioned by the state government and NAC to attempt to develop commercial clam farming in Chuuk. These farms have been set up following the original format used over the past decade by NAC (described above under §4.0); each farm has been provided with 2000 one-year old *T. derasa* clams.

6.2 Private sector

The private sector has been actively involved in aquaculture in Chuuk State. Two commercial companies are currently operating within the state and involve both local Micronesian citizens and foreign investors.

The Polle Trading Company
Based on Polle Island in Chuuk lagoon, Polle Trading Company focuses on a range of animals that target both domestic and international markets. These include: giant clams for food consumption (domestic and off island) and the aquarium trade; hard and soft corals for the international aquarium trade; wool sponges for domestic sale; pearl oysters; and marine finfish. The company was initiated in 1998 and is currently developing both land and water based facilities and finalizing marine lease agreements. Production of products is on a small scale, and there has been limited sale of product to date. The company has been involved in government sponsored training programs (e.g. NAC giant clam training) and has received outside consultant assistance in the development and planning stages of its operation.

The Micronesia Marine Co. Ltd
Micronesia Marine Co. Ltd has a mollusc hatchery (South Pacific Ocean Research Center) located on the island of Weno; operations commenced in early 2001. This hatchery has produced juvenile T*rochus niloticus* and (in association with several local communities) has released juveniles onto reefs with the objective of allowing these individual to mature and increase local stocks for commercial harvesting. The reseeding efforts have been small scale and survival and growth rates have not be determined to date. In October 2002 the facility was currently not culturing trochus.

The company has undertaken hatchery experimentation of black lip pearl oyster culture over the past several years on a small scale. Several trials have been undertaken with wild collected broodstock, but with limited success in spat production. Efforts are ongoing and oysters have been shipped to one investor's parent company in Korea for similar hatchery trails.

There are several small-scale giant clam grow-out nursery farms that are privately owned and community based operating within the state. These farms are extension farms of the government reseeding program and NAC aquaculture initiative.

6.3 Sponge

An experiential sponge demonstration farm was developed in 1997 on the island of Tonoas in Chuuk lagoon. The project was funded by US government, which supplied the technical assistance and equipment required. The farm is still in existence and maintained by the island's community. Small numbers of sponges have been sold on the domestic market.

6.4 Other species

Over the past decade several small-scale government -sponsored demonstration projects have been initiated in Chuuk to culture a variety of marine organisms. These have included rabbit fish and seaweed. All projects have been very small in scale (most were brief training workshops), and none have initiated any further activities.

There have been several fish cages deployed within the state for the purpose of holding marine fish destined for the live fish trade. It is unknown if these fish were fed during this holding period. These operations were short lived and are not operating at the time of writing. All fish were wild collected (hook and line) and held in lagoon cages for short periods of time before being sent to markets. Cyanide and other banned activities have been reportedly used during these operations. In addition, dynamite usage for the collection of reef fish has unfortunately been a common practice within Chuuk over the past several decades.

6.5 Future Priority Activities

The following aquaculture species have been identified by Chuuk State for future consideration.

Molluscs	
bivalves	giant clams, pearl oysters
gastropods	trochus
Finfish	milkfish, mullet, rabbit fish, grouper
Anthozoa	soft corals
Seaweed	edible (*Caulerpa* sp., *Gracilaria* sp.) and carrageen producing (*Euchema* sp.)
Sponges	wool sponges
Holothurians	sea cucumbers (commercial)

7. YAP STATE AQUACULTURE PROGRAMS

The state of Yap has no aquaculture hatcheries at stage, and none have operated within the state during the past decade. Giant clams have been Yap's main aquaculture species.

7.1 Giant Clams

There are several government-owned ocean nursery giant clam grow-out farms and several semi-private small-scale giant clam grow-out farms located both within the main island of Yap proper and the outer atolls. No commercial aquaculture ventures are currently operating in the state.

Yap state is part of NAC integrated aquaculture program and has received both giant clams and technical training from this program over the past decade (SPC 2001c). All clams received from this program have been cultured in government and semi-private and community -based ocean nursery giant clam farms with all government clams destined for reseeding purposes while the latter group of farmers undertake both reseeding and commercial options.

The first introduction of 12,000 giant clams (*T. derasa*) originated from Palau, with funding assistance from US agencies (SPC 2001c). Since this first shipment, clams have been sent to Yap from Palau (*H. hippopus* and additional *T. derasa*) and from Kosrae (*T. derasa*).

A marine survey undertaken in 1993 located several juvenile *T. derasa* clams on the reef flats of Yap proper confirming that natural reproduction and recruitment has occurred from the original introduced clams (Lindsay 1993). However, a high percentage of all clams introduced for culture in Yap state have perished; this has been attributed to limited site locations, inclement weather conditions, predators and neglect. High numbers have been lost to several severe typhoons during the 1990s.

The private sector has had very minimal involvement in aquaculture in Yap. Private involvement to date has been limited to several small-scale ocean nursery giant clam grow-out farms that have not yet reached commercial fruition. These farms are extension farms of the government-reseeding program and the NAC aquaculture initiative.

Five small-scale private clam farms have been jointly commissioned by the state government and NAC to attempt to develop commercial clam farming in Yap. These farms have been set up following the original format used over the past decade by NAC (described above under §4.0); each farm has been provided with 2000 one-year old *T. derasa* clams.

7.2 Sponge

An experiential sponge demonstration farm has been developed on the outer island of Ulithi in 1995. The project was funded by the US government, which supplied required the technical assistance and equipment. The farm is still in existence and maintained by the island's community. Limited numbers of sponges have been sold to the domestic tourism market.

7.3 Other species

Over the past decade several small-scale government sponsored demonstration projects have been initiated in Yap to culture a variety of marine organisms. These have included rabbit fish, freshwater shrimp and seaweed. All projects have been very small scale, (most have been brief training workshops), and none have initiated any further activities.

7.4 Future Priority Activities

The following aquaculture species have been identified by Yap State for future consideration.

Mollusc	
bivalves	giant clams, pearl oysters
gastropods	green snail
Crustaceans	mangrove crabs
Finfish	grouper, rabbit fish
Seaweed	edible (*Caulerpa* sp. and *Gracilaria* sp.)
Sponges	wool sponges
Holothurians	sea cucumbers (commercial)

Appendix 7 provides a list of aquaculture species highlighted by priority ranking (1-5) by the state of Yap. Highest priority is 1 and the lowest is 5.

8. CONCERNS, CONSTRAINTS AND DEVELOPMENT ISSUES

Aquaculture has been the focus of technical and development attention in FSM for well two decades, with numerous demonstration projects and documents emphasizing the high potential of certain species and specific methodologies for the development of aquaculture (FSM Government 2002b), with projected long-term sustainable employment opportunities. These predictions and demonstration projects currently continue. Despite the widespread interest and support from the national and state governments encouraging commercial activities, there has been very little commercial development to date, and at present there is no economically viable aquaculture facility operating within FSM.

It would appear that all sectors, including donor organizations, have had unrealistic expectations concerning the general prospects for commercial development of an aquaculture industry that provides even modest revenue earnings, and that these prospects have been overstated (FSM Government 2002b). Unfortunately, the majority of projects undertaken ceased to operate once donor- funding was removed. These results may not directly reflect on project delivery, but may instead reflect the lack of awareness and interest in these economic alternatives, and may indicate that these programs have not successfully targeted interested community groups and individuals. Nevertheless, selected aquaculture commodities do have realistic potential, but require an investment of time and revenue from the private sector, and support, guidance and legislation from the national and state governments. It is therefore expected that the future development of aquaculture within FSM will focus on high value non- perishable export products.

Economic assessments — including profit return analysis, market potential (domestic and international), value adding and infrastructure requirements, costs and reccurring expenses — have been poorly addressed in past aquaculture programs. This is clearly demonstrated by the lack of commercial companies actively involved in aquaculture. There is an urgent need to include economic assessments as an integrated component of all future aquaculture program development, especially those designed to increase long-term sustainable incomes. Economic viability, rather than the relative ease of culturing selected species, should be the driving force behind all future aquaculture programs. not species biological ease of culture. It is therefore recommended that only those species with economic potential should be considered for development.

FSM has a wide range of biological habitats suitable for the culture of organisms, and a variety of organisms have been successfully cultured. Successful production of these organisms has achieved primarily with the aid of technical assistance and funding. FSM has a shortage of skilled personnel, and capacity building and technology transfer are important requirements that should be addressed, especially when the private sector is involved. However, technical information and skills are a secondary concerns when considering the viability of FSM's aquaculture industry, as these are readily available within the region. Long-term economic viability is the overriding factor.

Several educational institutions have provided basic aquaculture skills and training. These programs have been well supported by the students and provide a through grounding on a wide range of necessary skills; unfortunately, the lack of commercially viable aquaculture companies has meant that graduating students are unable to secure work in this field.

There appears to be an illusion that the successfully production of an organisms directly leads to a successful, economically profitable industry. Sadly this is not the case. In addition, the assumption that the production of organisms from aquaculture activities will play a leading role in assisting FSM conserve and manage its natural resources (through reseeding programs) has yet to be demonstrated. One possible exception are the giant clam restocking programs in Kosrae state, which continually report juvenile settlement from cultured broodstock on their reefs. Nevertheless, reseeding aquacultured products will never replace sound environmentally- based marine management protocols as a basis for the mainteainance of healthy natural populations.

Technical assistance is required to implement long-term development of FSM's aquaculture industry. Assistance is required to develop reliable domestic and international markets, products and public awareness. The latter must involve the private sector, government (state and national), educational agencies and NGO's. In addition, improved communication and awareness between government, educational institutions and the private sector is required to prevent duplication of activities, allow for sharing of experiences and mistakes, make better use of funding opportunities and increase efficiency.

Above all, greatly increased public education and awareness programs need to be implemented before an industry is likely to develop on a commercial basis. The public sector must be instrumental in assisting the private sector to develop. Furthermore, there is a general lack of financial advice, awareness and assistance provided by both government and private sector lending institutions to develop aquaculture business. There are neither tax incentives nor other regulatory exemptions for aquaculture companies at present. These issues need to be addressed to provide an environment that is conducive to industry development.

Domestic markets for aquaculture products are small and are in local products compete directly with imported commodities, with the latter dictatinge price. Freight costs for perishable aquaculture commodities designed for off island markets (domestic and international) are high, and airfreight is very limited and unreliable. Furthermore, large markets for these products are a considerable distance from FSM airports, and travel times in some case preclude certain commodities from being economically viable.

Access to long-term land and marine leases for commercial aquaculture activities is problematic and currently little legislative support is available for long-term water usages. In Chuuk and Yap states, individuals and communities hold sovereignty rights over both land and water, which further complicates access agreements; state and municipal governments are empowered to manage land and water within the states of Pohnpei and Kosrae.

Codes of best practices should be developed for all aquaculture activities to ensureing quarantine facilities are in use and translocation of commodities within and outside the nation follow recent FSM government legislation (i.e. National Resource Management Law, title 23, FSM Code). International standards and conventions relating to for quarantine, traded species (e.g. CITES) and genetic and intellectual property rights all need to be enforced.

The development of aquaculture associations and development of working groups will assist information exchange and further promote the development of an aquaculture industry within the nation. Private sector interest and concerns need to be fully supported and addressed by the public sectors, and information exchange and transfer must be a priority. The development of an aquaculture industry must follow internationally acceptable environmental regulations and the integrity of the environment must be foremost in all development plans.

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10. APPENDICES

Appendix 1. Evaluation protocols for species with potential for aquaculture in the Federated States of Micronesia.

(Adapted and modified from Hayden 1988 and Lindsay, 2001).

Three major issues must be considered in evaluating the aquaculture potential of any species:

1. **Seedstock availability.** Can seedstock be collected from the wild or can be seedstock reliably and economically be produced in hatcheries? What impact will seedstock collection have on wild populations and related fisheries?
2. **Production Technology.** If seedstock are available, does the technology exist to grow-out the species economically? Issues to consider include site suitability, feed availability, access to trained staff, etc.
3. **Markets.** Can the product be sold at a price higher than the cost of production? What impact will increased production have on price and demand?

In addition, various aspects of the biology and culture of potential aquaculture species should be evaluated. These include:

Category	Remarks
Spawning natural and hatchery	- What is known about the reproductive behaviour of the species? - Has it been successfully reared in captivity? Can overseas data on the same or similar species be easily adapted locally? - Is natural seed readily available and plentiful? What about broodstock? - Knowledge of the reproductive biology, larval behaviour and adult maturation of a species (natural and hatchery) is essential in order to control or manipulate factors such as breeding, environment, nutrition, maturation, and metamorphosis. Such information is also necessary when enhancing (by selective breeding) desirable qualities such as rapid growth rate and adaptability to intensive culture. More importantly, it provides the information necessary to manipulate breeding cycles, so that production can take place outside the time constraints of the natural spawning seasons.
Ongrowing techniques	- It is essential to understand the habitat requirements of a species in order to develop ideal culture conditions, either for hatchery rearing or for enhancement of wild stocks. - Knowledge of the growth and behaviour of an organism (such as optimal growth conditions, feeding behaviour, feed conversion efficiency, etc.) will largely determine the potential for culture and the rearing methods which can be used (e.g. mangrove crabs are cannibalistic and so need individual grow-out containers).
Food supply	- Many of the species identified as good candidates for aquaculture may require research into suitable diets for some part of their life cycle. Species that consume natural phytoplankton (such as filter-feeding bivalves) are ideal, as they do not require artificial feeding. Fish species (such as milkfish and mullet) that consume both natural plankton and supplementary feeds are also ideal. Grouper and freshwater eels, however, require large quantities of a variety of foods, and could benefit from research to enhance their flesh colour when fed in captivity. - Availability of local material for feed is important. [A cost benefit compromise exists between species requiring large quantities of supplementary feed and the value and marketability of the product].

Diseases	- Aquaculture often requires that animals be handled frequently and kept in much higher densities than in their natural habitats. This added stress is a frequent cause of disease in many cultured species, especially finfish. Bivalves have a distinct advantage in this respect, as they typically do not require caging, and can be stocked at normal densities in their natural habitats. Diseased animals cannot be treated unless they are confined, however, so if infected, bivalve losses may be high. Treatment of diseased finfish is possible in ponds or via their feed.
Water quality issues	- Some species (such as filter-feeding bivalves) must be grown in very clean [but with high primary productivity] water to ensure the public health safety of the final product, despite the fact that they may grow faster and fatter in less pristine conditions. Other species (such as lobsters) produce metabolic by-products, which can become toxic to the species if particular care is not taken to maintain good water quality during culture.
Harvest and post-harvest handling	- For many species harvesting technology has already been developed or can be adapted from elsewhere. For others, it needs to be designed to ensure the quality of the product is retained.
Cost effectiveness of each stage	- One of the most important criteria to evaluate. - Costs of production for some species can be prohibitive. - Consider whether returns are attractive?
Markets	- Is there an existing market demand for the product? - Value in the local/export market? - Potential for export? - Will it require extensive marketing campaigns and what does this do to production costs? Many aquaculture ventures fail because they fall into the trap of being production-led because the species is easy to grow instead of being market-led. - Is aquaculture of the species increasing elsewhere in the world?
Status of species	- Was species introduced? - Is species indigenous? - Is species commercially fished locally? - Is species readily consumed? Some species would be regarded as pests if they were released into the wild and may therefore have strict quarantine requirements placed on them. If broodstock has to be imported, information will be required on the likely environmental impact of accidental or intentional release of the species.
Investment	- Is initial capital investment high and prohibitive? - Are maintenance costs high? - Is maintenance labour intensive and complicated?
Site Availability	- Are suitable sites available? - Ownership and potential lease options?

Appendix 2. **A comprehensive list of Ppotential aquaculture species that can be cultured in the tropics.**

Organisms		Priority Rating
Molluscs — bivalves	giant clams rock oysters pearl oysters green mussel venus shells (*Anadara*) ark shells (*Gafrarium*) scallops limpets	
Molluscs — gastropods	trochus green snail abalone	
Crustaceans	mangrove crabs lobster (marine) shrimp (freshwater) shrimp (marine) crayfish (freshwater)	
Fin fish	milkfish mullet rabbit fish grouper eels tilapia barramundi freshwater aquarium fish marine ornamental aquarium fish	
Anthozoa	hard corals soft corals	
Seaweed	edible (*Caulerpa* sp., *Gracilaria* sp.)	
	carrageen producing (*Euchema* sp., *Kappaphycus* sp.)	
Sponges	wool sponges	
Echinoderms	sea cucumbers sea urchins	

Appendix 3. State summary of aquaculture activities over the past decade.

Species	Gov. or Private	Native or Introduced	Culture environment	Culture technology	Culture system	Culture scale	Current status (2002)	Donor Agency
Kosrae								
Giant clams *T. gigas* *T. derasa* *T. maxima* *H. hippopus*	 Gov. Gov. Gov. Gov.	 Introduced Introduced Native Native/Intro.	 Marine Marine Marine Marine	 Tanks, Ocean Nursery and wild release	 Hatchery Hatchery Hatchery Hatchery	 Intensive – Hatchery Extensive grow-out	 Operational Government Semi-Private Government	 FSM Nat Gov. CTSA, SEA Grant, PAA, PIN OFCF, JICA
Trochus	Gov.	Introduced wild release	Marine	Tanks, Hatchery	Hatchery Operational	Intensive FSM Nat. Gov.	Not	Kosrae State, JICA,
Green snail	Gov.	Introduced	Marine	Tanks, wild release	Hatchery	Intensive Hatchery	Operational	Kosrae State, JICA
Hard and soft coral	Gov.	Native	Marine	Tanks	Grow-out	Extensive	Not Operational	FSM Nat. Gov. CTSA
Pohnpei								
Giant clams *T. derasa* *T. maxima* *T. Squamosa* *H. Hippopus*	 Gov. Gov. Gov. Gov.	 Introduced Native Native Native	 Marine Marine Marine Marine	 Tanks, Ocean Nursery and wild release	 Hatchery Hatchery Hatchery Hatchery	 Intensive – Hatchery Extensive grow-out	 Operational Government Semi-Private Government	 FSM Nat Gov. CTSA, SEA Grant, PAA, OFCF, JICA.
Trochus	Gov.	Introduced	Marine	Tanks, wild release	Hatchery	Intensive Hatchery	Not Operational	State Gov., JICA, OFCF
Sponges wool	Gov. Private	Native	Marine	Ocean Nursery	Lagoon	Extensive grow-out	Operational Small Scale PAA, PIN	CTSA, Land Grant, COM, CSP,
Pear l oysters	Gov. Education	Native	Marine	Tanks, Ocean nursery	Hatchery 2 small	Intensive – Hatchery Extensive grow-out	Operational Small scale	CTSA, Land Grant, State Government, PATS
Milkfish	Private	Introduced	Brackish	Tanks, Ocean nursery	Fry Imported, Land/water Grow-out	Intensive Hatchery Grow-out	Not – Operational	Private, FSM Development Bank

Marine shrimps	Private	Introduced	Brackish	Tanks, Ocean nursery	Fry Imported Land/water Grow-out	Intensive –Hatchery Grow out	Not Operational	Private, FSM Development Bank
Hard and soft coral	Gov.	Native	Marine	Tanks	Grow-out	Extensive	Not Operational	State. CTSA, Land Grant PATS
Sea weed	Gov.	Native/intro.	Marine	Ocean nursery	Grow-out small scale	Extensive operational	Not	State Gov.
Rabbit fish	Gov.	Native	Marine	Ocean cages	Grow out	Extensive small scale	Not operational	State Gov. COM, CTSA
Chuuk								
Giant clams *T. derasa* *H. hippopus*	Gov. Gov.	Introduced Native	Marine Marine	Tanks, Ocean Nursery and wild release.	Hatchery Hatchery	Intensive – Hatchery Extensive grow-out	Operational Government Semi-Private Government	FSM Nat Gov. CTSA, SEA Grant, PAA, PIN, JICA
Sponges Wool	Gov. Private	Native	Marine	Ocean Nursery	Lagoon	Extensive grow-out	Operational Small Scale	CTSA, Land Grant
Hard and soft coral	Private	Native	Marine	Tanks	Grow-out	Extensive	Not Operational	Private CTSA
Trochus	Private . and Gov	Introduced	Marine	Tanks, wild release	Hatchery	Intensive Hatchery	Operational	Private State Gov.
Pearl oysters	Private . and Gov	Native	Marine	Tanks, Ocean nursery	Hatchery	Intensive – Hatchery Extensive grow-out	Operational Small scale	Private State Gov.
Rabbit fish	Gov.	Native	Marine	Ocean cages	Grow out	Extensive small scale	Not operational	State Gov. COM, CTSA
Yap								
Giant clams *T. gigas* *T. derasa* *H. hippopus*	Gov. Gov. Gov.	Introduced Introduced Introduced	Marine Marine Marine	Tanks, Ocean Nursery, wild release.	Hatchery Hatchery Hatchery	Intensive – Hatchery Extensive grow-out	Operational Government Semi-Private Government	FSM Nat Gov. CTSA, SEA Grant, PAA, PIN, JICA
Rabbit fish	Gov.	Native	Marine	Ocean cages	Grow out	Extensive small scale	Not operational	State Gov. COM, CTSA
Sponges Wool	Gov Community	Native	Marine	Ocean Nursery	Lagoon	Extensive grow-out	Operational Small Scale	CTSA, Land Grant, State Gov.

Appendix 4. Aquaculture contact list

Government Agencies

National Government	Mr Francis Itimai Deputy Assistant Secretary for Fisheries Department of Economic Affairs PO Box PS-12 Palikir, Pohnpei, FM 96941 PH: 691 320 2620 Fax: 691 320 2079 Email: fsmfisheries@mail.fm
	Mr Mason Timothy Manager The National Aquaculture Center PO Box 807 Tofol, Kosrae, FM 96944 PH: 691 370 2069 Fax: 691 370 2651 Email: fisherieskos@mail.fm
Overseas Fisheries Cooperative Foundation (OFCF)	Atoll Resource Management Support Project PO Box 2112 Palikir, Pohnpei, FM 96941 PH: 691 320 8581 Fax: 691 320 3386 Email: OCFCFSM@mail.fm
Kosrae State Government:	Mr Robert Taulung Chief, Division of Fisheries Development Department of Agriculture, Lands and Fisheries PO Box 82 Tofol, Kosrae, FM 96944 PH: 691 370 3031 Fax: 691 370 3362 Email: fisherieskos@mail.fm
Chuuk State Government	Mr Romio Osiena Deputy Director Department of Marine Resources PO Box 207 Weno, Chuuk, FM 96942 PH: 691 330 2660 Fax: 691 330 4157
Pohnpei State Government	Mr Donald David Chief, Division of Marine Development Office of Economic Affairs PO Box Draw B Kolonia, Pohnpei, FM 96941 PH: 691 320 2795 Fax: 691 320 4241 Email: pnimd@mail.fm
Yap State Government	Mr Andrew Tafileichig Chief, Division of Marine Resource Management Department of Resources and Development PO Box 251 Colonia, Yap, FM 96943 PH: 691 350 2294 Fax: 691 350 4494 Email: mrmdyap@mail.fm

Educational Institutions

College of Micronesia	Mr Yasuo Yamada Vice President Co-operative Research Education PO Box 159 Palikir, Pohnpei, FM 96941 PH: 691 320 2480 Fax: 691 320 2972 Email: vpcre@comfsm.fm

College of Micronesia-Land Grant Programs	Dr Singeru Singeo Executive Director PO Box 1179 Kolonia, Pohnpei, FM 96941 PH: 691 320 2462 Fax: 691 320 2726 Email: ssingero@mail.fm
Pohnpei Agriculture Training School (PATS)	Father Greg Muckenhaupt Director PO Box 39 Kolonia, Pohnpei, FM 96941 PH: 691 320 4778 Fax: 691 320 6046 Email: gmuckenhaupt@nysj.org
Non-Governmental Organizations	
Conservation Society of Pohnpei (CSP)	Mr Willy Kostka Executive Director PO Box 2461 Kolonia, Pohnpei, FM 96941 PH: 691 320 5409 Fax: 691 320 5063 Email: csp@comfsm.fm Private Sector
Pohnpei State	Mr. Yalmer Helgenberger Director, Pacific Water Resources PO Box 1687 Kolonia, Pohnpei, FM 96941 PH: 691 320 3672 Fax: 691 320 3708 Email: pacskylite@mail.fm
Chuuk State	Mrs Iromy Bruton and Mr Larry Bruton Managing Directors Polle Trading Company PO Box 700 Chuuk State, FM 96942 PH: 691 330 Fax: 691 330 email: LarryBruton@mail.fm
National	Mr Stephen Lindsay Director Micronesian Aquaculture & Marine Consultant Services PO Box 2178 Kolonia, Pohnpei, FM 96941 PH: 691 320 7257 Fax: 691 320- 7257 Email: slindsay@mail.fm

Appendix 5. Donor agencies and organizations that can assist in aquaculture development within the Federated States of Micronesia

COUNTRIES	PROGRAM
Australia	AusAID, ACIAR, ASEOP, AVA
Canada	Pacific Development Programs
China	Pacific Development Programs
Europe	EU Pacific Programs
Japan	Overseas Fisheries Cooperative Foundation (OFCF), JICA
New Zealand	NZAID
United States	Department of the Interior (various programs)

INTERNATIONAL ORGANIZATIONS

ADB
FAO
SPC
UNDP
UNEP
USP
World Bank
WorldFish Center

International foundations
NGOs

Appendix 6. National Aquaculture Center giant clam contract agreement

FSM National Aquaculture Center
PO Box 1086
Kosrae State, FSM, 96944
PH/Fax: (691) 370-2069

CONTRACT AGREEMENT

This agreement between the National Aquaculture Center (NAC) and the individual name below (Clam Farmer) relates to the Sale, Repurchased and Marketing of Giant Clams.

1. The NAC will supply 4,000 juvenile clams to the farmer during the first year of this agreement.

2. NAC will lend the clam farmer the necessary cages, trays and frames for containing the clams. If and when the clam farmers are no longer raising clams, these materials will be returned to the NAC.

3. NAC will provide technical assistance and site survey to the clam farmers. Instructions for checking, cleaning, thinning and measurement of clams will provide by the NAC.

4. When the clams reach a length of 5 _ inches or larger, individual farmers may market the clams at their own price (e.g.: NAC will market the above size for US$2.00 per clam).

5. NAC will select 500 clams of the 4,000 for broodstock. Therefore, individual farmers can only market 3,500 clams.

6. If the farmer wishes to purchase clams form the NAC, the discount price will be US$0.50 cents per clam.

_____
Acting Manager Signature Date:_____

_____
Clam Farmer Signature Date:_____

Appendix 7. Yap State priority ranked aquaculture species

Highest priority is 1 and the lowest is 5.

Organisms		Priority Rating
Molluscs — bivalves	giant clams	1
	rock oysters	3
	pearl oysters	1
	green mussel	3
	venus shells (*Anadara*)	3
	ark shells (*Gafrarium*)	3
	scallops	3
	limpets	3
Molluscs — gastropods	trochus	2
	green snail	1
	abalone	3
Crustaceans	mangrove crabs	1
	lobster (marine)	2
	shrimp (freshwater)	3
	shrimp (marine)	3
	crayfish (freshwater)	3
Fin fish	milkfish	3
	mullet	2
	rabbit fish	1
	grouper	1
	eels	4
	tilapia	5
	barramundi	3
	freshwater aquarium fish	3
	marine ornamental aquarium fish	3
Anthozoa	hard corals	2
	soft corals	3
Seaweed	edible (*Caulerpa* sp., *Gracilaria* sp.)	1
	carrageen producing (*Euchema* sp., *Kappaph1ycus* sp.)	3
Sponges	wool sponges	1
Echinoderms	sea cucumbers	1
	sea urchins	2