Sustainable Aquaculture Evaluation and Options for the Utwe-Walung Conservation Area Kosrae State, FSM.

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Acronyms

CASO	Conservation Area Supporting Officer
CITES	Convention in International Trade of Endangered Species
DRC	Development Review Commission
FSM	Federated States of Micronesia
NAC	National Aquaculture Centre
NGO	Non Government Organization
OFC	Overseas Fisheries Corporation - Japanese Government.
SPBCP	South Pacific Biodiversity Conservation Program
SPC	South Pacific Commission
SPREP	South Pacific Regional Environment Programme
UWCA	Utwe Walung Conservation Area
UWMCA	Utwe Walung Marine Conservation Area

1.0 Executive Summary

An evaluation of all aquaculture sites and a review of information available on all past and present aquaculture activities were undertaken for Kosrae State, FSM. In addition, a general review of aquaculture programs within the Federated States of Micronesia (FSM) was included. Previous attempts to develop community-based aquaculture in Kosrae have not been successful and still require substantial Government assistance to continue basic initiatives.

The Utwe - Walung Conservation Area (UWCA) was evaluated for potential community based economic and sustainable aquaculture enterprises. Evaluations outside the Utwe – Walung Marine Conservation Area (UWMCA) were not included. However, information pertaining to the marine park is relevant to other areas of the island.

There are two "levels" of community based aquaculture development feasible for Kosrae. Both of which are limited by market demand and market access. These are:

1. Community based farming for subsistence purposes.
2. Community based commercial farming for domestic and international markets.

The prospect of large scale commercial aquaculture development within Kosrae is not an economic nor environmental prospect.

A list of potential species has been developed and basic life history data and culture methods relevant to the environmental parameters for Kosrae are included. Information pertaining to potential domestic and international markets is discussed.

Current export limitations (space and costs) and lack of economic data limits the prospects of community aquaculture to the cultivation of mangrove crabs (*Scylla serrata*) for the domestic markets. Additional information pertaining to the cost and quantity of local feed must be acquired before this venture is undertaken. The cultivation of mangrove crabs must be developed in conjunction with a suitable and enforceable management plan.

A number of recommendations based on the results of this study are discussed.

The UWMCA could also consider developing stock enhancement programs with the local communities. This could include species such as giant clams, marine fish (milkfish, mullet) and Trochus.

2.0 Background

The Federated States of Micronesia (FSM) consists of four separate states, one of which is Kosrae. The island of Kosrae comprises of one single island located in the easternmost section of the FSM. Kosrae, which is the second largest island in the FSM, is located 5

degrees north, and 163 degrees east, and has a landmass of 42.3 square miles (68 kilometres). The island consists of a main volcanic island, and a much smaller volcanic island located in the northeastern side of the island, Lelu. Approximately, seventy percent of the land mass comprises of steep and rugged mountains, with several peaking at over 2,000 feet (650 meters) above sea level. There is a narrow coastal strip surrounding the majority of the island that house the islands population.

Kosrae has an equatorial tropical climate, with high humidity, high temperatures and heavy rainfall. The average temperature is 81 degrees F (27°C), with only minor variations during the year. Humidity levels range between 78% and 95% as a result of the high rainfall 200 - 280 inches/year (470cm – 630cm/year). Steep mountain slopes, which rise rapidly within a few kilometres of the shoreline, cause rapid cooling, results in the high rainfall.

Kosrae is situated at the edge of the trade wind belt to its east, which is dominant between November and June. There are two main seasons: a dry season between May and October, and a wet season between November and May. The island rarely experiences typhoons, which tend to have their origins to the west, off the coast of Pohnpei and Chuuk.

In geological terms, Kosrae is quite young, having formed some 1-2 million years ago over a hot spot trace in the earth's crust. Kosrae is the geological youngest of the FSM islands. The main island consists of two rugged basalt mountain ranges rising to over 2,000 feet (650 meters). The highest point on Kosrae is Mount Finkol.

The island has a fringing reef around its entirety (there is no lagoon) with a proportion being exposed at low spring tides. The largest reef flat occurs on the western side of the island in the municipality of Walung. It is this region that the majority of shallow water aquaculture can be undertaken. In addition, several reef "blue holes" are located on the reef flats and can be used for aquaculture purposes. The reef edge and slope in general, are small less than 100 feet (30 meters) and drop away to deep oceanic water. These areas are not suitable for aquaculture. Tidal range is approximately 5 feet (1.8 meters).

There are a number of small rivers on the island that terminate into estuarine regions on the reef flat. The largest estuarine system is located within the UWCA. In addition, numerous freshwater springs occur commonly around the island, the majority present in times of heavy rainfall.

Seafood is an important part of the diet in Kosrae and is a particularly important source of dietary protein. Most subsistence fishing is undertaken by both genders. Women undertake the majority of inshore reef fishing and gleaning activities whilst the men partake in fishing off the reef, which includes spearing and harvesting on the reef slopes and pelagic fishing.

Population growth, urbanisation and the use of efficient fishing technology (nets) and loss of essential fisheries habitat have placed pressure on Kosrae's inshore fisheries resulting in over exploitation of fish stocks. The development of appropriate responsible aquaculture programs in conjunction with marine management plans may provide an opportunity for Kosrae to increase its fisheries sector production. Potential benefits from aquaculture development generally considered include:

- Increased protein
- Increase income generation
- And for selected species, import substitution

The term *aquaculture* is used in this report to include "the artificial production of marine and freshwater organisms". "The term "stock enhancement" is used in this report where organisms are released from artificially reared organisms to enhance natural stocks of that species.

3.0 Recommendations

The Utwe Walung Marine Conservation Area has the potential at the community level to cultivate marine and estuarine organisms, including commercial and subsistence activities. The development of sustainable aquaculture is a potential option to increase the opportunity for the local stakeholders to generate additional incomes. Large-scale aquaculture is not recommended for the Conservation Area nor Kosrae. Limited resources, limited economic potential and environmental concerns greatly inhibit the development of large aquaculture enterprises (such as shrimp farming).

All aquaculture development programs should be developed along side suitable resource management plans that provide the mechanisms for sensible control measures and enforcement.

The recommendations presented below can also apply and have wider implications for the island of Kosrae and should be reviewed in this context.

Several species are technically and environmentally suitable to be cultured within the UWMCA however only one species has the potential to be economically viable. It is therefore recommended that:

- The cultivation of the mangrove crab (*Scylla serrata*) for the domestic market be considered for development as an alternative source of income for the UWMCA. It has the highest commercial potential and is proposed for implementation. The development of this activity must be developed alongside a suitable management plan. Additional information pertaining to a regular source of feed and its associated cost must be evaluated economically before this program is implemented.

- In conjunction with the above activity an aquaculture grower association should be developed for the culture of mangrove crabs and the association must have clearly defined goals and objective. This association could take on a similar organization structure as the citrus growers association in Kosrae.

- A targeted public awareness program should be undertaken to provide information on possible aquaculture projects that have potential for the communities and families within the park boundaries. Discussions should include all culture activities required and possible marketing aspects. Community approval and support must be gained before these initiatives and other aquaculture projects are implemented.

- Additional species should be considered only once additional information is gained and when circumstances allow such enterprises to be economically viable.

- There is a need for professional assistance to develop technical aquaculture and business management skills for individual farms and the community at large.

- A marine resource management plan needs to be developed for the park, which includes regulations and permitting process for potential aquaculture programs. This also could include the processes required to secure marine tenure for aquaculture purposes.

- A resource evaluation is required to determine the existence, abundance, location and population size of the mangrove crab populations. This evaluation will also provide information to assist in the development of a management plan for this species.

- Assistance from an international volunteer program should be considered to assist in the development and implementation of public marine awareness and aquaculture programs.

4.0 Introduction

The Utwe-Walung Marine Conservation area was established through donor support assistance from the South Pacific Regional Environment Programme (SPREP) through their South Pacific Biodiversity Conservation Programme (SPBCP). A Conservation Area Supporting Officer (CASO) has been appointed to manage and develop the program. The objective of the marine park is to manage and protect the unique and underdeveloped marine environment in the southwest corner of Kosrae. The park is governed by community based management procedures, which aim to meet the needs and interests of the local resource users and owners while conserving the biological diversity within the Parks boundaries.

Community discussions have identified two areas for income generation that have a high probability of economic success, and are in conformity with the parks conservation objectives. These are ecotourism and aquaculture. In order to develop and implement sustainable aquaculture projects the marine park members requested a feasibility assessment to be undertaken.

The aquaculture consultancy has strengthened the capacity of the CASO, in consultation with village communities and other agencies, to identify the potential for aquaculture ventures following sustainable environmental and community management practises. The specific tasks as outlined in the TOR are:

1. Conduct basic survey and research on existing aquaculture activities on the island of Kosrae and other states of the Federated States of Micronesia (FSM). Draw information on issues, constraints and opportunities related to early attempts at development of aquaculture activities,

2. Undertake an evaluation of various options for the development of aquaculture initiatives in the context of the Utwe-Walung Conservation Area (UWCA) and its communities including:

- Identify the full range of potential aquaculture development options that might be suitable for the UWCA,

- Gather basic information on which species are appropriate, suitable cultivation procedures, the raw materials, capital and skills required to operate such ventures, the marketing potential and the economics for each proposed aquaculture resource and venture based on available data,

- Assess the relative suitability of the various options, on a range of criteria including potential profitability, social acceptability, risk and environmental impact.

3. Discuss in the form of a debriefing the outcomes of the evaluation and option study with members of the UWCA staff, and produce a report incorporating the findings of the above tasks with appropriate recommendations.

4.1 Utwe - Walung Marine Park (UWMP)

The Utwe-Walung Conservation Area lies in the southwestern corner of the island of Kosrae, the easternmost state of the Federated States of Micronesia (FSM). It currently extends from just west of the village of Utwe to a point west-southwest of the village of Tafunsak. The seaward boundary is the 12-mile territorial limit. The conservation area incorporates the Utwe-Walung Marine Conservation Area, which comprises the mangrove forests, mangrove channels, coral reefs and associated environments held in

trust by the Government of Kosrae, and managed by the Utwe-Walung Marine Park Board.

The Utwe-Walung mangrove wetland area is the largest area of mangroves on the island, and has some unique characteristics, including the fact that it exists behind sand and coral rubble barrier islands - a geomorphic feature considered to be different from most other mangrove forests of the Pacific region (Merlin et al 1993). The mangroves are particularly well developed, due largely to the fact that these forests have escaped the devastation caused to other mangroves in Micronesia from a major cyclone in 1918. Some trees are over 200 years old, approximately 60 percent of the mangrove forest has an average trunk diameter in excess of 30cm and individual fuliohfohl (*Sonneratia alba*) trees exceed 40m in height. The UWMCA also includes a freshwater swamp dominated by the ka tree (*Terminalia carolinensis*). Ka occurs in association with nunu (*Horsefieldia nunu*), which, like ka, is endemic in Kosrae and traditionally is its most important timber tree.

The UWMCA involves a marine environment including a fringing reef, reef crest and slope. The reef slopes of the marine park are in excellent condition and healthy, exhibiting high diversity of hard corals and other marine life. A marine resource evaluation to provide information on species presence and abundance has not been undertaken at this present stage and should be included in the programs list of activities. This information will provide the base line biological information to allow the development of appropriate marine management plans and marine reserves. The state Marine Resource Division (MRD) has implemented several coral monitoring sites within the park and several marine sanctuaries have either been legislated (Trochus) or currently under consideration (Giant Clam) within the parks proposed boundaries. The management of these small sanctuaries will need to be coordinated between all government agencies and community stakeholders.

The Trochus sanctuary is located just inside the northeastern side of the UWMCA in Walung. The sanctuary has been legislated into state law and includes the reef slope, reef crest, reef flat and associated mangrove forest on shore. MRD is responsible for both monitoring and enforcing the sanctuary. Monitoring of Trochus stock abundance and size is preformed on an annual basis within the sanctuary as well as around the island. All data generated is used to develop policies for Trochus harvesting within the state.

There are several coral "Reef Check" monitoring sites within the UWMCA as well as around the island of Kosrae. Each sites has a permanent transect that is used to collect data on percent live coral cover. Monitoring of these sites is a combined effort of MRD, DRC, a local NGO and interested individuals. All data collected is sent to reef Check for analysis.

In addition, there is a need for specific marine management plans to be developed and implement within the park. These management plans are required to enable subsistence activities to continue whilst providing a suitable system to be implemented that will

prevent species from being exploited. A sea cucumber marine evaluation was recently undertaken with recommendations to manage the commercial sea cucumber industry for the island of Kosrae. This report included sea cucumber stock abundance and recommendations for Walung, which is inside the proposed park boundaries. These activities are outside the terms of reference for this consultancy.

The target audience for this report is the Conservation Area Support Officer (CASO) for the marine park, the members of the UWMCA board, other government agencies and interested individuals within the community. The report therefore has been written to cater for this audience.

5.0 History of Aquaculture in Kosrae State

The following provides a brief outline of the history of aquaculture in Kosrae, including past and current activities that have been undertaken.

Kosrae has little tradition in the field of aquaculture and only a few species have been attempted. Traditionally several species of marine organisms (eg giant clams, milkfish, rabbit fish, mullet) have been held captive and in some cases fed, to be used for special occasions or to provide a reserve seafood supply in times of inclement weather. This practices is seldom used today.

All aquaculture projects that have been undertaken in Kosrae State have all been designed and implemented by the government (public sector) through external funding assistance from a variety of sources, the majority of which is derived from the compact of free association with the government of the United States of America. The funding assistance has provided infrastructure development (Kosrae Hatchery), technical training and advice primarily to State government employees and the regular opportunity to attend international workshops and conferences.

The FSM National Aquaculture Centre (NAC) has received the bulk of this assistance. The centre was commissioned in 1991 and has been involved in the culture of marine animals since then. This facility has targeted the production of Giant Clams and several marine gastropods (Trochus and Turbo). The centre regularly undertakes training programs on these animals for the FSM states.

The private sector has had very minimal involvement in aquaculture in Kosrae. Private involvement to date has been limited to several small-scale clam growout nurseries farms that have not yet reached fruition. These farms are extension farms of the NAC and all farmers have received advice and assistance.

There appears to be a general lack of aquaculture technical and marketing knowledge within the community, which further constrained by the lack of financial advice and assistance provided by both government and private sector lending institutions. An appropriate education awareness program is required to be developed and implemented

before an industry is likely to develop on a commercial basis. The public sector must be instrumental in addressing these concerns and assisting the private sector to develop.

All export opportunities for perishable aquaculture products that are both technically and environmentally viable for the park are not economically profitable at the present time. High airfreight costs and uncertainty of freight space combined with poor international marketing skills prevent export opportunities from being economically viable. This however may change in the future.

Future programs must be assessed also from a business perspective and marketing activities should be at least as important as methods of culture. The development of growers associations should contribute to this endeavour. Similar private sector associations are currently operating in Kosrae for agricultural produce and similar programs need to be developed for aqauculture products.

5.1 Giant Clams

Giant clams are the major aquacultured organisms cultured in Kosrae and within the FSM. These activities have been ongoing for over a decade.

The national government of the FSM established the National Aquaculture Center (NAC) in Kosrae state in 1990. This centre has been designed to produce giant clams for the dual purpose of restocking depleted reefs and to develop commercial clam farming within the FSM. Some success has occurred for the former, especially in Kosrae, unfortunately very little commercial development has occurred. This facility has produced giant clams since 1991 and has reseeded several 100,000 juvenile clams to the reefs of Kosrae and the other FSM states.

Four species of giant clams can be produced currently at this facility; these are *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 are *T. derasa*. Each species exhibits different growth parameters and have different commercial values and markets (eg: *T. maxima* aquarium trade, *T. derasa* domestic food trade). The various products and markets must be explored to produce a viable industry.

Giant clam restocking programs has been successful in Kosrae state, however very limited success has occurred in the other states. The majority of clams distributed to the other states of the FSM 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.

Clams destined for reef restocking programs have been provided free of charge from the NAC to the state marine resource divisions to be distributed to farmers and communities

at the discretion of these agencies. Training has been provided by the NAC to all prospective clam farmers

There have been several attempts in the past decade to develop commercial farms and markets for clams, both in Kosrae and the other states of the FSM by the NAC. Unfortunately, the farms and marketing activities have yet to reach their full potential.

Assistance is therefore required to develop reliable domestic and international markets for clam products. The involvement of both the private sector and government agencies (state and national) is required to develop an industry.

Currently, two small-scale private clam farms (2000 one year old *T. derasa* clams each farm) have been recently commissioned to attempt to develop clam farming in Kosrae. These farms have been set up following the original format used over the past decade. Marketing options for these new farms have not change significantly from the original programs. Appendix 1 provides a copy of the Memorandum Of Understanding between the farmers and the NAC.

A smaller giant clam hatchery is operating in Pohnpei state. The goals of this facility are similar to the NAC. This facility over the past five years has been jointly funded and operated by Overseas Fishing Corporation of Japan (OFC) and the states marine resource division. Clams have been produced for reef restocking programs and community based commercial farming. The limitations mentioned above are relevant for this operation. The duplication of activities of these facilities is a concern.

5.2 Trochus

During the past decade Kosrae State marine resource division has operated a trochus (*Trochus niloticus*) reseeding program. These animals have been cultured at the NAC with the assistance from Japanese Volunteers and have been reseeded on the reefs of Kosrae. High mortalities have been experienced (Mr Robert Tulung, personal communications).

Several reseeding sites are located within the UWMCA. Trochus have not been cultured for commercial purposes. The program is not currently culturing this animal and is focusing on recruitment and survival of the original batches of trochus. In addition, translocations of adult stocks from different sections of the reefs in an effort to increase population stocks of Trochus around the island of Kosrae have been undertaken. These translocations have occurred within the parks boundaries. The current Trochus sanctuary as described above is located within the parks boundaries.

5.3 Green Snail

Similarly, the green snail *Turbo marmoratus* has been introduced to Kosrae from Tonga by the state marine resource division and held at the NAC. This species has been released

on the reefs of Kosrae with the objective that in time a natural breeding population will establish itself and these animals, like Trochus, can be harvested for the shell trade. It will be quite some time before this can be clarified. The introduction sites are not within the UWMCA. Currently, there are no plans to cultivate this species at the NAC.

In addition, several small-scale government sponsored demonstration projects have been tried over the past decade to culture a variety of marine organisms. These include seaweed, hard and soft corals, rabbit fish, milkfish and mullet. These small-scale projects have not initiated any further activities.

Aquaculture programs in the other states of the FSM are similar to that of Kosrae and are listed below. Table 1 provides a list of aquaculture programs that have been undertaken within the FSM to the knowledge of the author. The table has been divided up into two categories, government and private operations. Within the private operations there is no commercially viable farm currently operating. The one exception may be the commercial pearl farm in Chuuk state. Information on this farm is not available but has financial assistances from foreign investors.

Table 1. List of government and private aquaculture activities undertaken within the FSM.

Species Cultured	Pohnpei	Kosrae	Chuuk	Yap
Commercial (Private)				
Milkfish	Yes*			
Giant Clams	Yes*	Yes*	Yes*	
Pearl Oysters			Yes*	
Sponges	Yes*			
Government (Public)				
Giant Clams	Yes*	Yes*	Yes*	Yes
Trochus	Yes#	Yes#		
Green Snails		Yes#		
Sponges	Yes*		Yes*	Yes*
Pearl Oysters	Yes*			
Rabbit fish	Yes		Yes	Yes
Hard Coral (experimental)	Yes*	Yes		
Soft Coral (experimental)	Yes*	Yes		

* Programs currently operating. All other programs have been discontinued.
# Organisms have been cultured and reseeded. No current propagation occurring.

6.0 Aquaculture Development in Kosrae

Despite the less than successful history in Kosrae, the community perceives aquaculture to be a viable means of generating incomes, increasing fisheries production and providing additional protein for the local population (authors personal communications). The processes involved to achieve these objectives are poorly understood in Kosrae.

Aquaculture development in the UWCA, Kosrae and the FSM can be broadly divided into two "levels" of community-based aquaculture. Both of which are limited by market demand and access and other external and internal factors. These are:

1. Community Based farming for subsistence purposes.
2. Community Based Commercial farming for domestic and international markets.

The prospect of large-scale commercial aquaculture development within the UWCA is neither an economic nor an environmental prospect. Limitations of available water, land, international markets and possible pollution problems exclude the development of large scale activities eg shrimp farming.

Community based farming for subsistence purposes has been attempted in the past in Kosrae with minimal success. The production of marine and freshwater organisms for the purpose of home consumption is a viable option within the park. Typical aspects of subsistence aquaculture are:

- Utilisation of existing bodies of water (reef, lagoon, estuarine and freshwater) or the construction of small size ponds, cages or other holding structures.
- Low level of input, both economic and labour. Species that do not require feeding (eg giant clams, corals) or require only supplement feeding that is readily available and cheap (eg mangrove crabs).
- Excess product may be sold or given to extended family members.

Community based commercial farming has not developed in Kosrae for either the domestic or international markets despite previous attempts. Typical aspects of commercial farming are:

- Construction of specialised aquaculture production facilities, including hatcheries, on land nurseries and growout ponds and farms.
- High level of capital investment and skilled personnel. Feed costs, algal production units etc.
- Market developments. Rely on stable and regular markets. Kosrae has limited domestic markets (small population); export markets are larger, however freight restrictions current constrain export.

6.1 Species Suitability Summary

Table 2 briefly summaries the basic data of each species examined during the evaluation of the UWMCA. Species profiles identified as potential aquaculture candidates have been individually discussed in Appendix 2. There are a number of assumptions made. All comments are desgined for small subsistence based farms. Seed stock is defined as being able to collect or culture enough juveniles to allow culture practises to be developed. Markets indicate that product can be sold currently. It does not reflect volume or potential revenue. A priority was assigned for each species considered for aquaculture. Species assigned a rating 3 or higher were not included in the evaluation. These species were excluded because they lacked suitable regular supply of seedstock, the lack of growout sites or lacked markets.

Table 2. briefly summaries the basic data of each species examined during the evaluation of the UWMP.

Species	Endemic	Previously Introduced (Surviving)	Seed Available Locally	Grow Out Sites	Markets Local L Export E	Market Potential	Priority (1-5)
Giant Clam	Yes	Yes (Yes)	Yes	Yes	L E	Medium	2
Trochus	Yes	Yes (Yes)	Yes	Yes	L	Low	3
Green snail	No	Yes (Yes)	?	Yes	L	Low	5
Abalone	Yes	No	?	Yes	E	Low	4
Rock Oyster	Yes	No	?	Yes	E	Low	3
Pearl Oysters	Yes	No	?	No	E	Low	5
Green Mussel	No	No	No	No	E	Low	5
Hard Corals	Yes	No	Yes	Yes	E	High	3
Soft Corals	Yes	No	Yes	Yes	E	High	3
Sponges	No	No	No	Yes	L E	Medium	3
Seaweed	Yes	No	Yes	Yes	L E	Low	4
Sea Cucumbers	Yes	No	Yes	Yes	L E	Low	4
Mangrove Crab	Yes	No	Yes	Yes	L E	High	1
Lobster (marine)	Yes	No	Yes	Yes	L E	Low	5
Shrimp (FW)	Yes	No	?	Yes	L E	Low	4
Shrimp (Marine)	No	No	No	No	L E	Low	5
Crayfish (FW)	No	No	No	Yes	L E	Low	4
Milkfish	Yes	No	?	Yes	L	Medium	2
Mullet	Yes	No	?	Yes	L	Medium	2
Rabbit fish	Yes	No	?	Yes	L	Medium	2
Grouper	Yes	No	?	Yes	L	Medium	3

Eels	Yes	No	?	Yes	L E	Low	4

FW = Freshwater

6.2 Species Technical Suitability Summary

Giant clams: Good potential, based on community development with the private sector involved in marketing. Propagation and distribution currently carried out by the NAC. Consistent supply and technical support required from NAC. Reliant on continuation of NAC.

Trochus: Poor potential for community based farming. Excellent potential as a harvested animal. Harvesting must be managed within the UWMCA.

Green Snail: Poor potential for community based farming. Current introductions are not located in the UWMCA. In time (15+ years) potential for harvesting of these animals may be an option.

Abalone: Very limited potential. No source of neither seedstock nor culture methods developed for community based farming.

Pearl Oysters: Very low potential for farming in Kosrae. No suitable environment, nor endemic stocks.

Rock Oyster: Low potential for community cultivation, almost no domestic or close international markets.

Green mussel: Low potential. Lack suitable grow out sites and no source of juveniles.

Hard Coral: Good potential. High species diversity and habitats for community based farming. Constraints present due to export limitations and costs of freight. Export only.

Soft Corals: Good potential. High species diversity and habitats for community based farming. Constraints present due to export limitations and costs of freight. Export only.

Sponges: Medium potential and suitable for community farming. No stocks available locally. An introduction programs needs to be developed before the culture of sponges is feasible.

Seaweeds: Low potential for cultivation, extremely limited domestic market potential. Income expectations to high for this activity.

Sea Cucumbers: Very low potential. Seedstock not available – need to be produced in a hatchery.

Mangrove Crab: Excellent potential and much interest in mangrove crab aquaculture. Location and seedstock available. Feed source needs to be developed and established.

Lobster (marine). Low potential for community based farming. High potential as a harvested animal. Harvesting must be managed within the UWMP.

Shrimp (Freshwater): Very limited potential. Very small domestic and off island markets. Seedstock supply unknown.

Shrimp (Marine): Very limited potential. Lack of land for culture and markets very limited. Environmentally not suitable.

Freshwater: Crayfish: Low potential for community farming. Must be imported and very limited markets.

Milkfish: High Potential for community based farming. Fish fry need to be sourced, should be locally available. Local market present. Possibly used by the tuna long line fishing fleet for bait.

Mullet: High Potential for community based farming. Fish fry need to be sourced should be locally available. Local market present. Possibly used by the tuna long line fishing fleet for bait.

Rabbit fish: High Potential for community based farming. Fish fry need to be sourced should be locally available. Local markets present.

Grouper: Limited potential – lack of available seedstock, lack of suitable farming sites and limited markets

Freshwater Eels: Limited potential due to lack of identified source of seedstock and culture sites, especially in the UWMCA.

7.0 Proposed Aquaculture Project Design

It is proposed that the culture of the mangrove crab (*Scylla serrata*) be considered for implementation as a community based aquaculture program for the UWCA. The culture of this animal is technically, economically and environmentally suitable for cultivation within the Kosrae marine park. Additional information is required before this program is initiated. This includes the development of a specific management plan for the collection of crabs suitable for culture and a guaranteed source of feed.

Three other aquaculture programs have been included in the report as they are technically and environmentally suitable for inclusion in the park. However, each animal requires additional biological information or changes in international airfreight chargers and space before they become economically viable alternatives. They are: Giant Clams, Hard and Soft Corals and three species of fish (Milkfish, Rabbit Fish and Mullet). All four programs are discussed below and specific cultured requirements can be found in Appendix 2 and 3.

7.1 Mangrove Crabs

The wild collection of mangrove crabs for both subsistence and commercial sale (domestic and off island markets) has been undertaken within the UWMCA for many years. Population stocks have decreased in recent years, which has caused concern within the general public and has initiated a moratorium that restricts the collection and sale of mangrove crabs.

It is clear that mangrove crab populations are declining (authors personal communication) and a well-structured management plan must be developed to preserve stocks whilst allowing subsistence and commercial activities access to stocks. The development of a management plan is outside the scope of this TOR, however the author wishes to highlight the importance of an enforceable management plan. The management plan must include the wild collection of stock for subsistence and commercial activities (includes aquaculture) as well as preservation measures.

Mangrove crabs can be cultured within the UWMCA and sold domestically. The Utwe mangrove areas and channel are ideal locations for the cultivation of mangrove crabs. The life cycle of mangrove crabs is extremely complex and the culture of these animals from fertilised eggs to juveniles is extremely difficult, requiring complex hatchery equipment and specialised skills. The culture of crabs from eggs to juveniles is not an option for Kosrae at the present time.

The cultivation of mangrove crabs from juveniles to adults is a viable option for Kosrae and for the UWMCA.

Juvenile crabs of various sizes can be collected from the wild (cages, nets, hand caught etc) and kept in a range of devices designed to prevent the escape of the animal. Similar size crabs are cultured together and all crabs should have their large claws tired to their body (this prevents fighting and damage to individual animals) whilst under cultivation. Mangrove crabs are territorial, aggressive to each other (especially the larger males) and are cannibalistic when food is not available.

Holding devices can be made out of various natural and man-made products. A standard holding pen of $100m^2$ is recommended which is constructed out of plastic mesh (25 mm), wood or PVC to add support and held in place by wooded stakes. The mesh should be dug into the substrate at a minimum of 1 meter to prevent crabs from burrowing out of

the cage. A cage bottom can be included, however this increases costs and crabs will burrow through the mesh. The mesh at the top of the cage should be above the high water marker and should be turned over and inwards (0.5 meter) to prevent crabs from climbing out of the cage.

There are two different culture methods pertinent to the culture of crabs within the UWMCA. Both are designed to maximise the weight of the crab to gain maximum returns.

Mature large crabs of suitable market size can be held for short periods of time (less than 3 weeks) to maximise crab weight. Crabs are held in the above-mentioned pens and fed a high protein diet (fish skeletons and offal). At least 10 percent body weight per day should be fed. Once individual crabs have attained maximum weight they are removed and sold. Stocking density of these crabs can be up to 5 per meter squared as long as high water exchange occurs in the holding pen.

Juvenile crabs can be collected and placed into these pens and on grown till market size. High protein feeds should be administered at 5 percent of average body weight The stocking density of smaller crabs that are to be cultured for extended periods of time (3-8 months) should be no more than 10 per meter squared. The stocking density should be reduced as the crabs grow.

A locally obtainable and cheap source of feed must be secured before the cultivation of mangrove crabs is undertaken. One source is waste (gills, guts and bones) from the local tuna fishing fleet. The cost of this feed will be a major factor determining the economical viability of this project.

A community based mangrove crab farmers association or similar community group should be developed. This, at least in the initial phases will require the CASO and board members of the park to play a lead role to develop the association and gain community acceptance. This association should actively work with each farmer to provide technical assistance or at least, act as a conduit to request assistance and more importantly, the link between the individual farmers and the markets. The association should include public awareness promotions of the program and assist with marketing the products. The association may wish to take on the role of marketing the crabs for domestic consumption. This is a relative simple activity that requires no specialised equipment or knowledge.

Crabs can be sold both domestically and off island. There is a large domestic market and if managed correctly cultured crabs will provide good profit returns. Mangrove crabs are sold locally for US$2.00-2.50 per pound. Revenues derived from off island shipments are considerably higher. Current export constraint and costs may reduce profits to uneconomic levels. The export of cultured crabs will need to be evaluated in the future.

7.2 Giant Clam

The culture of giant clams at the present time within the UWMCA is not recommended. Constraints of high export freight cost and limited space availability render all international markets for clam products currently uneconomical (refer Appendix 2). This however may change in the future. Clams cultured for the Kosrae domestic markets are totally reliant on the continued production from the NAC. The uncertainty of future production cost of juveniles and the documented lack of domestic sales in the past is a major limiting factor to the economic viability of such a venture.

It is therefore suggested that additional information, that was not available during this evaluation, addressing these issues is required before such a program should be considered. Therefore, this activity should be suspended until this information is gathered and an economic evaluation can be determined.

A summary of suggested culture activities for giant clams within the park is described in Appendix 2 and culture requirements in Appendix 3.

7.3 Hard and Soft Corals

The culture of hard and soft corals at the present time within the UWMP is not recommended.

These products are cultured only for international markets. Current constraints of high export freight costs and limited space availability render all international markets for these products currently uneconomical (refer Appendix 2). This however may change in the future.

A summary of suggested culture activities for Hard and soft corals within the park is described in Appendix 2 and culture requirements in Appendix 3.

7.4 Milkfish, Mullet and Rabbit Fish

The culture of these fish species at the present time in the UWMP is not recommended.

Biological information pertaining to the life cycle of these fish particularly the location, timing and numbers of juveniles is required before estimations of populations stocks can be determined, both for management and culture purposes. If, this information is favourable then a pilot experimental program should be developed that harvests juvenile fry and cultures them to suitable market size. This pilot program would also require a marketing study to determine profitability of such a venture.

A summary of suggested culture activities for these species of fish within the park is described in Appendix 2 and culture requirements in Appendix 3.

8.0 Aquaculture Development Issues

To develop any aquaculture enterprise a clear business plan specifying the goals of each step in the process of culturing the animal through to marketing must be clearly identified. In addition, all economic considerations and environmental attributes and regulations (state and national laws) should be included. If all sections of the business plan appear to provide potential economic gains then the program should be considered. If not, the project should not be developed until the limitations highlighted become viable.

Kosrae has several constraints to the domestic development of aquaculture, as highlight above. In addition, the current space limitations and cost of airfreight excludes all export items from being economically viable. These constraints may change in the future and may allow these activities to become profitable.

All hard corals and giant clams are listed under Appendix II of the Convention in International Trade of Endangered Species (CITES). To allow all aquacultured products being sold into international markets a letter from the local government agency designated as the CITES signatory must accompany all shipments. Currently, the manager at the NAC holds this position. It is recommended that this role be handed over to a Kosrae state government department, such as the Development Review Commission (DRC). Several signatures should be lodged to prevent problems with shipping if an individual is unable to sign on a particular day.

The location of the main shipping dock, tuna cold storage facility and the shipyard to the marine park should be considered when evaluating potential sites for any aquaculture operation. The area were these facilities are located has the highest potential for an accidental environmental incident. To date no such disaster has occurred.

Provisions or legislation should be implemented to allow prospective community; individual and non-public companies the ability to have legal access to the marine environment to allow aquaculture activities to be undertaken. These provisions should incorporate an environmental component that should be enforced.

The development of several aquaculture programs within UWMCA is reliant on the provision of adequate numbers of seedstock being collected from the wild. Information on the availability of regular stocks at the quantity required should be a priority before these programs are initiated. The importance of a regular supply of seed is imperative for any aquaculture project to be successful and profitable over time. The one exception is giant clams. Currently, there is a regular supply of these animals being produced at the NAC. The continued production of clams at this facility is imperative to the success of clam farming.

An example: there is potential in farming milkfish for bait for the tuna long-line fishery based in Kosrae, but there does not appear to be adequate quantities of fry available to

support a large-scale milkfish grow-out industry. Although there are quantities of fry that may be able to support small-scale aquaculture ventures.

All large-scale aquaculture programs weather undertaken within the UWMCA or Kosrae will be dependent on the development of hatcheries to consistently supply larger numbers of seedstock. The cost of these operations and the availability of culture areas preclude this type of commercial development. Furthermore, the lack of suitable feeds and feed ingredients to support the development of a large aquaculture industry may become a major constraint. There is no 'trash fish' resource that can be used to supply trash fish for grow-out, as is commonly used in Asia. There are no commercial abattoirs that could supply high protein meals for use in compounded feeds.

9.0 Conclusions

Four community based aquaculture programs based on environmental and technical attributes have been discussed and are suitable for culture activities within the park. Cultured products include both domestic and international market opportunities. These are: Mangrove Crabs, Giant Clams, Hard & Soft Corals and Milkfish, Mullet, Rabbit Fish

Current constraints on international air freight, both space availability and cost, and the uncertainly of on-island expertise currently render two of the program uneconomical. These two programs should not be considered for development at the present time. These are: Hard and Soft Corals and Giant Clams cultured for off island markets (aquarium markets).

In addition, the culture of giant clams for the domestic market is reliant on the production and access of juveniles from a government hatchery. The uncertainty of future production and cost from this facility and the documented lack of domestic sales of these animals in the past is a major constraint to the economic viability of such a venture. Additional information is required before such a program should be undertaken.

Similarly, the uncertainty of accessing a continuous and reliable stock of juvenile milkfish, rabbit fish and mullet provide insufficient information to allow an economic evaluation to be undertaken. Additional information is required before such a program should be undertaken.

These programs may well become viable alternatives in the future as local circumstances change and additional information is collected.

It is therefore recommended that a program be initiated to cultivate the mangrove crabs (*Scylla serrata*) for the Kosrae domestic market. It has the highest commercial potential and is technically and environmentally viable for the UWMCA. The development of this activity must be developed alongside a suitable management plan. Additional information pertaining to a regular source of feed and its associated cost must be evaluated economically before this program is implemented.

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Appendix 1.0 National Aquaculture giant clam contract agreement. (Provided by the Acting NAC Manager, Mr Mason Timothy).

FSM National Aquaculture Center
Department of Resources & Development
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 ½ inches or larger, individual farmers may market the clams at their own price (eg: 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 3,5000 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 2.0 Summary of culture options for giant clams, hard and soft corals and fish for the UWCA.

Giant Clams

The culture of giant clams in Kosrae is totally depended on the production goals and continued activities of the NAC. Without the NAC producing juvenile clams though their hatchery, community based clam farm is not possible.

Giant clams can be cultured on the Walung reef flat and in particular, in and around the blue hole located seaward of the village. Currently the NAC broodstock and juvenile clams are farmed in this area. Similar methods should be employed, including off bottom cage culture and regular monitoring and cleaning protocols. Training course undertaken by the NAC staff would be required.

Two species of giant clams are currently produced by the NAC. These species are *T. derasa* and *T. maxima*. The later species is harder to cultivate but demands higher returns to the farmer if access to the international marine aquarium markets can be developed. *T. derasa* is a faster growing clam and can be sold to the domestic food market. This species can also be sold to the aquarium market but returns are lower.

The current airfreight cost and space availability precludes the economic viability of culturing clams for any international market. Currently, one KG of perishable product air freighted from Kosrae directly to California is US$6.00. Similar freight cost from Fiji for the same animal is US$1.00 a KG. The 6-fold increase in freight chargers alone clearly indicates the negative competitiveness of products from Kosrae. Unless much cheaper freight costs can be obtained it is clearly not profitable to culture clams for this market.

Discussions would need to be undertaken with the NAC to determine the cost of juvenile clams for the domestic market. Currently, the policy of the NAC is to supply all potential clam farmers with 4,000 one year old *T. derasa* and all associated equipment required to cultivate them free of charge. Each farmer is also taught techniques required to cultivate these animals at their farm site. Arrangements must be made to have a continued supply of clams, if not for free at a nominal cost. The cost of juvenile clams will be a determining factor on potential revenue generated to the clam farmer.

Juvenile clams should be acquired from the NAC at approximately one year of age. Therefore, both species (*T. derasa* and *T. maxima*) would require being cultured for an additional year before suitable market sizes are attained. Clam mortality rates should not exceed 10 percent per annum (+ 1 year old). However, correct farming techniques and diligence of the farmer is extremely important to the successful cultivation of these animals.

A grower association as mentioned above should be developed to assist in the sale of these products as well as regulate the parks management protocols on this species.

The NAC has domestically sold giant clams (*T. derasa*) for the past 5 years. The numbers sold have been small. A 2-3 year old clam is sold for US$2.00. From data provided by the NAC, 1500 clams on average have been sold annually. This is a very small number. This market may expand if suitable marketing promotions and regular availability of product is forthcoming. This information will need to be research and clearly defined before any program is initiated

Giant clam meat and shell products can also be sold (domestically and international) and clam farms may be an additional activity tourist may wish to see. This can be in the form of guided tours over the farms, direct purchase of product (meat, shell) and direct revenue from the parks general admission fees.

Hard and Soft Corals

The cultivation of hard and soft corals is technically and environmentally suitable within the park. There are numerous species of corals that are found on the reefs of Kosrae that are suitable for cultivation. Furthermore, endemic species should be considered, as these will provide an international marketing advantage.

There are no domestic markets for these products. The sole market for these cultivated animals is the international marine aquarium industry. Therefore, these products are totally reliant on export and a company with the skills and marketing expertise to sell the product. Airfreight space and chargers current preclude this activity from being profitable as indicated above. Until such time that freight chargers are competitive to other regions the cultivation of hard and soft corals should not be undertaken.

The cultivation of hard and soft corals relies on removing portions (fragments) of coral colonies living on the reefs. Small portions (1-3 cm) are removed from the host colony and reattached to an artificial substrate. The coral is on grown (usually between 3-6 months) so the fragment reattaches itself and growth occurs. These corals are then exported via airfreight to America and sold into the marine aquarium trade. Cost per coral to cultivate is extremely small (excluding labour) and the majority of products would be ready for market within 4 months. Once the initial planting has been completed there is very minimal labour required. Survival rates from collection to harvesting should be less than 5 percent.

Cultivation techniques are very simple and can be taught to the community in a relatively short period of time. The Walung reef flat and blue hole area is suitable to coral farming. A growers association as described above would also be pertinent for this activity.

Milkfish, Mullet and Rabbit Fish

The three above mentioned fish are a popular food fish in Kosrae. Natural stocks are declining (fisheries division pers. comm.), however popularity and demand remains high.

These three fish species can be cultured within the UWMCA. The Utwe mangrove areas and channels are ideal locations for the cultivation of these fish. The life cycle of these fish is complex and the culture of these animals from fertilised eggs to juveniles is extremely difficult, requiring complex hatchery equipment and specialised skills. Currently, these facilities are not available in Kosrae. The culture of these fish from eggs to juveniles is not an option for Kosrae.

The cultivation of these fish from juveniles to adults is technically viable for Kosrae and for the UWMCA. Juvenile fish of various sizes should be available to be collected from the wild (cages, nets, hand caught etc) and kept in a range of devices designed to prevent the escape of the animals. Once caged these fish can be cultured till market size is attained.

All three species of fish have similar requirements and can be cultured individually or together. If cultured together, competition of resources and food will occur, usually resulting in one species dominating the other. For commercial purposes it is recommended to culture the species individually.

The holding devices can be made out of various natural and man-made products. The standard pen described above for the culture of mangrove crabs is suitable for these fish. In addition, larger pens can be utilised as well as earthen ponds. The size and design of these pens should be designed for the location where cultivation is undertaken; number of fish cultured and feed availability. Furthermore, fish capture must be considered and incorporated into the design.

Mullet and milkfish both will jump out of the water and therefore all cages should included mesh that is at least 1 meter above the high water level.

All three species do not require additional feeding if cultured at low stocking densities (less than 15 fish per meter squared). However, fish cultured at higher densities will require additional feeding. Imported fish feeds are ideal for maximum growth and survival of these fish, however imported feeds are high priced, difficult to obtain in Kosrae and may in fact inflate the cost of production beyond potential profits. Locally obtainable fish feed should be sourced. These include waste vegetables, grass clipping, rice, seaweed etc. All three species are herbivorous with milkfish able to consume almost any food item, plant or animal. The culture of these fish should target the domestic market. Currently, all three fish species are sold in the local markets and all are sold as "reef fish" which retail between US$1.25 – 1.50 per pound.

The development of fish farming for these species is reliant on the regular collection of juvenile fish from the wild. Each species exhibits an annual spawning period, were adult fish, especially milkfish and mullet actively move into the estuarine and mangrove regions to spawn. The eggs are fertilised and small juvenile fish can be found in large schools within the mangroves. This is especially apparent in the UWMCA mangrove

areas and channels. These schools of small fish will need to be captured and transported to the cages to be on grown.

Biological data on the spawning periods of these fish to estimate total population of each fish species so that the wild collection of juvenile fish for aquaculture will not detrimentally affect the natural population stocks. Therefore, a management plan for this activity should be undertaken and explained to the community before any aquaculture activities are undertaken.

Technical assistance will be required to assist the CASO and community to develop aquaculture programs for these fish. A marketing survey of local fish markets should be undertaken to provide a base line study on potential market size; price paid and demand for these potential aquaculture species.

Appendix 3.0 Species Profiles: Evaluation of species with potential for aquaculture in Kosrae. (Adapted from Hayden 1988 AND Rimmer, et al, 1999).

There are three major issues used to evaluate the potential of any species for aquaculture. These are:

1. Seedstock availability. Can seedstock be collected from the wild (and what impact will this have on wild populations and related fisheries) or can seedstock reliably and economically be produced in hatcheries?
2. Production technology. Given that seedstock are available, does the technology exist to grow-out the species economically? Included in this are issues such as 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 impacts will increased production have on price and demand?

Hayden (1988) expanded this basic format to consider various aspects of the biology and culture potential of aquatic species. A modified version of Hayden's scheme has been used to evaluate the suitability of endemic and previously introduced species for aquaculture in Kosrae (see below).

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 is easily adapted locally? Is natural seed readily available and plentiful? What about broodstock? Knowledge of the reproductive biology, larval and behaviour and adult maturation of a species (natural and hatchery) is essential in order to control or manipulate such factors as breeding, environment, nutrition, maturation, and metamorphosis. It also gives the information necessary to enhance 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 the organism such as the optimal growth conditions, feeding behaviour, feed conversion efficiency, etc. will largely determine the potential for culture and the rearing methods which can be used, eg. Mangrove crabs are cannibalistic and so need individual growout containers.
Food Supply	Many of the species identified as being 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, which consume both natural plankton and supplementary feeds, are also ideal. Snapper, 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 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 kept in much higher densities than in their natural habitats, and to be handled frequently. This added stress is a frequent cause of disease in many cultured species especially finfish. Again, bivalves have a distinct advantage in this respect as they do not often have to be caged, and can be grown in at normal densities in their natural habitats. The obverse side to this is that diseased animals cannot be treated unless they are confined, so once infected, losses may be 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 high productivity] water to ensure the public health safety of the final product even though 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. Are returns attractive?
Markets	Is there existing market demand for the product? Value in the local/export market? Any 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?

Mollusc	Common Name: Giant clams Scientific Name: *Tridacna spp. Hippopus spp.* Local Name: Netula Status: Endemic: *T. maxima, T. squamosa, T. gigas*, H. hippopus**. Reintroduced: *T. gigas*, H. hippopus* from Palau Introduced: *T. derasa* from Palau * Local Population Extinct.
Description	Large, ornate, marine clams, with brightly coloured mantles. Several species in the genera Tridacna and Hippopus are widely distributed throughout the Asia-Pacific region. Giant clam populations have decreased in many parts of the Asia-Pacific due to over harvesting, and there are several hatcheries in the region undertaking reseeding projects. Kosrae has the National Aquaculture Centre that is currently producing clams.
Spawning (Natural)	Giant clams are protandrous hermaphrodites, becoming simultaneous hermaphrodites in later years. In the tropics, there is no reproductive seasonality, but at the northern and southern limits of distribution spawning is restricted to a short summer season. Generally, clams will release sperm first, followed by eggs. Sperm release is triggered in nature by the presence of a spawning inducer associated with ripe eggs.
Spawning (Hatchery)	Hatchery techniques well established. Giant clams can be induced to spawn using thermal manipulation in combination with use of gonadal solution, or by injection of serotonin.
Settling/ Rearing (Natural)	The larval stage lasts for 7–15 days, after which the larva develops a foot and settles as a pediveliger. Soon afterwards it metamorphoses into a juvenile clam or spat. Juvenile clams are capable of extensive movement up to a size of several centimetres. Sunlight is a prerequisite for clam culture.
Settling/ Rearing (Laboratory)	Techniques well established. Larvae are reared in circular tanks or raceways, then transferred to nursery tanks after settlement.
Ongrowing (Natural) Techniques	Well established. Small clams may need to be protected from natural predators when transplanted to lagoons. Larger clams can be grown out directly on the substrate. *T. maxima* takes 5 years to reach 10-cm in length (when 50% are fully mature), 8–10 years to reach 15-cm, and 15–20 years to reach 20-cm.
Ongrowing (Culture) Techniques	Juvenile clams usually transferred to lagoon at 1 year of age. Small clams need to be protected from natural predators and cultured on trays placed in protective cages. Clams are removed from these cages at about 3 years of age.
Food Supply	Naturally occurring feeds / photosynthetic zooxanthellae
Disease	Diseases well documented. Many problems relate to environmental stressors.
Water Quality Issues	Reef lagoon water required, with minimal influence from terrestrial run-off.
Harvest & Postharvest Handling	For the aquarium trade, clams cleaned individually, and shipped in oxygenated seawater in plastic bags. Meat content ranges from 15 to 20% of total weight.
Markets (current)	Giant clams are harvested (illegal) and sold locally for their meat. A small industry has developed from culture T. derasa from the NAC. 2 year old clams are currently sold for US$2.00. There is an existing market for juvenile clams in the aquarium trade. This option

	has not been explored today in Kosrae. Potential is high.
Markets (potential)	Small cottage industry using shells for handicrafts. Potential export market for marine aquarium trade.
Status of Species	Endemic species *T. squamosa*: very low wild populations. *T. maxima*: low wild populations. Re-introduced species *H. hippopus*: Approximately 20,000 individuals remaining from earlier introductions and cultured offspring. These have reached maturity. *T. gigas*: Approximately 100 individuals. The majority are male with a small percent have reached female maturity. These are broodstock. Introduced species *T. derasa*: approximately 30,000 individuals remaining from earlier introductions and cultured offspring. These have reached maturity. All mature clams are held at the Walung blue hole. It is proposed to make this site a sanctuary for these stocks. Some clam thief is occurring of broodstock.
Investment requirement	Major investment is in the hatchery. Already operating, government supported. Relatively little infrastructure is required for grow-out. Investment required to export products. Not currently available.
Suitable site availability	Site requirement for lagoon giant clam farming are as follows: Depth: shallow depth of sea <10 m including intertidal; wave action is minimal; water visibility must be good. Water Temperature: should be within 25-30(C. Salinity: best in oceanic salinities in the range of 32–35 ppt. Substrate Type and Wave Exposure: sandy areas are good for giant clams. Seagrass beds are also good provided the seagrass beds have a firm, sandy bottom. The area must be calm with good water circulation. Areas exposed to strong currents are not good as currents/waves destroy cages, overturn clams, etc. Water Quality and Pollutants: water within the area must be free from pollution or has minimum pollution. The area must be sited away from sources of pollution such as factories, sewage plants, fishing docks, near river mouths etc. Water Clarity: the area must be clear with good light penetration. The Walung reef flat and associated blue holes are suitable. This is within the UWCA.
Remarks	The highest priority should be given to the development of this product. Community awareness and training programs must be undertaken. Community cooperative need to be developed to provide an avenue to sell products. Qualifies private company or individual need to be involved to develop the export markets. Project is reliant on continued production from the NAC. Price structure for juveniles clams form the NAC must be priority and economically viable for all.
References	Braley (1992), Munro (1993), Richards (1994),

Crustacean	Common Name: Mudcrab / Mangrove crab Scientific Name: *Scylla serrata* Local Name: Powa Status: Endemic
Description	Large crab (up to 24-cm carapace width), generally brown or greenish-brown in colour with heavy claws and the last pair of walking legs modified to form 'paddles'. Mangrove crabs are widely distributed throughout the Indian and western Pacific Oceans, where they are typically found in estuarine and mangrove habitats .
Spawning (Natural)	Male crabs deposit spermatophores in the female's spermathecum after the female has moulted. The sperm cells can remain viable for up to 7 months. The fertilised eggs are attached in a mass to a set of feathery pleopods beneath the abdominal flap. A female crab may carry as many as 2–5 million eggs.
Spawning (Hatchery)	Technology still largely experimental. Mature crabs will spawn in hatchery conditions, but there is great variability associated with their reproductive performance.
Settling/ Rearing (Natural)	Female crabs migrate offshore to hatch their eggs in an oceanic environment more favourable to the pelagic larval stages. The zoea larva proceeds through a series of up to 5 moults over a period of about 3 weeks, during which time it is transported by tidal currents back to the estuarine environment. Megalopae settle onto suitable substrate if available and become juvenile crabs after about 5–12 days.
Settling/ Rearing (Laboratory)	Largely experimental. After spawning, the fertilised eggs attach to the pleopods of the female crab. A single crab will carry 2– 5 million eggs for 10–14 days until they hatch as zoea stage 1 (Z1) larvae. The zoeal and megalopa stages are fed on rotifers and brine shrimp. During the later stages of larval rearing, material is added to the tanks to provide settlement substrate for settled megalopae and first stage crabs.
Ongrowing (Natural) Techniques	Mangrove crabs are typically found in areas of muddy substrate associated with mangrove vegetation, in sheltered tropical to sub-tropical estuaries, embayments and the lower reaches of rivers and tidal streams. Mangrove crabs are carnivorous scavengers, and are cannibalistic. They attain a carapace width of 8–10-cm in their 1st year, and 13–16-cm in their 2nd year
Ongrowing (Culture) Techniques	Crabs are grown out in ponds, or in enclosures in ponds or rivers. Stocking rates range from 0.05/m2 for extensive culture, 1.5m2 for ponds, and up to 5/m2 for enclosures. Majority of culture is the collection of juvenile animals that are held captive till market sizes are attained. Fattening of stocks also occurs to maximise weight and returns. Crabs can reach about 400 g in 3–5 months, depending on the initial stocking size. Survival is 50–90%.
Food Supply	Extensive culture relies on natural production. Higher stocking densities require supplementary feeding, which is usually trash fish, offal or other trash seafood products (crabs, mussels, etc.).
Disease	Little information.
Water Quality Issues	Relatively tolerant of poor water quality conditions.
Harvest &	Mangrove crabs can be readily transported live to markets. Live mangrove crabs

Postharvest Handling	are commonly found in all fish market in Kosrae. A recent moratorium on the collection and sale of all crabs has been introduced for the next six month by the government in order to preserver stocks and await the results of a mangrove crab study.
Cost effectiveness of each Stage	Unproven – production technology remains largely experimental.
Markets (current)	No crabs are sold currently due to the moratorium. Previously, crabs retail for approximately US$2.00 per pound and could be found in all fish markets and available at several of the island restaurants. Crabs were exported for both commercial activities and gifts form Kosrae. The limit was one cooler per person (approximately 30 crabs).
Markets (potential	Local and export markets are available. Limitations on export maybe present depending on freight restrictions.
Status of Species	*Scylla serrata* is endemic to Kosrea, as well as the FSM. Local stocks believed to have declined. A management plan for these animals must be developed which allows for the preservation of the population whilst allowing subsistence and commercial activities to be undertaken. Restrictions should be implemented on all commercial activities.
Investment requirement	Major constraint to mangrove crab culture is seed availability. Initial culture trials can utilise juvenile crabs, but a hatchery would be needed to provide adequate quantities of seed to develop a large-scale culture industry. A mangrove crab hatchery is not a viable enterprise for Kosrae.
Suitable site availability	Numerous sites are suitable for construction of fixed cages. The mangrove area in the UWCA is suitable location for crab farming.
Remarks	Mangrove crab aquaculture currently depends on wild-caught seed to supply stock.
References	Brown (1993), Richards (1994), Keenan and Blackshaw 1999.

Anthozoa	Common Name: Hard Corals Scientific Name: Numerous Local Name: Eka, Kele Status: Endemic:
Description	Large diversity of forms and species. Kosrae is reported to have over 200 species of hard corals. Many genera are widely distributed throughout the Asia-Pacific region. These animals form the coral reefs of the world. Coral reefs in Kosrae are health and the diversity of species allows cultivation.
Spawning (Natural)	Hard corals can reproduce sexually and asexually. Sexual reproduction is a yearly event and is synchronised for the different species. Normally dictated by tide and moon phase. The majority of species spawn at night. Asexually reproduction is generally from fragmentation of the mature colony.
Spawning (Hatchery)	Technology still largely experimental. Hatchery techniques for sexual reproduction have been developed for several species. The majority use wild collected colonies when gametes are ripe. Combination of water temperature, light and feeding can manipulate spawning times. Most coral reproduction for aqauculture is by fragmentation.
Settling/ Rearing (Natural)	The larval stage lasts for 7–15 days, after which the larva metamorphosis and larvae attach to the substrate. Once attached there is no more movement. All coral reef building corals require sunlight (presence of zooxanthelae) and thus water depth is limited.
Settling/ Rearing (Laboratory)	Techniques still developing. Larvae are reared in circular tanks or raceways, and then transferred to nursery tanks or the sea after settlement.
Ongrowing (Culture) Techniques	Juvenile corals usually transferred to lagoon to be ongrown. Can be attached directly onto the reef (stock reseeding programs) or cultured on off bottom cages, racks etc.
Food Supply	Naturally occurring feeds / photosynthetic zooxanthellae
Disease	Diseases not well documented. Many problems relate to environmental stressors.
Water Quality Issues	Reef lagoon water required, with minimal influence from terrestrial run-off. Is dependent of species cultured.
Harvest & Postharvest Handling	For the aquarium trade, animals are attached to a foreign object, normally a cement coral rock mixture and harvested once large enough to be sold to the markets. Fragments require 3-5 months before harvesting. They are exported in boxes in oxygenated seawater in plastic bags.
Markets (current)	No current use in Kosrae. No local market. Illegal to collect life coral.
Markets (potential)	Cultured hard coral are sold to the marine aquarium trade. Therefore these markets are export only and require skilled individuals to prepare the animals for shipments. Market is large, if competitive.
Status of Species	Endemic species.
Investment requirement	Minor investment required for fragmentation culture. Investment is required to export the product. A small operation with running seawater is required.
Suitable site	Site requirement for coral farming are as follows:

availability	Depth: shallow depth of sea <10 m including intertidal; wave action is minimal; water visibility must be good. Water Temperature: should be within 25-30°C. Salinity: best in oceanic salinities in the range of 32–35 ppt. Species dependent. Substrate Type: The area must be calm with good water circulation. Off bottom culture systems should be used. Water Quality and Pollutants: water within the area must be free from pollution or has minimum pollution. Water Clarity: the area must be clear with good light penetration. Walung reef flat and blue holes are suitable.
Remarks	Hard coral cultivation is suitable for Kosrae if a guaranteed market to export the product off island is available. Currently not available. Freight limitations are discouraging for any large scale operation. Good community project that must have private sector involved.
References	Vernon, 1990,

Anthozoa	Common Name: Soft Corals Scientific Name: Numerous Local Name: Eka, Fusrasrsasr Status: Endemic:
Description	Large diversity of forms and species. Many genera are widely distributed throughout the Asia-Pacific region. These animals are associated with coral reefs of the world.
Spawning (Natural)	Soft corals can reproduce sexually and asexually. Sexual reproduction is a yearly event and is synchronised for the different species. Normally dictated by tide and moon phase. The majority of species spawn at night. Asexually reproduction is generally from fragmentation that has been "torn" from the mature colony.
Spawning (Hatchery)	Technology still largely experimental. Hatchery techniques for sexual reproduction have been developed for only several species. Combination of water temperature, light and feeding can manipulate spawning times.
Settling/ Rearing (Natural)	The larval stage lasts for 7–15 days, after which the larva metamorphosis and larvae attach to the substrate. Once attached there is no more movement. The majority of soft corals require sunlight and thus depth is limited.
Settling/ Rearing (Laboratory)	Techniques still developing. Larvae are reared in circular tanks or raceways, and then transferred to nursery tanks or the sea after settlement.
Ongrowing (Culture) Techniques	Juvenile corals usually transferred to lagoon to be ongrown. Can be attached directly onto the reef (stock reseeding programs) or cultured on off bottom cages, racks etc.
Food Supply	Naturally occurring feeds / photosynthetic zooxanthellae
Disease	Diseases not well documented. Many problems relate to environmental stressors.
Water Quality Issues	Reef lagoon water required, with minimal influence from terrestrial run-off. Is dependent of species cultured. Some species can tolerate a wide range of environmental parameters (temperatures, salinity, sediment).
Harvest & Postharvest Handling	For the aquarium trade, animals are attached to a foreign object, normally a cement coral rock mixture and harvested once large enough to be sold to the markets. Fragments require 3-5 months before harvesting. They are exported in boxes in oxygenated seawater in plastic bags. High shipping mortalities are recorded with most species when shipped. Toxins produced from the sting cells contaminate shipping water and death may occur.
Markets (current)	No current use in Kosrae. No local market.
Markets (potential)	Cultured soft coral are sold to the marine aquarium trade. Therefore, these markets are export only and require skilled individuals to prepare the animals for shipments. Market is large, if competitive.
Status of Species	Endemic species.
Investment requirement	Minor investment required for fragmentation culture. Investment is required to export the product. A small operation with running seawater is required.
Suitable site availability	Site requirement for coral farming are as follows: Depth: shallow depth of sea <10 m including intertidal; wave action is minimal;

	water visibility must be good. Water Temperature: should be within 25-30°C. Salinity: best in oceanic salinities in the range of 32–35 ppt. Species dependent. Substrate Type: The area must be calm with good water circulation. Off bottom culture systems should be used. Water Quality and Pollutants: water within the area must be free from pollution or has minimum pollution. Water Clarity: the area must be clear with good light penetration. Walung reef flat and blue holes are suitable.
Remarks	Soft coral cultivation is suitable for Kosrae if a guaranteed market to export the product off island is available. Currently not available. Freight limitations are discouraging for any large scale operation (refer hard coral section above).
References	Vernon, 1990,

Osteichthyes	Common Name: Milkfish Scientific Name: Chanos chanos Local Name: Polyah Status: Endemic
Description	A widely distributed marine and estuarine species that is cultured for both food fish and bait for the tuna long-lining industry.
Spawning (Natural)	Milkfish spawn year-round at locations near the equator, but for only 3–6 months at higher latitudes up to about 21oN or S. During the breeding season, small to large schools of milkfish occur near the coast or around islands where reefs are well developed.
Spawning (Hatchery)	Broodstock are held in large (usually 80–100 m3) concrete tanks where they spawn naturally. Milkfish can be induced to spawn using exogenous hormones but this is rarely practised in commercial hatcheries.
Settling/ Rearing (Natural)	The eggs and larvae are pelagic for up to 2–3 weeks. The larvae migrate towards the coast and 10–17-mm postlarvae (fry) move inshore into coastal wetlands, mainly mangrove swamps and lagoons, where they metamorphose to juveniles. In the Philippines, large numbers of milkfish fry are captured to provide seedstock for aquaculture. The fry are captured using various types of seine and bag nets. Fry capture, handling and storage techniques are now well developed and mortality during capture is low: generally 1–8% during capture, and up to 9% during storage and transport. Because of seasonal variability in the abundance of milkfish fry, fry are abundant and low-price during the peak months, and scarce and high-priced during the lean months. It is unknown the timing and intensity of milkfish spawning and fry availability.
Settling/ Rearing (Laboratory)	Fingerling production technology is well established for milkfish. Some countries that are major producers of milkfish, e.g. the Philippines, rely almost totally on collection of fry from the wild. Taiwan and Indonesia rely heavily on hatchery production of milkfish fry to support their grow-out industries. Indonesian researchers have developed a particularly successful hatchery technology. The 'backyard hatchery for milkfish' uses large concrete rearing tanks for production of microalgae, rotifers and for rearing the milkfish larvae. A private company in Pohnpei has produced milkfish from imported hatchery stocks from Taiwan for both bait for the tuna long line industry and human consumption. This operation has been closed for the last year, but is expected to open in the near future.
Ongrowing (Culture) Techniques	Milkfish are grown out in large ponds, usually ca. 1 ha in area. The ponds are usually shallow (30–70 cm) to promote growth of benthic algae. The ponds are fertilised with a combination of inorganic and organic fertilisers to promote blooms of algae, which provide feed for the milkfish. Milkfish are farmed at densities of 20,000 fish/ha without supplementary feeding, or 50,000 fish/ha with supplementary feeding. Growth to 14–16 cm fork length (tuna bait size) takes about 2½ months and survival is 70–80%. Milkfish farms in the Philippines range in size from 1 to 250 ha, with an average of about 16 ha. Yield ranges from 423 kg/ha to 1,056 kg/ha, with larger farms having higher yields. Although milkfish farming is traditionally carried out in ponds, there has been a recent trend to the culture of milkfish in pens and cages. Cage and pen culture

	systems rely heavily on the use of artificial feeds.
Food Supply	Milkfish feed on a range of algae, including planktonic and benthic green and blue-green algae. Farming techniques include promotion of mats of algae on the pond substrate (called 'lablab' in the Philippines) to provide feed for the milkfish. Milkfish will readily take artificial pellets, and supplementary feeding will promote growth and allow increased stocking densities. Milkfish pellets are low in protein (<24%) and relatively inexpensive compared with many other aquaculture feeds. A higher protein feed (more expensive) produces higher oil content in the fish, which is sort after for the bait in the tuna longline industry.
Disease	Milkfish diseases are well documented. Milkfish are particularly prone to diseases associated with handling.
Water Quality Issues	Tolerant of a wide range of water quality conditions. Can be grown-out in salinities ranging from freshwater to saltwater.
Harvest & Postharvest Handling	For food fish, usually grown to 350 g or larger. Milkfish grown out for tuna bait are 14–16 cm fork length.
Markets (current)	Currently, milkfish are caught as accidental fish and sold locally. The prise varies between US$1.00 - US1.35. They are classed as reef fish.
Markets (potential)	In addition to the production of milkfish for human food, milkfish can be raised to supply bait for tuna long-line fishing. Milkfish cultured in various parts of the world, In Pohnpei, the market for milkfish for tuna bait is between US$0.18-0.25 each. Indonesia currently produces around 6 million milkfish per month for this market.
Status of Species	Endemic. Wild populations of milkfish in Kosrae is believed to be low and no information exists in terms of spawning, fry occurrence etc.
Investment requirement	Reasonably high level of capital investment required to set up broodstock / hatchery operation. Grow-out also requires high level of investment, particularly grow-out ponds for large-scale culture.
Suitable site availability	Many smaller brackish water ponds and lakes are suitable for milkfish, but large-scale production would require construction of ponds. The Mangrove areas on either side of the UWCA are suitable. Potential for small-scale polyculture with mangrove crabs in cages.
Remarks	Limited production of milkfish for human consumption could be undertaken using milkfish cultured in existing mangrove systems within the park and elsewhere on the island. However, fry supply is uncertain. Development of large-scale milkfish farming for tuna bait would require development of a hatchery facility or the regular importation of eggs/fry (as in Pohnpei). Economic viability of production of milkfish for tuna bait needs to be evaluated before large-scale farming operations are proposed.
References	Bagarinao (1998)

Osteichthyes	Common Name: Mullet Scientific Name: *Mugil cephalus*, and several other species. Local Name: Ac, Kuraf Status: Endemic
Description	Mullets are widely distributed throughout the tropical and subtropical regions between latitudes 42oN and S. Within this range they are important food fish. Mullets, mostly *Mugil cephalus*, are cultured in a number of countries.
Spawning (Natural)	Mullet undertake extensive spawning migrations. Information pertaining to this is not documented for Kosrae, however it is expected to occur either before summer or directly after. Female mullet generally spawn 1.0 – 1.5 million eggs.
Spawning (Hatchery)	*M. Cephalus* is either captured from the wild, or held in ponds or tanks prior to transfer to spawning tanks. Although *M. cephalus* will undergo seasonal maturation in captivity, this species will not spawn naturally. Fish are induced to spawn using various natural or synthetic hormones. Females must have egg diameters >600mm to be successfully induced. If spawning does not occurs, eggs and milt are manually stripped from female and male broodfish and are then mixed to fertilise the eggs. *M. Cephalus* can be spawned out of season by maintaining them at a constant temperature of 21oC and photoperiod of 6L/18D.
Settling/ Rearing (Natural)	Newly hatched larvae are planktonic and transparent. Postlarval mullet enter estuaries when they are 2–3 cm long. The fish form schools and move to shallow nursery areas, which may be located from the lower estuaries to freshwater reaches of tidal creeks.
Settling/ Rearing (Laboratory)	*M. cephalus* is generally reared in indoor hatchery tanks. Larvae commence feeding about 5 days after hatching. The early larval stages are fed on oyster trochophores, rotifers and copepods. Later larval stages are fed Artemia nauplii and ground artificial food. The larvae reach 3-cm in about 45 days.
Ongrowing (Natural) Techniques	In Australian waters, *M. cephalus* reaches an average of 15-cm fork length at 1 year, 24-cm at 2 years, and 33-cm at 3 years. They mature at the end of their third year, at 30–35-cm. Growth data for the species found in Kosrae are lacking, and growth trials need to be carried out to establish the aquaculture potential of the local mullet species.
Ongrowing (Culture) Techniques	There is a wide range of grow-out techniques used to culture mullet, but these can be broadly classified as three types: Extensive culture is carried out in salt or fresh-water. No supplementary feed is provided and the mullet reach 300–600 g in about 1 year. Polyculture is carried out with marine prawns or milkfish in saltwater, or other finfish species in freshwater. Intensive culture is generally carried out at higher stocking densities. Yields of up to 7 tonnes/ha have been reported for intensive culture.
Food Supply	Mullet are algal grazers and detrital feeders on the surface of bottom sediments. Most culture systems rely on natural productivity as the major feed source. Various artificial diets have been used experimentally and have generally resulted in faster growth. An Israeli study found that about 75% of the food eaten by *M. cephalus* originates directly from the water column. Hence, there is potential to polyculture mullet with bottom feeding and dwelling organisms eg mudcrabs.
Disease	Like most finfish, mullet are susceptible to a range of diseases. Disease

	occurrence is often associated with poor management or nutrition.
Water Quality Issues	Can be grown-out in salinities ranging from freshwater to saltwater, although grows better in salt- or brackish-water. Has a wide temperature tolerance and will grow well at relatively low temperatures. Sensitive to low dissolved oxygen conditions.
Harvest & Postharvest Handling	Mullet are generally sold whole in Kosrae.
Cost effectiveness of each Stage	Schools of juvenile mullet are common in estuarine areas of Kosrae, however it is reported that stocks have declined over the past decade. These would provide a source of fry to support a small-scale aquaculture industry. However, growth trials are needed to determine the culture potential of the local species. Because of the feeding habits of mullet, supplementary feeding, while preferable, is not essential. A variety of feed types can be used to supplement the natural feeds of mullet. Mullet growth rates are generally slower than milkfish.
Markets (current)	Mullet are normally sold for between US$1.00 - US$1.35 per pound. They are a popular local fish and demand is relatively high.
Markets (potential)	Export potential for roe. Mullet roe is a highly priced commodity in Japan and Taiwan.
Status of Species	Endemic. Several species have been reported to exist in Kosrae, but it is suspected that there are few *M. cephalus*.
Investment requirement	Small-scale mullet culture could be undertaken with little investment, if juvenile fish are readily available as seedstock.
Suitable site availability	Many smaller brackish water ponds and mangrove areas within the park are suitable for mullet culture. Potential for small-scale polyculture with mangrove crabs in cages.
Remarks	Limited production of mullet for human consumption could be undertaken using mullet cultured in existing mangrove systems within the park and elsewhere on the island.
References	Richards (1994), Liao and Chao (1983), Lee and Kelley (1983), Cardona and Castello (1994),

Osteichthyes	Common Name: Rabbitfish Scientific Name: Siganus spp. Local Name: Mulap Status: Endemic
Description	Rabbitfish are common inhabitants of reef habitats and estuaries throughout the tropical and subtropical areas of the Indo-Pacific region. Rabbitfish are notorious for their venomous dorsal and ventral spines.
Spawning (Natural)	Attain sexual maturity in under one year.
Spawning (Hatchery)	May spawn naturally in conjunction with moon phase, or may require simulation of tidal conditions. Rabbitfish can be successfully spawned using hormonal induction techniques.
Settling/ Rearing (Natural)	Larval development varies with the species, temperature, food availability, etc. Juveniles of some species may be abundant at certain times of the year. Although now uncommon, certain villages in Samoa have a specific fishery for juvenile rabbitfish when they appear in large schools.
Settling/ Rearing (Laboratory)	Larval rearing techniques have been developed for several species of siganids, including *Siganus guttatus* and *S. vermiculatus*, in the Philippines, but there is currently no commercial hatchery production of rabbitfish
Ongrowing (Culture) Techniques	Siganids can be farmed in net cages. In the Philippines, cages 3–4-m (3-m up to 15-m (5-m (2-m are used. Fish are stocked at 30–40 /m2. For siganids farmed in ponds, the recommended stocking density is around 50,000 fish/ha but Siganus fuscescens is stocked at densities of up to 150,000 fish/ha. Fish stocked at 5–6-cm can reach marketable size of 200–300-g in 5–8 months. Survival is usually 70–80%. Siganids may also be polycultured with carnivorous species, such as groupers, where they help control algal fouling on the net cages.
Food Supply	Rabbitfish are herbivorous. Siganids in cage culture are fed pollard (finely ground bran together with the scourings obtained from wheat) once a day at 3-5% body weight. Alternatively, the pollard is mixed with algae (mainly filamentous green algae and Ulva) and vegetables.
Disease	Rabbitfish, like most finfish, are subject to a range of diseases, particularly protozoan infestations, in culture conditions
Water Quality Issues	Euryhaline, suitable for estuarine to full seawater conditions. Can survive reduced oxygen conditions.
Harvest & Postharvest Handling	Rabbitfish are generally sold in Kosrae .
Markets (current)	Rabbitfish are normally sold for between US$1.00 - US$1.35 per pound. They are a popular local fish and demand is relatively high.
Markets (potential)	May be some potential for export to neighbouring islands, depending on market price.
Status of Species	Several species of rabbitfish occur in Kosrae.
Investment requirement	Small, if regular seedstock sources can be identified in Kosrae.

Suitable site availability	Many brackishwater ponds and mangrove areas are suitable for rabbitfish culture. There are many sites with the UWCA.
Remarks	There is some potential for rabbitfish culture in Kosrae if sources of juveniles can be found to provide seedstock for grow-out. Rabbitfish could be polycultured with mangrove crabs. An investigation can be conducted to confirm whether the fishery for juvenile rabbitfish still exist in certain areas of the park and island. These can be sources for juvenile seedstock for culture.
References	Lee (1998)