GOVERNMENT OF SAMOA
FISHERIES DIVISION
MINISTRY OF AGRICULTURE, FORESTS, FISHERIES
AND METEOROLOGY

SAMOA FISHERIES PROJECT
an **AusAID** - assisted project of the Fisheries Division,
Ministry of Agriculture, Forests, Fisheries & Meteorology.

EVALUATION OF THE POTENTIAL FOR AQUACULTURE IN SAMOA

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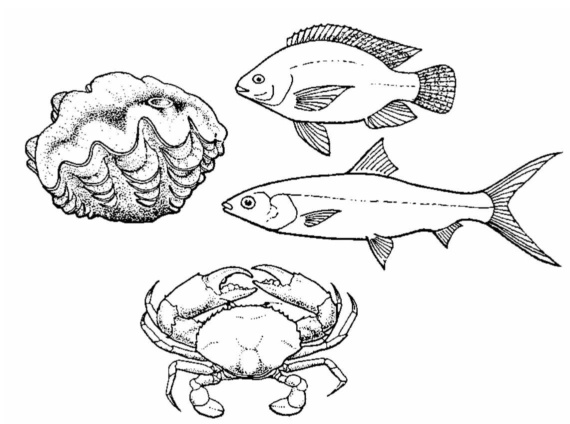

Endorsed on behalf of the Fisheries Division

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Executive Summary

This report is an outcome of Aquaculture Assessment of Local Species component of the Samoa Fisheries Project. The overall objectives of this component were to:

1. Assess the potential of Samoa's marine and freshwater aquatic flora and fauna for aquaculture.
2. Design and implement culture trials of selected species at the Division's aquaculture facility or other sites, where the assessment provides reasonable justification.
3. Review trialed species in terms of their potential for broad-scale culture, and the capacity of the Division to realise the potential of selected species.

The approach taken to achieve these objectives was:

1. The potential for aquaculture development of Samoa's indigenous flora and fauna was assessed by reviewing information on endemic species, and on other species that support aquaculture industries in the Asia-Pacific region.

2. Visits were made to a range of sites on Upolu and Savai'i with a view to identifying specific sites that could be used for grow-out trials, as well as providing recommendations on potential aquaculture development at these sites. The sites were evaluated in terms of their potential suitability for the species assessed in (1.) above.

3. Small-scale trials were undertaken at several sites on Upolu and Savai'i, involving:
   - mud crab farming in cages;
   - transplantation of bivalve molluscs;
   - survey for any remnant populations of redclaw.

Mud crab (*Scylla serrata*) grow-out trials were undertaken at Saanapu Safata, Upolu. Insufficient data were gathered from the trial because of the theft of the mud crabs from the grow-out enclosure on two occasions. Baseline economic analyses undertaken as part of this component indicate that grow-out of mud crabs shows considerable promise for village-level aquaculture in some areas of Samoa, provided that input costs remain low.

Translocation trials of the bivalves *Asaphis* (Venus shell or *tugane*), *Anadara* (ark shell, cockle or *pae*) and *Gafrarium* (sunset shell or *pipi-tu*) were undertaken at several sites on Upolu and Savai'i. Although mortality of most translocated populations was high (due to predation), and growth was poor, the trials demonstrated that this method is a possible means of augmenting declining or locally extinct species. It can also be a means of creating a new fishery, and protein source, provided environmental factors are satisfied. However, further investigation of factors affecting the survival and growth of translocated shellfish is necessary to improve the success of future translocations.

A trapping survey in the Falefa river system, near the Solaua area where redclaw (*Cherax quadricarinatus*) were introduced in the 1990's for commercial aquaculture, failed to find any remnant redclaw populations. Consequently, any further aquaculture development with redclaw in Samoa would require re-introduction of this species.

Based on the results of these trials, we recommend that the work commenced under the Samoa Fisheries Project – Local Species Aquaculture component be continued:

1. We recommend that additional mud crab grow-out trials be undertaken in conjunction with private individuals, families or small groups to assess the biological and economic viability of mud crab farming in Samoa.

2. We recommend that further translocation trials be undertaken with the shellfish *Asaphis, Anadara* and *Gafrarium* and that these trials assess in more detail the impacts of predation and site suitability (including substrate and water quality) on the survival, growth and reproduction of the translocated shellfish.

The introduction (or re-introduction) of exotic species was specifically beyond the remit of the Samoa Fisheries Project. However, we have identified excellent potential for the aquaculture of the Pacific oyster and the Philippine green mussel, both species which have been trialed in the past in Samoa. We have also identified the introduction of trochus as a priority, to develop harvest fisheries for the meat and shell as has been done in other Pacific countries. Consequently, we recommend that the aquaculture potential of both oysters and mussels be re-examined, and trochus fisheries developed:

4. We recommend that further assessment trials be undertaken in Safata Bay with triploid Pacific oyster (*Crassostrea gigas*) spat imported from Hawaii to minimise the risk of wild populations of *C. gigas* becoming established in Samoa.

5. Because spat of the Philippine green mussel (*Perna viridis*) are no longer available, we recommend that Fisheries Division monitor the availability of *P. viridis* spat in the South Pacific with a view to undertaking culture trials with this species should a source of spat become available.

6. We recommend that Fisheries Division address the issue of trochus (*Trochus niloticus*) reseeding in Samoa through participation in the ACIAR project proposed by Dr Chan Lee.

All introductions should be carried out in accordance with the ICES Code of Practice on the Introductions and Transfers of Marine Organisms.

The Fisheries Division now has a major investment in aquaculture research and development in the Giant Clam Hatchery at Toloa, and in staff training and development undertaken under the Samoa Fisheries Project. The Toloa hatchery can be used for production of clams and trochus, and also as a quarantine facility for the import of any exotic species for aquaculture development in Samoa. Options for the continued operation of the Giant Clam Hatchery are discussed in this report.

Abbreviations and Acronyms used

ACIAR	Australian Centre for International Agricultural Research
AusAID	Australian Agency for International Development
BW	body weight
CIF	cargo, insurance and freight
DEC	Division of Environment and Conservation, Department of Lands, Survey and Environment (Samoa)
FAO	Food and Agriculture Organisation of the United Nations
FD	Fisheries Division, Department of Agriculture, Forests, Fisheries and Meteorology (Samoa)
IFREMER	Institut Francais de Recherche Pour l'Exploitation de la Mer
ICES	International Council for the Exploration of the Sea
IUCN	International Union for the Conservation of Nature
JICA	Japan International Cooperation Agency
PVC	poly-vinyl chloride
SAT	Samoan Tala
SPC	Secretariat for the Pacific Community
SPREP	South Pacific Regional Environmental Program
TIPU	Trade and Investment Promotion Unit, Department of Trade, Commerce and Industry (Samoa)

Exchange rates used

AUD 1	SAT 1.67
USD 1	SAT 3.31

Introduction

Background

This report is an outcome of three inputs over the period 1999–2001 by the Specialist for the Aquaculture Assessment of Local Species, the Aquaculture Adviser and Fisheries Division counterparts for the Samoa Fisheries Project, an AusAID-assisted project of the Fisheries Division of the Ministry of Agriculture, Forests, Fisheries and Meteorology. See Appendix 1 for the Terms of Reference for this component.

The overall objectives of this component were to:

1. Assess the potential of Samoa's marine and freshwater aquatic flora and fauna for aquaculture.

2. Design and implement culture trials of selected species at the Division's aquaculture facility or other sites, where the assessment provides reasonable justification.

3. Review trialed species in terms of their potential for broad-scale culture, and the capacity of the Division to realise the potential of selected species.

The approach taken to achieve these objectives was:

1. The potential for aquaculture development of Samoa's indigenous flora and fauna was assessed by reviewing information on endemic species. Because it was apparent that Samoa has an extremely limited number of species suitable for aquaculture, this review was expanded to include species which are not native to Samoa, but which had previously been introduced and which had no apparent negative environmental impact.

2. Visits were made to a range of sites on Upolu and Savai'i with a view to identifying specific sites that could be used for grow-out trials, as well as providing recommendations on potential aquaculture development at these sites. The sites were evaluated in terms of their potential suitability for the species assessed in (1) above.

3. Small-scale trials were undertaken at several sites on Upolu and Savai'i, involving:
   - mud crab farming in cages;
   - transplantation of bivalve molluscs;
   - survey for any remnant populations of redclaw.

During the initial part of the study, it rapidly became apparent that there are few local species in Samoa suitable for aquaculture use. After consultation with the Team Leader for the Samoa Fisheries Project and Fisheries Division staff, the evaluation was widened to include species that are not native to Samoa, but which have been introduced in the past with no apparent negative environmental impacts. Those species that have demonstrated negative environmental impacts or lack of suitability for culture (e.g. the yabby *Cherax destructor*) were not considered for re-introduction to Samoa. Where there is strong argument for the re-introduction of previously trialed species (i.e. good market demand, positive results from previous aquaculture trials) we have assessed opportunities to develop these species for aquaculture development in Samoa.

Definitions

Aquaculture is defined here according to the definition currently used by FAO for statistical purposes, i.e: 'Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated. For statistical purposes, aquatic organisms which are harvested by an individual or corporate body which has owned them throughout their rearing period contribute to aquaculture while aquatic organisms which are exploitable by the public as a common property resource, with or without appropriate licences, are the harvest of fisheries.'

This report also discusses culture-based fisheries, as defined by FAO, i.e.: 'Activities aimed at supplementing or sustaining the recruitment of one or more aquatic species and raising the total production or the production of selected elements of a fishery beyond a level which is sustainable through natural processes'. In this sense culture-based fisheries include enhancement measures which may take the form of: introduction of new species; stocking natural and artificial water bodies; fertilisation; environmental engineering including habitat improvements and modification of water bodies; altering species composition including elimination of undesirable species, or constituting an artificial fauna of selected species; genetic modification of introduced species.

Aquatic environments of Samoa

Samoa (sometimes called Independent Samoa and formerly known as Western Samoa) is located in the central Pacific Ocean between 13^o and 15^o S, and between 171^o and 173^o W. It consists of two major and seven small islands, all volcanic in origin, of which four are inhabited. The two larger islands, Upolu (1,115 km^2) and Savai'i (1,810 km^2), are rugged and mountainous with about 40% of Upolu and 50% of Savai'i characterised by steep slopes descending from volcanic crests. There is a narrow coastal strip, four to five kilometres wide, around both Upolu and Savai'i and most of the population of Samoa lives in over 200 villages distributed around the coast of these two islands (Fig. 1). Only about 27% of the population live on Savai'i. The highest population density is in and around the capital, Apia, located on the north coast of Upolu. The two remaining inhabited islands, Manono (5 km^2) and Apolima (2 km^2), lie off the western tip of Upolu (Morton 1988, SPREP 1993, Bell and Mulipola 1995).

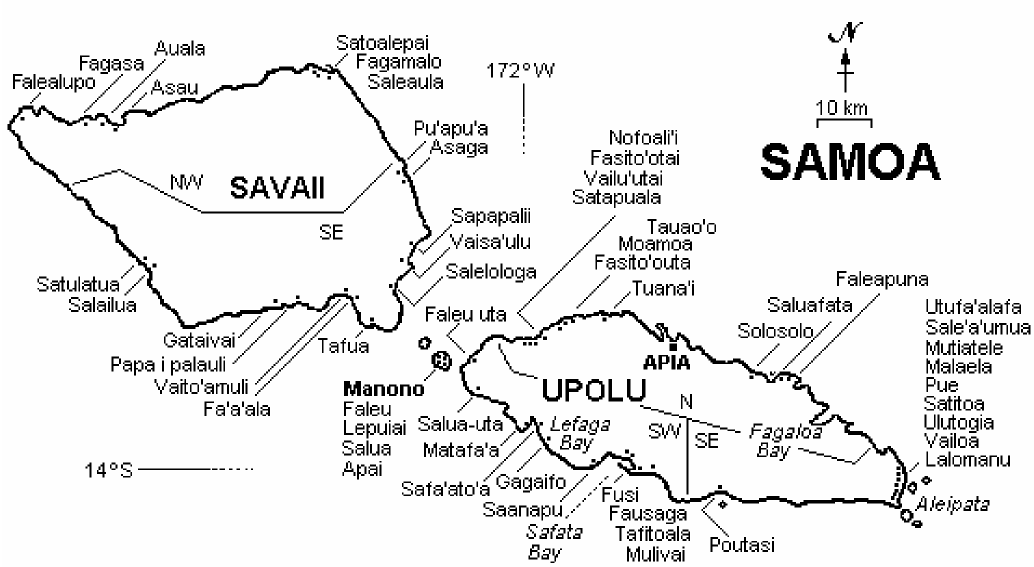

Figure 1 Map of Samoa, showing the distribution of villages around the coasts of Upolu and Savai'i. A selection of villages only is shown on this map, these being the villages that are directly involved in community-based extension program which is part of the Samoa Fisheries Project.

Samoa has a tropical and maritime climate, with pronounced wet and dry seasons. The annual range of surface water temperatures is 23–29^{o}C. The prevailing winds are from the south-east trade winds (May–October) which drive the ocean currents in the region. Moist, north winds prevail during the warmer months (October–April). Annual rainfall ranges from about 2.5 m on the coast to over 6 m at higher elevations. Tidal range is about 1 m. Samoa lies to the south of the South Equatorial Current and ocean productivity is moderately low (Morton 1988, Zann 1991, 1997, SPREP 1993, Bell and Mulipola 1995).

Samoa lies near the northerly edge of the cyclone belt and is occasionally influenced by cyclones. The most severe cyclone in recorded and oral history (i.e. for several centuries) was Cyclone Ofa in February 1990. Cyclone Ofa caused significant loss of life, catastrophic damage to both terrestrial and reef environments, and $200 million in property damage. Cyclone Ofa was followed by another severe tropical cyclone, Cyclone Val, in 1991, which caused widespread damage to infrastructure (Zann 1991, 1997).

Narrow coral reefs fringe most of the coastline, and enclose a mainly shallow lagoon. The reef front drops rapidly into deep water. Because Upolu's reefs range from only a few centuries old to over 10,000 years old, they include all stages in reef evolution, from recent lava flows with only a veneer of corals to mature barrier reefs with infilled lagoons. Because of the high calcification and erosion rates of coral and algae, and the natural and human-induced terrestrial erosion, lagoons are very shallow from infilling. Average depths are about 1-m in leeward reefs and 2–3 m in windward reefs. The shoaling of lagoons is most advanced in the sheltered northern shelf where the lagoon is up to 3-km in width but only 0.5–1.0-m deep. The discharge of fresh water from streams and rivers in the geological past has hindered reef growth in certain areas, creating deep embayments (bays and harbours) and narrow underwater canyons (known as 'deeps') along the edge of the reef. The largest embayment, at Apia, was formed by the Vaisago River (Zann 1991).

Both Upolu and Savai'i have little in the way of freshwater resources. Both islands have mountainous interiors and the rivers are short and have small catchments. Consequently, there is considerable temporal variation in river flows. Many creeks and rivers flow strongly after rain, but drop within a few days. Samoa has few freshwater fish species, but there has been little study of the indigenous freshwater fauna (Taule'alo 1993). The environmental impact assessment of the Afulilo hydroelectric power project found only five species of freshwater fish in the Afulilo Basin, Vaipu Swamp, and Ta'elefaga Stream: freshwater eel (*Anguilla* sp.), pipefish (*Dorichthys* sp.), jungle perch (*Kuhlia rupestris*), and two species of goby (*Sicyopterus micrurus* and *Stiphon elegans*) (Waugh *et al*. 1991).

There are a number of estuarine systems associated not only with rivers, but also with the numerous freshwater springs that occur commonly on both major islands. Many of these estuaries have been degraded by the construction of the coastal road system on both Upolu and Savai'i, where the construction of solid concrete and rocky causeways have reduced tidal inundation. Some mangrove areas and wetlands have been drained and reclaimed for development. Mangrove systems are usually small in extent, and total about 160 ha on Upolu and only about 5 ha on Savai'i (Zann 1991, 1997). The best remaining mangrove areas in Samoa are at Sataoa–Saanapu and at the western end of Lefaga Bay (Taule'alo 1993, Mulipola 1997).

The majority of the population of Samoa lives in over 200 small coastal villages in more arable areas with streams or springs for drinking water and coral reefs for fishing. Samoans are a Polynesian people who have maintained a traditional way of life as subsistence farmers / fishers. The social unit is based on the extended family (the *aiga*) headed by an elected leader (the *matai*) who represents the aiga in the village council (*fono*). The collectively owned aiga lands extend from the reef to the inland mountains. Sea tenure was formerly universal. While this lapsed in some areas during colonial times it has been widely formalised since the 1990 Fono Act recognised the legality of local government (fono) bylaws (Zann 1997).

Seafood is an important part of the diet in Samoa, and is a particularly important source of dietary protein. Annual fish consumption is around 57 kg per capita per annum Passfield *et al*. (2001). Most subsistence fishing is done on an artisanal basis in near-shore and lagoon waters – collecting shellfish and trapping, spearing, and trolling fish. Traditionally, both men and women engaged in fishing, using the *paopao* (traditional outrigger canoe), diving in the lagoons, or wading in the lagoons and along the coral reefs. According to the 1989 agricultural census, 69% of agriculturally active households engaged in fishing and gleaning activities, and 67% used all their catch for home consumption (Taule'alo 1993).

Rapid population growth, urbanisation, use of destructive fishing techniques, introduction of commercial fisheries, and loss of essential fisheries habitat have placed pressure on Samoa's inshore and offshore fisheries. Fishing pressure has increased significantly and many fish stocks have become extremely vulnerable to environmental disturbances and overfishing (Mulipola 1997). Aquaculture, developed responsibly, provides an opportunity for Samoa to increase its fisheries sector production. Potential benefits from aquaculture development will accrue in three main areas:

1. increased protein in the diet;
2. increased income generation through sale of product;
3. for selected species, replace imports (see 'Market information' section, p. 15).

Aquaculture in Samoa

The history of aquaculture in Samoa was briefly reviewed in the initial report (Rimmer *et al*. 1999a), to provide some background on the forms of aquaculture that have been attempted in the past, and to identify possible reasons for the failure of various aquaculture ventures in Samoa.

Samoa has little tradition in the field of aquaculture. A traditional form of giant clam ranching was practised on village reefs and in lagoons where the community placed giant clams in a fenced-off area for special occasions or to provide a reserve seafood supply in bad weather. Because of the paucity of species in Samoa suitable for aquaculture, most aquaculture development has involved the introduction of a range of finfish, crustaceans, molluscs, and seaweed, including:

Seaweeds: euchema *Kappaphycus alvarezii* and *Euchema denticulatum*;
Mussels: Philippine green mussel *Perna viridis*;
Oysters: Pacific oyster *Crassostrea gigas*;
Gastropods: trochus *Trochus niloticus* and green snail *Turbo marmoratus*;
Giant clams: *Tridacna gigas* and *T. derasa*;
Freshwater prawn: *Macrobrachium rosenbergii*;
Marine prawn: *Penaeus monodon*;
Freshwater crayfish: yabby *Cherax destructor* and redclaw *C. quadricarinatus*;
Freshwater finfish: tilapia *Oreochromis mossambicus* and *O. niloticus*.

Further details of the history of aquaculture development in Samoa and the results of the various trials undertaken can be found in Bell and Ropeti (1995) and Bell and Mulipola (1998).

Aquaculture development in Samoa

Despite a less-than-successful history in Samoa, aquaculture is widely recognised as a viable means for increasing fisheries production, providing additional protein for the local population and a means of generating income. The National Environment and Development Management Strategies for Samoa recognises the potential role of aquaculture, and lists one of the activities to 'increase the harvestable stocks of fish and other marine resources' as: 'Develop fish farming to supplement natural stocks' (SPREP 1993).

Aquaculture development in Samoa can be broadly divided into two types:

1. Village-level or subsistence aquaculture.

2. Commercial or large-scale aquaculture.

Village-level aquaculture is already being partly addressed under the Samoa Fisheries Project with the expansion of Nile tilapia aquaculture in local waterways, and the provision of giant clams to participating villages. Typical aspects of village-level aquaculture are:

- Utilisation of existing water bodies, or construction of small ponds, e.g. for tilapia aquaculture.

- Low-level inputs. Species able to grow and reproduce with no or minimal feed inputs (such as tilapia and giant clams) are ideal for village-level aquaculture. Where cultured species require supplementary feeding, a feed supply that does not divert protein from human consumption needs to be identified.

- Local consumption or sale. As is the case with traditional fishing, the product of most village-level aquaculture is consumed by members of the village or is sold locally.

Commercial aquaculture has not yet developed in Samoa, despite previous attempts using a range of species (Rimmer *et al*. 1999a). Typical aspects of commercial aquaculture are:

- Construction of specialised aquaculture production facilities, particularly ponds and hatcheries.
- High level of inputs. Compounded feeds are required to support the aquaculture of most species at the commercial level.

- Market development. Commercial aquaculture relies on relatively large markets. In Samoa, this would include the Apia Fish Market, and hotels and restaurants. For high-value commodities, export may be an option.

There are some major constraints to the development of commercial aquaculture in Samoa:

1. Lack of hatcheries to support seedstock supply. Although the Fisheries Division giant clam hatchery at Toloa will allow the production of seedstock of clams and of trochus, the production of seedstock of other species would require the addition of an microalgae production facility (see additional discussion on the future use of this facility, p. 45).

2. Lack of sites for large-scale aquaculture.

3. Lack of compounded feeds and suitable feed ingredients.

Species suitability summary

The following table (Table 2) briefly summarises the suitability of the species examined in the initial report for aquaculture development in Samoa (Rimmer *et al*. 1999a). As well as endemic species, a number of previously introduced species were assessed. The major criteria for assessment were:

1. The availability of seedstock in Samoa.

2. Availability of grow-out sites.

3. Market demand (not listed in the table, but discussed starting p.15).

Based on these criteria, plus the more detailed species assessments undertaken for the first report, we assigned a priority for each of the species considered for aquaculture development in Samoa. Species assigned a rating higher than 3 were not considered during the site survey, either because of the lack of available seedstock or the lack of grow-out sites. Tilapia and giant clams were also generally not included in the site survey because both species are already being propagated under a separate component of the Samoa Fisheries Project.

Table 2 Summary of the suitability of species considered in this study for aquaculture development in Samoa. Priority rating: 1=highest, 5=lowest.

Species	**Endemic**	**Previously introduced (surviving)**	**Seedstock available locally**	**Grow-out sites available**	**Priority (1–5)**
Edible seaweeds	✓		✓	?	4
Euchema	✗	✓ (✓)	✓	✓	2
Pearl oysters	✓		✗	✓	3
Giant clams	✓	✓ (✓)	✓	✓	1
Pacific oyster	✗	✓ (✗)	✗	✓	2
Green mussel	✗	✓ (✗)	✗	✓	2
Trochus	✗	✓ (?)	✗	✓	1
Sea cucumbers	✓		✗	✓	4
Mangrove crab	✓		✓	✓	1
Spiny lobster	✓		✗	✗	5
Freshwater crayfish	✗	✓ (?)	?	✓	1
Freshwater prawn	✗	✓ (✗)	✗	✓	4
Penaeid prawns	✗		✗	✗	5
Mullet	✓		✓	✓	1
Rabbitfish	✓		?	✓	2
Milkfish	✓		?	✓	3
Freshwater eels	✓		?	✓	3
Grouper	✓		✗	✗	5
Tilapia	✗	✓ (✓)	✓	✓	1
Barramundi	✗		✗	✗	4

Comments – species potential

Edible seaweeds (*Caulerpa*, *Gracileria*)

Limited potential for expansion due to specific and complex site requirements. *Gracileria* is cultured in ponds, which are not available.

Euchema (*Kappaphycus*)

Previously trialed at several sites in Samoa. Economics need to be evaluated for Samoa.

Pearl oysters (*Pinctada margaritifera*)

Limited potential due to lack of broodstock, and few suitable grow-out sites.

Giant clams (*Hippopus hippopus*, *Tridacna* spp.)

Good potential, if villages conserve stocks. Propagation and distribution are being carried out under the Samoa Fisheries Project.

Pacific oyster (*Crassostrea gigas*)

Excellent potential based on previous grow-out trials and established markets in Samoa. Re-introduction should be carried out in conjunction with private industry.

Green mussel (*Perna viridis*)

Excellent potential based on previous grow-out trials in Samoa. Supply of seedstock not currently available.

Trochus (*Trochus niloticus*)

Excellent potential as shown in other Pacific island countries. Flesh and shell can be used. Juveniles should be propagated in planned giant clam hatchery at Apia.

Sea cucumbers (*Holothuria* spp., *Stichopus* spp.)

Seedstock not available – need to be produced in a hatchery. Grow-out through stocking in reef lagoons.

Mud crab (*Scylla serrata*)

Excellent potential and much interest in mangrove crab aquaculture. Limited (but not quantified) supply of seedstock from the wild. Feed source need to be established.

Spiny lobster (*Panulirus penicillatus*)

Limited potential due to apparent specific high-quality water conditions and limited seedstock availability. Larval rearing techniques for *Panulirus* species not yet commercially viable.

Freshwater crayfish (*Cherax quadricarinatus*)

Excellent potential for stocking in dams and ponds throughout Samoa. Potential for commercial culture in Solaua area if ponds can be sealed.

Freshwater prawn (*Macrobrachium rosenbergii*)

Limited potential: previous experience suggests that this species is not economic for culture in Samoa.

Marine prawns (*Penaeus* spp.)

Limited potential. Lack of locally produced seedstock and lack of suitable grow-out sites.

Mullet, rabbitfish, milkfish

Good potential for euryhaline finfish species where seedstock is available. Grow-out techniques could include stocking water bodies, and polyculture in mangrove crab cages.

Freshwater eels (*Anguilla marmorata*)

Limited potential due to lack of identified source of seedstock. Grow-out in ponds and lakes.

Grouper (*Epinephelus* spp., *Plectropomus* spp.)

Little potential – lack of available seedstock, local species unsuitable for hatchery production, lack of suitable sites for cage culture. Disease introduction concerns if species introduced.

Tilapia (*Oreochromis* spp.)

Excellent potential. Propagation and distribution being carried out under the Samoa Fisheries Project.

Barramundi (*Lates calcarifer*)

Little potential. Lack of available seedstock, lack of suitable sites for cage or pond grow-out. Potential disease introduction concerns.

Site suitability summary

To assess the potential for culture of various species in Samoa, we surveyed a total of 28 sites on the islands of Upolu and Savai'i to determine their potential culture suitability. Full details of each site are contained in an earlier report for this component (Rimmer *et al*. 1999b).

Table summarises the recommended species for culture / stocking at each of the sites surveyed. Priorities were assigned with regard to the priority for aquaculture development of that species, and with regard to the comparative potential of the individual sites.

Notes:
Euchema: no specific areas were examined for their suitability for Euchema culture because a survey of Upolu and Savai'i was undertaken several years ago by FAO.
Pearl oysters: additional detailed surveys would be needed to determine whether the nominated areas are suitable for pearl oyster culture. These recommendations are based on reports of deep areas in the locality. Detailed site surveys were not undertaken because of the difficulty in developing pearl oyster culture in Samoa (lack of broodstock and hatchery).
Trochus: these sites refer to the lagoon areas adjacent to the villages, not necessarily to the specific sites inspected. Generally, there is potential for trochus reseeding throughout Samoa. High priority areas are those recommended by Amos (1996) for initial introductions of adult trochus.
Mullet, rabbitfish, milkfish: these species are to a large extent interchangeable, and their culture will depend on availability of seedstock.
Freshwater eel: sites listed for freshwater eel culture are largely nominal – there are no identified sources of seedstock in Samoa.

Table 2 Summary of suitability of sites on Upolu and Savai'i inspected for this study.
Key to abbreviations: Water: F: freshwater; B: brackish; S: salt water.
Priority: H: high; M: medium: L: low.
Culture method (in parentheses): R: raft; T: tray / rack; C: cage; P: pond; S: stocked.

Upolu Sites	**Water**	**Euchema**	**Pearl oysters**	**Pacific oyster**	**Green mussel**	**Trochus**	**Redclaw crayfish**	**Mangrove crab**	**Mullet**	**Rabbitfish**	**Milkfish**	**Freshwater eel**
Vaitele	S	–	–	–	–	M (S)	–	H (C)	M (P)	M (P)	M (P)	–
Malua College	S	–	–	–	–	M (S)	–	H (C)	H (P)	H (P)	H (P)	–
Satapuala	B–S	–	–	–	–	M (S)	–	L (C)	H (P)	H (P)	H (P)	–
Poutasi Falealili	F–B	–	–	–	–	M (S)	H (S)	–	M (P)	M (P)	M (P)	M (P)
Salani	F–B	–	–	–	–	M (S)	H (S)	–	L (P)	L (P)	L (P)	M (P)
Mulivai Safata	F–B	–	–	–	–	M (S)	H (S)	M (C)	M (P)	M (P)	M (P)	M (P)
Fusi Safata	B	–	–	H (T)	M (R)	M (S)	–	H (C)	H (C)	H (C)	H (C)	–
Saanapu Safata	B	–	–	–	–	M (S)	H (S)	H (C)	H (C)	H (C)	H (C)	M (P)
Fagalii	F	–	–	–	–	M (S)	H (S)	–	–	–	–	M (P)
Saoluafata	B	–	–	–	–	M (S)	L (S)	H (C)	H (C)	H (C)	H (C)	L (P)
Faleapuna	B	–	–	–	–	M (S)	–	–	H (C)	H (C)	H (C)	L (P)
Malaela	F	–	–	–	–	M (S)	H (S)	M (C)	M (C)	M (C)	M (C)	H (P)
Matafaa Lefaga	B–S	–	–	–	–	M (S)	–	H (C)	L (C)	L (C)	L (C)	–
Fasitoo-tai	F	–	–	–	–	M (S)	M (S)	–	–	–	–	L (P)
Samatau	B–S	–	–	–	–	M (S)	–	–	M (C)	M (C)	M (C)	–
Sauniatu	F	–	–	–	–	–	H (S)	–	–	–	–	M (P)
Solaua	F	–	–	–	–	–	H (P)	–	–	–	–	M (P)
Saleimoa	B–S	–	–	–	–	M (S)	M (S)	M (C)	H (P)	H (P)	H (P)	–

Savai'i Sites	**Water**	**Euchema**	**Pearl oysters**	**Pacific oyster**	**Green mussel**	**Trochus**	**Redclaw crayfish**	**Mangrove crab**	**Mullet**	**Rabbitfish**	**Milkfish**	**Freshwater eel**
Auala	B	–	–	–	–	M (S)	L (S)	H (C)	H (P)	H (P)	H (P)	–
Asau	S	? (R)	L (R)	H (R)	H (R)	H (S)	–	L (C)	H (C)	H (C)	H (C)	–
Manase	F–B	–	–	–	–	M (S)	L (S)	–	–	–	–	L (P)
Lelepa	S	–	–	–	–	M (S)	–	L (C)	M (C)	M (C)	M (C)	–
Sato'alepai	B	–	–	–	–	H (S)	H (S)	H (C)	H (C)	H (C)	H (C)	L (P)
Saleaula	B–S	–	L (R)	M (R)	M (R)	M (S)	–	M (C)	M (C)	M (C)	M (C)	–
Pu'apu'a	B	–	–	–	–	M (S)	–	M (C)	M (C)	M (C)	M (C)	L (P)
Asaga	F–B	–	–	–	–	M (S)	H (S)	M (C)	M (C)	M (C)	M (C)	L (P)
Lano	F–B	–	–	–	–	M (S)	H (S)	M (C)	M (C)	M (C)	M (C)	L (P)
Sapapalii	B–S	–	–	–	–	M (S)	M (S)	L (C)	L (C)	L (C)	L (C)	–

Market information

Inshore fisheries

Seafood produced by the inshore fisheries of Samoa is sold locally in the Apia Fish Market, the Fugalei market, at roadside stalls, or directly to hotels and restaurants. Fisheries Division samples product at various sales points to estimate the total production of inshore fisheries each year.

The initial report (Rimmer *et al*. 1999a) included an overview of the inshore fisheries production based on Fisheries Division data for 1996–97 and 1997–98. Since then, the inshore fisheries production database has been upgraded and data gathering and checking procedures improved. The most recent data gathered (2000–2001) is believed to be the most accurate (Table 3).

Table 3 Total weight, total value, and average price per kilogram of seafood products landed and sold via the Apia Fish Market and other outlets (retailers, roadsides, etc.) in 2000–2001. Data from Fisheries Division Annual Report for 2000–2001.

	2000–2001		
Species / group	**Weight (kg)**	**Value (SAT)**	**Price per kg**
Caulerpa	11,790 bags	$57,771	$4.90 per bag
Tridacna maxima	1,140	$5,135	$4.50
Octopus	970	$10,690	$11.00
Cockle (*tugane*)	1,658 bags	$8,041	$4.85 per bag
Lobsters	2,956	$52,108	$17.60
Mud crabs	1,462	$29,459	$20.15
Unicornfish (*Naso* sp.)	8,204	$81,828	$9.97
Mullets	4,591	$35,039	$7.63
Parrotfish (Scaridae)	3,574	$25,560	$7.15
Surgeonfish (Acanthuridae)	3,105	$23,617	$7.60
Rabbitfish (Siganidae)	943	$6,453	$6.84
Groupers (Serranidae)	898	$6,415	$7.15

Based on the 2000–2001 data (Table 3), there are some general conclusions that can be drawn regarding inshore fisheries production in Samoa:

Crustaceans

Lobsters are the dominant crustacean harvested in Samoa, accounting for 63% of crustacean landings (by weight). Mud crabs are second to lobsters in terms of total production, accounting for 31% of crustacean landings.

Molluscs

Giant clams are the dominant mollusc sold in Samoa, accounting for around 53% (by weight) of sales of molluscs. Octopuses are the second most commonly sold mollusc, comprising 45% of mollusc sales. The smaller shellfish, such as *pae* (*Anadara*) and *pipi* (*Asaphis*) are sold only in small quantities. However, there are relatively large quantities of *tugane* (*Gafrarium*) sold (around 1 tonne per annum), mostly from roadside stalls.

Finfish

Unicorn fish (*Naso* sp.) and mullets are the largest and second-largest components of finfish landings, accounting for 29% and 16% respectively (by weight).

Imported seafood

Samoa imports some seafood, mainly for use in hotels and restaurants in Apia, and for government functions. Generally, imported seafood comprises species not naturally found in Samoa, although some lobsters are imported. Seafood import data from the Central Bank of Samoa (Table 4) indicate that Samoa imports around SAT$20,000 worth of oysters and around SAT$60,000 worth of mussels each year.

Discussions with local seafood importers indicated that these data grossly underestimate the value of seafood that is imported to Samoa. One importer pointed out that seafood is often brought in by individuals travelling from New Zealand, and thus does not appear on the Central Bank records. Another importer estimated that he imported around 400 dozen oysters per week. At SAT$1 per oyster, this is equivalent to about SAT$250,000 per year.

There is thus an opportunity to replace at least SAT$27,000, and probably in excess of SAT$250,000 p.a. worth of imports by developing locally based aquaculture industries for oysters and mussels.

Table 4 Value of seafood products imported into Samoa in 1998, 1999 and 2000 (in Samoan Tala). Data suppled by Central Bank of Samoa, September 2001.

	Lobsters	Shrimps and prawns	Oysters and scallops	Crabs	Mussels	Total
1998	2,259	27,154	19,509	6,342	62,415	117,679
1999	13,987	13,866	13,933	176	52,776	94,738
2000	–	–	501,483	–	1,124,70	1,625,853

Proposed culture trials

Based on the assessment of potential species for aquaculture in Samoa (Rimmer *et al*. 1999a), and the survey of sites on the islands of Upolu and Savai'i (Rimmer *et al*. 1999b), we proposed that the following culture trials be undertaken by Fisheries Division in conjunction with the AusAID Samoa Fisheries Project.

1. Mud crab grow-out trials

1.1. Trials to be undertaken in cages 100 m^2, constructed from plastic mesh and using stakes to hold the mesh in place. Mesh to be dug in a minimum of 1-m below the substrate, or mesh to be turned under 1-m to prevent crabs burrowing out of the cage. Mesh to be turned over and inward 30-cm to prevent crabs climbing out of the cage.

1.2. Fisheries Division to identify sources of feed for mud crab cage trials. One source is waste (gills and guts) from the tuna long-line fishery. Villages may be able to utilise the exotic pest African snail as a good source of protein for mangrove crab trials.

1.3. Mud crabs to be stocked at $1/m^2$ in cages, and fed at least once daily at 5% body weight per day.

1.4. Fisheries Division to liaise closely with villages undertaking these trials to ensure that crabs are being fed regularly and on as high-protein diet as possible. This may necessitate Fisheries Division organising to supply tuna waste to villages.

1.5. Fisheries Division to sample crabs once per month to estimate survival and growth.

1.6. Grow-out trials should be undertaken at two or more of the following proposed locations:

- Saanapu–Sataoa Safata;
- Matafaa Lefaga;
- Sato'alepai;
- Vaitele. This will be a commercial trial and will most likely be undertaken on land, using concrete tanks subdivided to house each crab individually.

2. Redclaw crayfish survey

2.1. Fisheries Division to undertake a survey of the Falefa River system to determine whether there are any surviving redclaw from earlier introductions / culture in the Solaua area.

3. Redclaw grow-out trial

3.1. If redclaw are found in the Falefa River, they should be transported live to the Fisheries Division facility at Apia and maintained in the freshwater tanks there. The redclaw tanks should be covered with shadecloth to reduce light intensity and bundled lengths of PVC piping added to the tanks to provide cover. The redclaw can be fed on a diet of chicken pellets and high-protein feed (fish offal, etc.).

3.2. Once the redclaw crayfish at Fisheries Division start breeding, the juveniles can be introduced to a number of ponds, identified in the site suitability summary, to establish populations.

4. Mullet grow-out trial at Satapuala ponds

4.1. Inlet / outlet structure requires modification. Plastic fly-screen mesh should be added to the existing mesh to restrict the influx of larval and juvenile fish. A weir structure should be added to increase the water height at low tide and reduce tidal fluctuations in the pond. This will also help maintain productivity in the pond.

4.2. As far as possible, all fish should be removed from the pond. Since the pond cannot be completely emptied, harvesting will rely on netting fish from the ponds.

4.3. Pond restocked with mullet, preferably several species. Growth between different species to be compared with a view to identifying the species most suitable for culture.

5. *Anadara, Gafrarium* reseeding

5.1. Fisheries Division to identify areas where *Anadara* and *Gafrarium* could be reseeded.

5.2. Seedstock to be transplanted from Safata Bay to identified areas.

5.3. Transplanted *Anadara* and *Gafrarium* to be monitored every three months for:

- growth;
- mortality;
- reproductive status.

Note: the following recommendations relate to the re-introduction of species already trialed in Samoa. All the species listed below have previously been introduced to Samoa with no evident negative environmental impacts. In most cases, introduced species were rapidly harvested to extinction once culture activities ceased, which indicates their susceptibility to over-harvesting and supports the lack of environmental impact associated with their introduction. All introductions should be carried out in an environmentally responsible fashion, with the agreement of the Department of Lands, Surveys and the Environment.

6. Re-introduction of trochus

6.1. Adult trochus to be released on reefs as per recommendations of Amos (1996). A minimum of 500 to be released (at least 200 at each site). Trochus to be sourced from Fiji or another Pacific Island country.

6.2. Trochus to be checked for the presence of diseases or parasites prior to introduction to Samoa.

6.3. Broodstock trochus to be maintained at the Fisheries Division / Samoa Fisheries Project mollusc hatchery. A minimum of 200 broodstock to be introduced.

6.4. Juvenile trochus to be produced at Apia hatchery, and re-introduced to lagoon and reef areas throughout Samoa, as identified by Amos (1996). Nursery area, with protection from predators, to be established on a reef near the Apia hatchery.

7. Re-introduction of redclaw crayfish

7.1. In the event that Fisheries Division is unable to locate any existing populations of redclaw crayfish in the Solaua area (Recommendation 2), it is recommended that redclaw are re-introduced to Samoa for aquaculture purposes.

7.2. Broodstock to be tested for diseases, including crustacean viral diseases, prior to introduction.
7.3. Broodstock should be maintained at the Fisheries Division facility in Apia. The redclaw tanks should be covered with shadecloth to reduce light intensity and bundled lengths of PVC piping added to the tanks to provide cover. The redclaw can be fed on a diet of chicken pellets and high-protein feed (fish offal, etc.).
7.4. Juveniles transplanted to suitable fresh- and brackish-water bodies on Upolu and Savai'i, as identified in site selection summary.

8. Re-introduction of Pacific oyster

8.1. Pacific oysters to be re-introduced to Samoa for rack and raft culture trials in Safata Bay (Upolu) and Asau Bay (Savai'i).
8.2. Fisheries Division undertake a survey of oyster importers in Samoa to determine the likely market for oysters, and obtain price data where available.

Local species aquaculture trials

Following on from the identification of species and sites suitable for local species aquaculture trials, small-scale trials were undertaken at several sites on Upolu and Savai'i, involving:

- mud crab farming in cages;
- transplantation of bivalve molluscs;
- survey for any remnant populations of redclaw.

The locations, discussed in the text, are shown in Figure 2.

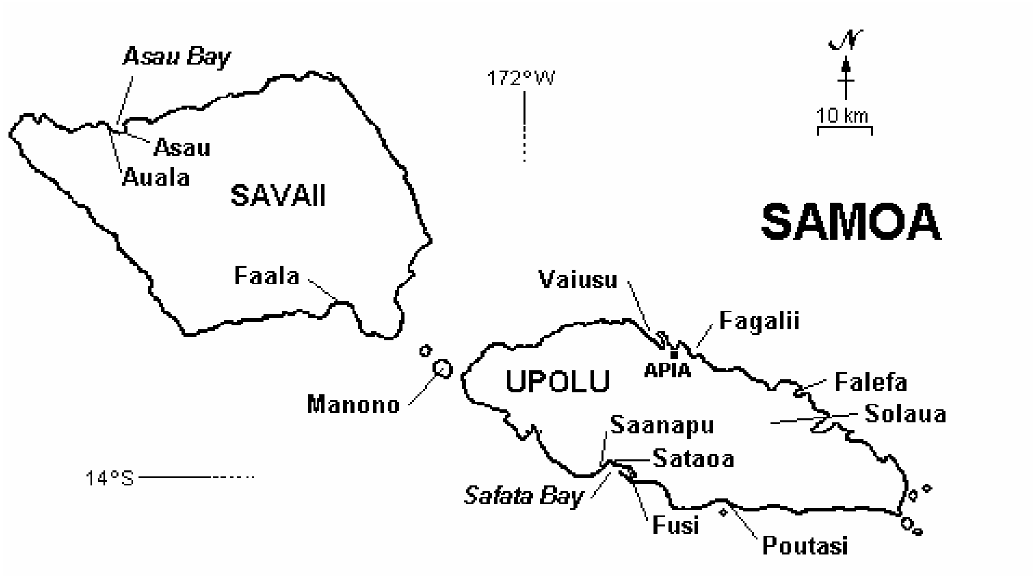

Figure 2 Map of Samoa showing location of sites involved in local species aquaculture trials, and mentioned in this report.

Mud crab grow-out trials

The initial evaluation of the potential for local species aquaculture in Samoa established the potential for mud crab (also known as mangrove crab, or *paalimago* in Samoan) grow-out culture at a number of sites on Upolu and Savai'i. Representatives of several of the villages visited during the first input expressed an interest in developing mud crab culture.

Mud crab grow-out culture is based on the collection of small (100 g or larger) mud crabs that are cultured in enclosures constructed in mangrove areas. Enclosures are constructed using plastic mesh material of a size sufficient to retain the smallest crabs to be stocked. A 30-cm wide strip of plastic or other smooth material is placed at the top of the mesh to prevent the mud crabs climbing out of the enclosure. The mud crabs are fed daily on trash fish, commencing at 10% body weight (BW) day^{-1}. The feed rate is adjusted monthly for increasing biomass, and decreased at 1% BW day^{-1} each month until reaching 5% BW day^{-1} where the feed rate stays until harvest. Grow-out from small to market size crabs (about 400 g) takes around 6 months (Baliao *et al*. 1999a,b, Triño *et al*. 1999). Additional details of mud crab biology and their potential for aquaculture can be found in Appendix 2 which contains the selected species evaluations from the evaluation report (Rimmer *et al*. 1999a) relevant to this report.

Saanapu trial

Objective

To assess the biological and economic feasibility of mud crab grow-out in Samoa using an evaluation site at Saanapu Safata.

Trial sites

Initially, the mud crab trials were planned for the villages of Saanapu and Sataoa, which are situated near Safata Bay on the southern coast of Upolu (Fig. 2). The Saanapu–Sataoa area contains one of the best remaining mangrove areas in Samoa (Taule'alo 1993, Mulipola 1997). To retain this important coastal habitat, the Saanapu–Sataoa area has been declared a Conservation Area.

One pen was successfully constructed at Saanapu, but, despite promises of support, the response from Sataoa was less enthusiastic (see Appendix 3 for a more detailed report on this problem). Consequently, the second pen was not constructed at Sataoa as originally planned.

Because of the Conservation Area status of the Saanapu–Sataoa area, both the Division of Environment and Conservation, and the South Pacific Regional Environmental Program were notified of the proposed trials prior to their inception. Both DEC and SPREP are supportive of the concept of undertaking mud crab culture trials in the conservation area, subject to minimising any environmental impacts.

At Saanapu, the enclosure was constructed on open sites without mangrove vegetation, to avoid damaging any mangrove plants during the construction process. The enclosure was constructed in the inter-tidal zone, so that about half the enclosure was below low tide level. Salinity of water at the Saanapu site ranged from about 12 to 20 ppt.

Enclosure design

The 150 m^2 (10 × 15 m) cage was constructed of plastic mesh (2-cm × 2-cm mesh size) supported by poles placed about 1-m apart. Two panels of 1-m wide mesh were overlapped to construct a fence about 1.7–1.8-m high. The mesh was dug into the substrate about 0.5-m to prevent crabs digging under the fence. A 50-cm wide strip of black plastic was placed at the top of the mesh to prevent crabs getting purchase and escaping over the top of the fence. Lengths of PVC pipe (ranging in size from 100-mm to 150-mm diameter) were provided as shelters to help reduce cannibalism. Three or four trenches (0.3–0.5-m deep) were dug into the substrate below low tide level to provide refuge areas for crabs at low tide.

Stocking and feeding

For the initial stocking, 107 crabs were provided by Fisheries Division and were stocked in the Saanapu enclosure over the period 22 December 2000 to 11 April 2001. The stocking density was 0.7 crabs m^{-2}, and the sex ratio was about 1:1 (55 male and

52 female crabs). Crabs averaged 106-mm carapace width (range: 72–174 mm) and 198 g in weight (range: 54–400 g) at stocking. Total initial biomass was 16 kg.

For the purposes of the experimental trials, the crabs were fed on frozen Mossambique tilapia (*Oreochromis mossambicus*) captured on Savai'i and transported frozen to Apia. At Fisheries Division, the frozen tilapia were divided into weighed amounts based on the daily feed requirements for each cage, and the frozen batches supplied to the villages. FD staff visited the site twice a week to supply feed and to monitor and maintain the experiment. The crabs were fed daily at an initial feeding rate of 10% body weight (BW) day^{-1}. The Pulenuu was responsible for feeding the crabs daily.

Results

One-day trapping surveys were conducted on two occasions in April 2001 (four months after the initial stocking) to monitor crab growth. The first survey was conducted at night and yielded only 1 medium-size crab from 4 traps set. The second survey was conducted at daytime and yielded one medium size crab and three small crabs. These small crabs were believed to have entered the fence from outside. The trapping surveys indicated that the number of crabs in the fence had decreased dramatically.

On 20 and 23 April 2001, at low tide, FD staff conducted a through search for crabs within the fence. No crab was located.

The Pulenuu's son who fed the crabs daily explained that a flashlight was seen flashing in the fence some nights. This indicated that someone was fishing for the crabs at night. Inspections of the fence by FD staff during some weekly visits confirmed parts of the fence were slit open, indicating that someone had cut the fence to get in.

On 7 May 2001 the Pulenuu relayed to FD staff that the crab poacher has been identified and that their village was to meet on 9 May 01 to decide on his fate. On 8 May 2001 the Pulenuu and a representative from the village visited the Office requesting a re-start of the trials. FD staff that met with the representatives include Etuati Ropeti, Tauvae, Faataui, and Lui Bell. The village representatives offered an apology concerning the situation with the trial and confirmed that their village had identified the poacher and was calling a special meeting on 9 May 2001 to decide on the fate of the poacher and to find out whether there were more than one person involved. They requested for a chance to start the trial again. Our disappointment was expressed but explained that if the trial was to start again, the village will have to be fully responsible for providing small crabs to stock the fence. FD will continue to provide technical advice and feed (Mozambique tilapia from Vaisala Savai'i).

Second attempt

The villagers restocked the crab enclosure with 45 crabs over the period 15–29 June 2001. These crabs averaged 98 mm in length (range: 79–116 mm) and 166 g in weight (range: 79–269 g).

These crabs were also stolen soon after they were stocked into the enclosure.

Other sites – Sataoa, Moataa, Sato'alepei

Sataoa

A second site was chosen for a mud crab grow-out trial at Sataoa (see Figure 2). A number of meetings were held with village representatives during September–October 2000, and a site visit was undertaken on 11 October 2000 to test water retention at the proposed enclosure site. During these meetings, it was explained to the village that their contributions would include labour to construct the fence, supply of posts, supply of small crabs, maintenance of fence, security as well as feeding the crabs on a daily basis.

Actual construction of the enclosure was planned with village representatives for 13 October 2000. However, during the visit on 11 October, the village informed that they had decided to postpone the construction to the following Thursday, 19 October 2000. The Fisheries team went to Sataoa on 19 October with all the material required to construct the fence. Upon arrival, only the *Pulenuu* and another *matai* were there. Because of the lack of interest demonstrated by the village (despite their expressions of support for the trial) it was decided not to construct the enclosure at Sataoa, but to investigate other potential grow-out sites.

The Fisheries Division report on the Sataoa trial is appended (Appendix 3).

Moataa

Two additional sites in the Moataa area were assessed; both of these are suitable for mud crab grow-out culture, although Moataa (2) is preferred because of higher salinities and easier access. Site evaluations for the trial grow-out sites are appended (Appendix 4).

Construction of mud crab pens did not go ahead at either of the Moataa sites because of unresolved land tenure issues regarding the mangrove areas: the ownership of these areas (individual / family or community / village) is in dispute. Without resolution of this tenure issue, Fisheries Division was unable to progress the mud crab trial at this site.

Sato'alepei

An assessment of the brackishwater body adjacent to the village of Sato'alepei, on Savai'i, indicated its potential for mud crab culture. A major advantage of using Sato'alepei would be access to quantities of Mozambique tilapia (*O. mossambicus*) which was used in the Saanapu trial as feed for the mud crabs. Trials under the existing project concentrated on sites on Upolu for logistical reasons, particularly relatively easy access for Apia-based Fisheries Division staff who were monitoring the crab cages 2–3 times per week. However, there is still potential for Fisheries Division to undertake mud crab culture trials at Sato'alepei.

Discussion

Because of the theft of both batches of stocked crabs, it is difficult to provide a biological or economic assessment of this trial. However, the development of village-level aquaculture in Samoa is likely to be more difficult than private individual or company-based aquaculture ventures. The lack of enthusiasm by the Sataoa villagers (despite the stated support for the project) and the theft problems at Saanapu indicate that only a dedicated group within the village will have the capacity to initiate and maintain even a small-scale aquaculture venture of this type. Future development of mud crab aquaculture ventures should be limited to private individuals or groups within the community, such as youth or church groups with strong leadership.

Economic evaluation

A simple economic model of mud crab aquaculture was developed for these trials. The model incorporates a number of biological variables (growth and survival) as well as capital (construction) costs and operating costs. Using the model, sensitivity analyses were carried out for survival, seedstock crab cost, feed cost, and selling price.

Price – weight relationship

To estimate the income that might be generated from mud crab aquaculture, we investigated the relationship between price and weight for mud crabs listed in the Fisheries Division Inshore Fisheries Survey Database. The mud crab data had to be edited because of numerous obvious inaccuracies in the data. The data were grouped into one-tala price classes, then we removed data that was obviously inaccurate, such as:

- any crabs larger than 2.5 kg in weight;
- large crabs worth only a few tala;
- any crabs that were obviously too large or too small for that price class (generally, crabs less than about 0.1 g in weight; for larger size classes less than about 0.3 g in weight).

Because of the inaccuracy of the original data, and this subjective editing of the data set, these results should be treated with considerable caution. However, they do provide a useful relationship between mud crab weight and market price that we used to develop a predictive equation for use in the economic model. The averages for each price class were used to estimate the predictive equation using GenStat 5.41. The predictive equation was: $P = W \times 36.2 - 5.83$, where P is the price in SAT and W is the live weight in kilograms ($F=238$, $P<0.001$, $r^2=0.926$). The averages for each price class and the price-weight predictive equation are shown in Figure 3.

Labour was costed at the fairly nominal rate of SAT$2 per man-hour. It is difficult to put an accurate cost on the time of village labour, but this figure is accepted as a reasonable estimate of the minimum wage in Samoa. Construction labour was estimated at 80 man-hours, and operating labour at 360 man-hours (i.e. 2 hours per day for feeding and monitoring the crabs).

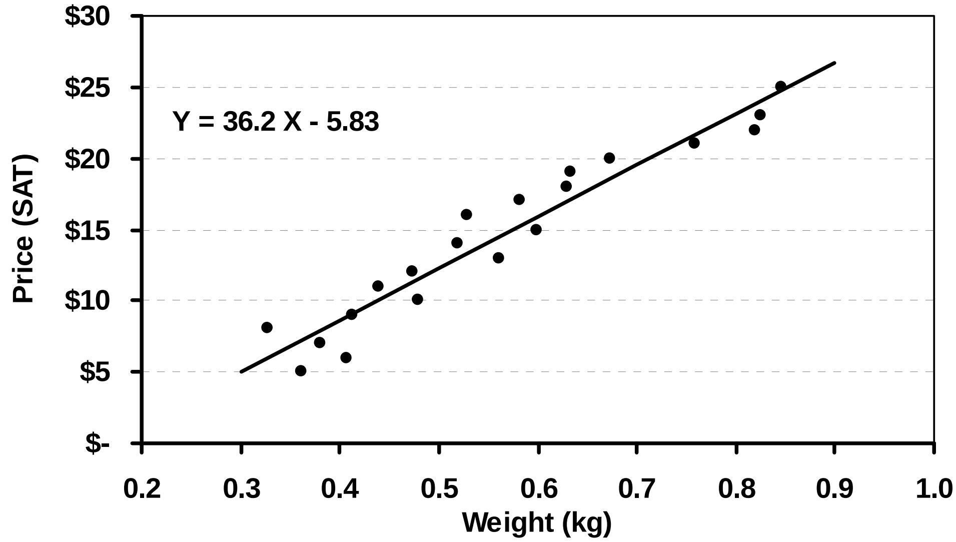

Figure 3 Average weight for crabs grouped into one-tala price classes, and equation for predicting price based on weight.

Capital costs for one 150 m^2 enclosure as used in these trials were:

Item	Unit cost	No. units	Cost
Plastic mesh	SAT $277	3 rolls	SAT $831
Posts	SAT $0	50 posts	SAT $0
Plastic strip	SAT $371	0.5 roll	SAT $186
Monofilament	SAT $55	2 rolls	SAT $110
PVC pipe	SAT $69	2 (× 3 m lengths)	SAT $138
Labour	SAT $2	80 hours	SAT $160
Total			**SAT $1,425**

Baseline parameters used for the sensitivity analyses were:

Enclosure size	150 m^2
Initial stocking density	2 crabs m^{-2}
Initial size	200 g
Final size	600 g
Grow-out period	6 months
Initial feed rate	10% BW day^{-1}
Decrease in feed rate (per month)	1% BW day^{-1}
Mortality rate	10% $month^{-1}$
Capital costs	SAT $ 1,425
Crab seedstock (each)	SAT $ 1
Feed (per kg)	SAT $ 0.50
Labour (feeding)	SAT $ 720
Sale price (per crab)	SAT $18

Note that the profit data given below do not include any allowance for capital costs, but include only operating costs.

Survival

Mortality rate per month	Survival	Profit
10%	59%	SAT $ 1,238
8%	66%	SAT $ 1,535
6%	73%	SAT $ 1,859
4%	82%	SAT $ 2,213

Seedstock crab cost

Cost	Profit
SAT $ 1	SAT $ 1,238
SAT $ 2	SAT $ 938
SAT $ 3	SAT $ 638

Feed cost

Feed cost per kg	Profit
SAT $ 0.50	SAT $ 1,238
SAT $ 0.75	SAT $ 960
SAT $ 1.00	SAT $ 682
SAT $ 1.50	SAT $ 125

Market price

Size (g)	Price	Profit
500 g	SAT $12	SAT $ 651
550 g	SAT $14	SAT $ 945
600 g	SAT $16	SAT $ 1,238
650 g	SAT $18	SAT $ 1,532
700 g	SAT $20	SAT $ 1,825

These simple analyses indicate that there is potential to repay the capital costs within the first one or two crops, provided that input costs are kept as low as possible and survival and growth are maximised.

All the variables examined impacted on profitability. The most sensitive factor influencing profitability was feed cost – doubling the cost of feed effectively halves the profit, even though feed costs remain relatively low at SAT $1 per kilogram. In comparison, doubling the cost of seedstock crabs from SAT $1 to SAT $2 only reduced profitability by around 25%. Because of the high leverage of feed price on profitability of mud crab grow-out, feed costs will need to be kept as low as possible, certainly under SAT $1 per kilogram.

Unfortunately, insufficient data were generated from the Saanapu trial to provide better input data to evaluate the economics of mud crab culture in Samoa.

Shellfish transplantation

Background

In the first phase of the AusAID-assisted Fisheries Division Community-based Project, requests were made for re-stocking depleted shellfish species during a national workshop for women from villages involved in the project. The shellfish species concerned previously formed part of the subsistence/artisanal fishery but workshop participants reported that populations have either declined drastically or ‘disappeared’ altogether. Factors contributing to the declines or disappearances of these shellfish species include: cyclones, over-fishing and environmental degradation.

Prior to the initiation of the translocation trials, confirmation was sought from villages concerned. As a result, three species of shellfish were transplanted into four villages (two on Savai’i and two on Upolu islands) for these trials:

1. Venus shell, *Gafrarium tumidum* (with a small number of *G. pectinatum)*, known locally as *tugane*, were transplanted to lagoons in Asau and Auala villages on Savai’i Island;
2. *Anadara antiquata* (known locally as *pae* or *asi*) was transplanted into the lagoon at Fagalii village on Upolu Island;
3. *Asaphis violascens*, sunset shell (known locally as *pipi-tu*) was transplanted into the lagoon at Poutasi, Falealili, also on Upolu Island.

The sunset shell, *A. violascens*, belongs to the Family Psammobiidae. It is an active burrower and is usually deeply buried in sandy, often coarse to gravelly bottoms, in littoral and sublittoral zones to depths of 20m. It is a suspension feeder, and is dioecious. Sexual maturity is reached at about 6 months with size ranging from 18–20 mm. During the trial it was observed that the adult animals burrowed much deeper than the juveniles did.

The cockle *A. antiquata* belongs to the family Arcidae, subfamily Anadarinae which is recognised for its farming potential. Most species of *Anadara* are intertidal or marginally subtidal in their distribution (Broom 1985). All of the commercially important *Anadara* species are essentially soft substrate dwellers. Toral-Barza and Gomez (1985) collected *A. antiquata* in the Philippines from an area with vast seagrass beds of sandy-muddy sediments mixed with coral rubble. Broom (1985) reported that in the Indo-Pacific region, *A. antiquata* is usually found in the sublittoral area inhabiting rocky crevices and attached to rocks and stones by a slender byssus. Other species of *Anadara* are extensively farmed in Asia. Tebano (1990) reported that transplanting of *A. maculosa* to intertidal areas for subsistence farming is common in Kiribati. The same species has also been successfully introduced into other outer islands of Kiribati, creating new fisheries there.

G. tumidum belongs to the family Veneridae, and are found on sandy-muddy sediments. It is a short-siphoned suspension-feeder, which feeds on particles in suspension near the bottom.

The fishery in Samoa for the three shellfish species reported here is conducted mainly on the subsistence level with the women and children in the villages doing most of the collection. However, *Asaphis* and *Anadara* are occasionally sold in bundles at the

Fugalei Agricultural market while *Gafrarium* is sold almost everyday along the road at Vailoa and Vaiusu villages.

Methodology

Site selection

Prior to determining the translocation, a preliminary survey was conducted in villages to which the shellfish were to be transplanted to determine the existence of the species concerned and the availability of suitable habitat/substrate for the specific species. The existence of the species was determined by asking the villagers and actual collection of live or dead specimens from the site. Determining the existence of a suitable habitat/substrate was done by taking substrate samples from possible sites within the village lagoons of target villages and comparing those with substrate samples from source villages where the particular shellfish species is plentiful. Salinity and water temperature measurements were also taken.

Specimen Collection and Transportation

Asaphis

A total of 750 *A. violascens* were collected from the villages of Manono, Asau and Faala and translocated to Poutasi, Falealili on 27 March 2000.

Anadara

Specimens used for the translocation trials were collected from Fusi Safata over a period of three days by a collector from the village. The animals were kept in a sack under seawater near the collection area until the transplant date. The specimens were transported dry in a cooler by car from the source village to the target village. The trip took about 45 minutes, thus the *Anadara* were out of the water for about 1 hour. Upon arrival at Fagalii (the recipient village) the *Anadara* were immediately transferred to the planting area. Most of the transferred *Anadara*, 148 of the total 204 transplanted, were marked by filing a notch on the shell margin (refer King 1995). To assist the *Anadara* bury into their new substrate, they were pushed down to about half their body with the siphon up.

Gafrarium

Specimens used for the translocation were obtained from the villages of Fusi Safata and Vaiusu. *Gafrarium* from Fusi Safata were collected the day before they were brought to the Fisheries Division office, but those from Vaiusu were bought the day before they were transported to Savai'i. All *Gafrarium* were kept overnight in the sea in sacks before they were transported to Savai'i. On the day they were transported, specimens were put in sacks and the sacks placed in plastic trash bags. Because of the distance of the recipient villages, the *Gafrarium* were shipped by plane. The *Gafrarium* were out of the water for about three hours.

Sampling

It was originally planned that bi-monthly sampling to determine growth and mortality would be conducted. However, due to the difficulty in sampling the shellfish, because they bury in the substrate, and to avoid creating disturbances to the animals as well as the substrate, it was determined that these parameters would be established towards the end of the trials. The bi-monthly sampling was limited to collection of dead shells. To estimate growth, a notch was filed on the shell margin of some of the animals translocated (refer King 1995). Growth at the later date was then estimated by the increase in distance from the old shell margin to the new shell margin.

On 29 August 2001, length measurements were taken on 37 *A. violascens* translocated at Poutasi. Six of these animals were brought back to Fisheries for examination of gonadal development. It was observed that the area with coarse rubble had increased. This buildup had been caused by strong ocean currents in the area.

On 30 August 2001, three snorkelers conducted a 2-hour search for the transplanted *Anadara* at Fagalii. All *Anadara* found were counted and measured, and for marked animals, the original length, as indicated by the filed notch, were also measured to give shell length increment during the whole period. Due to the limited number of *Anadara* planted and those recovered, only five specimens were taken for examination of gonad development and meat content.

On 22 August 2001, the site at Auala was searched for live *Gafrarium* as well as shells or shell fragments. The shells had to be dug up from the sandy/mud substrate, counted and measured. The live specimens with the filed notch were measured for their length, while dead specimens were noted. Six specimens were taken for gonad development and meat content analysis.

Gonad Development and Meat Content

Five of the 61 live *Anadara* specimens recovered on 30 August 2001 were sacrificed for gonad development examination as well as for meat content weights. Since the gonad envelops the visceral mass, the outer layer of the visceral mass was cut and the presence of gonads (male gonad is usually cream in colour while female is orange) determined. For comparison, five *Anadara* specimens of approximately the same shell lengths, were collected on 10 September 2001 from Fusi Safata (the source village of *Anadara* planted at Fagalii) and examined.

For *Asaphis*, 6 specimens were examined for gonad and their meat content weighed. Specimens of the same species were purchased from the Fugalei Fish Market for comparison.

The *Gafrarium* specimens that were put aside for analysis on the 22 August 2001, unfortunately were not analysed on time (the shells were forgotten at Salelologa, Savai’i). When they did arrive to its destination for analysis, the meat had already withered/thinned after a week since it was taken from Auala. A second sample of 6 specimens were brought from Savai’i on the 12 September and placed in the freezer. These specimens were thawed, weighed and measured the following day. For comparison, live, fresh specimens of *Gafrarium* were bought and their gonad development and meat content was weighed and measured.

Because larger shellfish often have proportionally heavier shells, the relationship between meat weight and total weight changes as the size of the animal increases.

Thus comparisons between meat weight to total weight can only be undertaken on populations of similar sizes. Population size in this study was compared using unpaired t-tests for shell length and shell weight data from the source and destination populations. Where there was no significant difference between the populations, the meat weight to total weight ratio was analysed to provide an index of the condition of the shellfish sampled.

Results

Presence of Selected Shellfish Species and Suitable Substrate in Targeted Villages

Asaphis

The translocation trial of *Asaphis* sp. was conducted at Poutasi Falealili village on Upolu Island. Interviews and surveys confirmed the presence of the same shellfish species in the village shore. Examination of the substrate sample from the target village also confirmed similarity to those of the source villages.

Anadara

Translocation of *Anadara* was targeted for the village of Fagalii on Upolu. Interviews with members of the village management committee indicated that *Anadara* was present in their adjacent lagoon prior to the two cyclones in 1990 and 1991. This was confirmed by the presence of many dead *Anadara* shells found in the lagoon area. However, it was noted that the substrate was different from that of the source village because of the higher sand and rubble composition. The village committee members interviewed informed that the lagoon was deeper with less rubble prior to the cyclones mentioned above. Nevertheless, several patches of suitable habitats were identified within the lagoon area. One such area, where the *Anadara* were planted, is about 10 m from shore. Unfortunately, this makes this area also easily subjected to fresh-water influx during heavy rains.

Gafrarium

The *Gafrarium* translocation trials were conducted in two villages, Asau and Auala on Savai'i Island. Interviews and a survey conducted at the two village lagoons confirmed the presence of *G. pectinatum* but very sparse. In fact only live specimens of juvenile *G. pectinatum* were found. The substrate at Asau and Auala villages were quite different from those at the source villages (Fusi Safata and Vaiusu on Upolu Island) in that the substrate at the target villages have no mud content but mostly sand. The only exception was a brackish pond at Auala of which one side has a very similar substrate to those of the source villages. However, no *Gafrarium* specimen was located within this pond.

Growth

Asaphis

The original average shell length for the animals translocated to Poutasi was 44.2 mm.

Of the six specimens taken to the Fisheries, four were marked. Table 5 records measurements obtained from these animals indicating shell height increments. The shell height increment for the total 17.2 months ranged from 1.0 to 6.0 mm and averaged 2.4 mm.

Table 5 Shell height measurements for *Asaphis* specimens obtained from Poutasi Falealili on 29 August, 2001.

Sample no.	Current shell height (mm)	Initial shell height (mm)	Shell height increment (mm)
1	31.6	25.6	6.0
2	32.1	30.6	1.5
3	31.0	30.0	1.0
4	34.0	33.0	1.0

Anadara

A total of 50 marked *Anadara* (from the original 148 marked) were recovered on 30 August 2001. Of the 50 marked *Anadara* recovered, 27 had clear shell length increment while the other 23 had no or very little increment. Thus shell increment range for all live marked *Anadara* recovered is 0–9.5 mm, while shell increments on the 27 *Anadara* that showed clear shell growth range from 2.0 to 9.5 mm. The average shell increment for all marked *Anadara* recovered is 2.8 mm over 17.2 months (0.16 mm per month) while the average shell increment for marked *Anadara* that had clear growth is 5.2 mm (0.30 mm per month).

Squires *et al.* (undated copy) recorded growth rates for *A. tuberculosa* in Colombia for specimens 33–46 mm which showed growth of about 1 mm per month on the average. Tookwinas (1985) reported 18mm *Anadara* spat in Southern Thailand grew to 40mm in 18 months. Broom (1985) reported that *A. granosa* in natural beds takes approximately six months to grow to 4–5 mm in length. However, growth rates in bigger animals are lower.

Gafrarium

The 100 marked (filed) *Gafrarium* transplanted to Auala on 27 September, 2000 had an average length of 39.47 mm. Bi-monthly measurements for *Gafrarium* were inconsistent. However sampling was conducted on three different dates. On 8 February 2001, a sample of 48 marked *Gafrarium* was measured. The average length obtained was 37.9 mm. The second sample of 43 marked specimens was obtained on the 4 May 2001. The average length obtained was 38.9 mm. On 22 August 2001, a thorough search was conducted for *Gafrarium* and 30 marked specimens were found inside the cage. This was the number measured for the sample with an average length of 39.1mm. During this last visit, 27 dead shells plus shell fragments were found inside and outside the cage. While shell measurements after each consecutive sampling after the first sampling on 8 February 2001 showed increases in averages length of marked *Gafrarium*, all averages were lower than the original average length on the transplanting date. This shows that the bigger specimens in the original stock were missing (dead). Upon examination of the marked specimens, the edge of the shells had not shown much growth since they were first transplanted.

Generally, growth for *Gafrarium* is fairly slow though constant throughout the year (Baron and Clavier 1992). Growth for *Gafrarium* in Samoa at one particular area where this bivalve is harvested, Sogi, has been recorded to be ~1mm per month (Imo 2001). According to Imo (2001), physical factors of temperature and salinity changes affect growth of *G. tumidum*. In this case, exposure to a new environment, which may not have the ideal parameters, including productivity of the water, may have been the main causes of the slow growth.

Survival

Asaphis

It was not possible to estimate the survival for *Asaphis* specimens transplanted into Poutasi Falealili.

Anadara

The total number of *Anadara* original planted on 24 March 2001, was 204. The total number of live *Anadara* recovered on 30 August 2001, or 17.2 months from the date of the transplanting, was 61. This represents approximately 30 per cent survival from the original number stocked. However, locating live *Anadara* is difficult particularly if the whole animal is buried thus requiring a skilful eye to locate the open siphon. Thus, the actual survival could be higher due to those animals that could not be located. The total number of dead *Anadara* collected during bi-monthly visits was approximately 50. This further indicates that there may be other live *Anadara* that were missed by the collectors on 30 August 2001. However, there were also dead shells not found because they were either buried in the substrate or removed by village committee looking after the trial without keeping any records. It was noted that the majority of dead *Anadara* shells collected in any single day was during the total search on 30 August 2001. Three weeks prior to this date, heavy rains caused high siltation and lower salinity in the area due to high fresh-water influx from a nearby stream. This could have caused prolonged low salinity resulting in the mortality.

Of the 61 *Anadara* recovered on 30 August 2001, fifty were marked, thus approximately 34 % of the marked *Anadara* were recovered after 17.2 months.

Gafrarium

The trials for *Gafrarium* took place at two villages, Asau and Auala. A total of 1002 animals were stocked at Asau on the 6 April 2001. A search was conducted four weeks after the translocation for the transplanted *Gafrarium*. Unfortunately, very few live animals were recovered. Shell fragments were found in the sand and on the bottom surface, a consequence of high predation in the area from suspected predators such as manta rays, mangrove crabs and other natural predators of *Gafrarium*. Shell fragments recovered from Asau were crushed indicating predation from crushing predators such as rays and crabs.

For the village of Auala, two sites were chosen. The first site was inside the turtle sanctuary, an enclosed brackish water pool inundated with changes in tide. The second site was outside exposed to the sea, opposite to the turtle sanctuary. The latter site was marked by stick poles. A total of 1082 *Gafrarium* was split up and translocated initially to both these sites. Unfortunately it suffered a similar case to that at the Asau site. Very few whole shells were recovered from the outside site (exposed), mostly shell fragments. A similar situation was recorded in the turtle sanctuary. At the latter site, high predation was owed to mudcrabs inhabiting the muddy substrate in the pool.

Following this experience, it was decided that a cage should be introduced to reduce predation. On 8 February 2000, a plastic mesh (1” mesh) of size, 2m x 1m x 0.5m was used at the site inside the turtle sanctuary. A second stocking was also carried out with a total of 1009 animals. One hundred marked (filed) animals were placed inside the cage, for sampling and monitoring purposes. The cage was placed over these animals and inserted into the substrate. The rest of the other animals were planted outside, around the cage and the area was marked with stick poles. The Asau site was not re-stocked as predation was too high.

Survival of *Gafrarium* translocated to Auala was very low. This was attributed to the high predation within the site area and probably to the unsuitability of the physical environment. In total, 2091 *Gafrarium* were translocated at different stocking dates, 100 animals were planted inside the cage and 30 survived. However animals placed outside the cage were not included.

Gonad Development

Asaphis

All of the six specimens of *Asaphis* that were examined for gonad development showed thin meat. No gonads were apparent over the visceral mass. Specimens purchased from the Fish Market on the same day also showed thin meat with no apparent presence of gonads except for one specimen that had a small amount of gonadal development.

Anadara

All of the five *Anadara* specimens from Fagalii that were examined had no apparent gonads. Examination under the microscope did not reveal the presence of any gonads. However, of the five specimens obtained from Fusi Safata for comparison, three were females and two males. Of the three females, gonads were free-flowing when the outer layer of the visceral mass was cut.

Gafrarium

The *Gafrarium* from Auala that was examined under microscope, showed no gonad development. Six live specimens were obtained on 14 September 2001 from Vailoa, where the (original) stocks were obtained, and their gonads examined. All of the six specimens yielded gonads that were physically obvious when the gills were removed and was further confirmed under the microscope.

Meat Content

Asaphis

Table 6 lists weight relations of *Asaphis* specimens collected from Poutasi Falealili. Meat comprises approximately 21% of the total weight but ranging from 14.9 to 24.6 %. Meat composition in relation to total weight of specimens purchased from the market were comparable with those translocated. In common with other bivalves, shell weight comprises the largest portion of the total animal weight.

Table 6 Total, meat and shell weight measurements for *Asaphis* specimens obtained from Poutasi Falealili on 29 August 2001.

Sample no.	Total shell length (mm)	Total wet wt (g)	Wet meat wt (g)	Shell wt (g)	Wet meat wt to total wt (%)	Wet shell wt to total wt (%)
1	51.0	22.1	5.3	9.1	24.0	41.2
2	54.7	23.3	4.7	9.7	20.2	41.6
3	56.0	24.7	5.1	10.6	20.6	42.9
4	48.8	18.4	3.9	8.5	21.2	46.2
5	53.8	23.6	5.8	8.5	24.6	36.0
6	52.6	24.8	3.7	12.4	14.9	50.0
Average	**52.8**	**22.8**	**4.8**	**9.8**	**20.9**	**43.0**

Anadara

Table 7a lists information on five *Anadara* specimens obtained from Fagalii on 30 August 2001. In terms of weight, the meat comprises 11.2–14.5 % of the total *Anadara* weight, averaging 12.9%. The shell, however, comprises an average of 67.4% of the total weight. In comparison, the five *Anadara* specimens obtained from the wild at Fusi Safata (the source village of the *Anadara* at Fagalii) show higher meat content (14.6–21.4%) as recorded in Table 7b.

Table 7a Meat content of *Anadara* sp. specimens collected from Fagalii on 30 August 2001.

#	Shell Length (mm)	Total wet wt (g)	Total wet meat weight (g)	Shell weight (g)	Wet meat wt to total wt (%)	Wet shell wt to total wt (%)
1	74.5	128.9	18.7	85.1	14.5	66.0
2	78.0	140.3	18.6	88.8	13.3	63.3
3	70.0	95.4	12.2	64.2	12.8	67.3
4	86.0	163.0	18.3	114.5	11.2	70.2
5	71.0	113.0	14.1	79.1	12.5	70.0

Table 7b Meat content of *Anadara* specimens collected from Fusi Safata on 10 September 2001.

#	Shell Length (mm)	Total wet wt (g)	Total wet meat weight (g)	Shell weight (g)	Wet meat wt to total wt (%)	Wet shell wt to total wt (%)
1	77.5	142.1	20.8	96.9	14.6	68.2
2	66.0	109.2	18.2	74.0	16.7	67.8
3	87.0	178.3	31.4	122.6	17.6	68.8
4	89.0	199.3	42.7	126.7	21.4	63.6
5	86.0	198.8	40.4	126.6	20.3	63.7

Anadara sampled from both Fagalii and Fusi Safata were similar in size with respect to shell length (t-test, $P>0.05$) and shell weight (t-test, $P>0.05$). An analysis of the wet meat weight to total weight ratio for the two populations showed that the Fusi population had a significantly higher wet meat weight to total weight ratio (t-test on arcsine transformed data, $P<0.01$) (Fig. 4).

The presence of gonads in the specimens from Fusi Safata seem to contribute to the higher wet meat weight/total weight in these animals as compared to those from Fagalii. However, Squires *et al* (undated copy) could not establish a clear relationship between meat weight and maturity for *A. tuberculosa* in the coast of Colombia. They reported that in June, when the largest number of mature animals occurred, meat weights were relatively low, but in November when the numbers mature were also high, meat weights were comparatively high. They reported that for *A. tuberculosa* in Colombia, meat weight as a percentage of total weight showed month to month differences. In three months over one year, most percentages were lower than 20%. Generally meat weights were 36% of total weight at small sizes (10–20 g in total weight and 36–42 mm shell length) and only slightly more than 15% at large sizes when the shell was thicker and contributed more to the total weight.

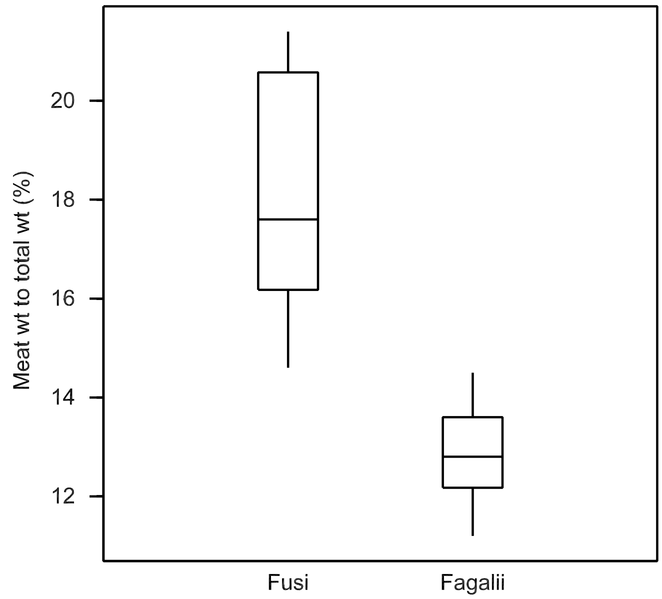

Figure 4 Boxplot of wet meat weight to total weight proportions of *Anadara* sampled from Fusi Safata (source population) and Fagalii (destination population), August – September 2001.

Gafrarium

The *Gafrarium* specimens for meat content analysis were frozen (overnight). Samples were thawed for approximately one hour when examined. Prior to analysis, the shells had opened up which led to loss of water contained within the shell cavity. The shells and the meat were weighed, regardless, as shown in Tables 8a and 8b.

The total weights of *Gafrarium* from Auala could not be used as most of the water content was lost when specimens were thawed. However, meat content of two specimens were comparable with those from Vailoa.

The *Gafrarium* sampled from Vailoa were significantly larger than those sampled from Auala with respect to both shell length (t-test, $P<0.01$) and shell weight (t-test, $P<0.01$). Consequently, the wet meat weight to total weight proportions could not be compared between the two populations.

Table 8a *Gafrarium* meat content from Auala on 13 September 2001.

#	Total shell length (mm)	Total wet weight (g)	Wet meat weight (g)	Shell weight (g)	Wet meat wt to total weight (%)	Wet shell wt to total weight (%)
1	43.0	23.1	1.9	19.9	8.2	86.1
2	38.8	15.1	Empty	14.7	–	–
3	35.0	14.9	0.7	13.5	4.7	90.6
4	35.5	13.5	0.6	11.5	4.4	85.2
5	36.9	13.4	1.1	11.3	8.2	84.3
6	35.4	15.7	0.9	13.8	5.7	87.9

Table 8b *Gafrarium* meat content from Vailoa on 14 September 2001.

#	Total shell length (mm)	Total wet weight (g)	Wet meat weight (g)	Shell weight (g)	Total meat wt to total wt (%)	Wet shell wt to total wt (%)
1	51.3	49.1	5.1	35.6	10.4	72.5
2	49.4	44.1	3.9	33	8.8	78.2
3	48.8	43.2	3.3	30.6	7.6	70.8
4	44.0	31.0	2.9	22.7	9.6	73.2
5	43.9	30.1	2.4	21.6	8.0	71.7
6	46.3	33.7	2.9	25.4	8.6	75.4

Conclusions

The most relevant measure of a successful translocation of a shellfish species would be the ability of the translocated specimens to not only survive and grow, but to naturally reproduce in the 'new' area, resulting in spat settlement and growth to maturity. The time and resources available for this study precludes a thorough investigation of reproduction and recruitment in the translocated shellfish, but some general conclusions from the study are noted below.

Asaphis

It was not possible to estimate survival of the translocated *Asaphis*. However, the comparable results in terms of meat content and gonadal development from the translocated specimens and those purchased from the market, indicate that the site at Poutasi Falealili is capable of supporting such a small-scale fishery, the level of which is not known.

Anadara

The survival of the translocated *Anadara* at Fagalii for more than 12 months from the original stocking is only 30%. However, actual survival could be higher due to the fact that buried *Anadara* is very difficult to locate and some could have been missed during collection. No signs, as to the cause of mortality, could be apparent from the dead shells collected. Meat weight composition, as compared to the total animal weight, is lower in translocated specimens when compared to specimens collected from the source village. A possible explanation is the absence of gonads in the translocated specimens. However, Squires *et al*. (undated) found that it was not possible to establish a clear relationship between meat weight and maturity for *A. tuberculosa* on the coast of Colombia. The absence of gonads in the translocated specimens could have resulted from a recent spawning activity. However, it is also possible that the area is not productive enough to enable the animals to produce gonads. Thus monthly monitoring of gonad and meat development is necessary. [This was not possible with the current work because of the limited number of animals]. If the results obtained on specimens from Fagalii is reflective of the real situation there, then a possible explanation for the higher meat content and presence of gonads in *Anadara* from Fusi is the much higher productivity in the water in Fusi.

Gafrarium

Despite high predation at the sites, coupled with related physical factors (salinity, temperature, sediments), *Gafrarium* did survive throughout the trial period. Though few animals survived long after the initial stocking, it did demonstrate that *Gafrarium* can be translocated can be carried out since specimens still survived inside a protected or artificial environment. If possible, better site selection and experimental design could improve the survival of *Gafrarium*, and consistent monitoring would enable a more thorough assessment of the factors influencing translocated shellfish populations.

Predation was very high at both the Asau and Auala sites and thus the introduction of the cage to reduce predation. This proved efficient and mortality from predation was reduced. Not so many shell fragments were found within the cage. However, dead shells continued to be found in the cage possibly from stress to adapting to a new environment as well as that the site may not have been suitable for its growth. The physical, chemical and biological requirements were not at its optimum or similar to its original habitat to allow it to survive or adapt better.

Examination of gonadal tissue of *Gafrarium* from Auala did not reveal that they were bearing gametes. A possible reason could be adaptation to a new environment or the effects of the ambient environment. The combination of temperature and salinity factors has been demonstrated to impact on the reproductive cycles of molluscs (Baron and Clavier 1992). This in effect may have caused *Gafrarium* to suspend gonad production. A measure of success of the trials would have been if *Gafrarium* were capable of gamete production in its new environment and a breeding stock to be established. An extended trial period to establish the population and to reach breeding stage would have been more suitable.

Although the overall results of the translocations conducted were not remarkable, it proves that this method is a possible means of augmenting declining or locally extinct species. It can also be a means of creating a new fishery provided environmental factors are satisfied. However, further investigation of factors affecting the survival and growth of translocated shellfish is necessary to improve the success of future translocations.

Redclaw survey

As noted in the initial report (Rimmer *et al*. 1999a), redclaw crayfish have considerable potential for village-level aquaculture in Samoa. Many villages have small ponds or water bodies that would provide excellent habitat for redclaw. It is expected that redclaw would breed successfully in most of these ponds, and establish self-reproducing populations (provided that they are not over-harvested). Redclaw should be able to be polycultured with tilapia, although there may be some trophic overlap because both redclaw and tilapia are detritivores. Redclaw will survive and breed in moderate salinities, such as are typical of these ponds. Redclaw crayfish would provide additional protein intake in villages, and there would be markets for them in hotels and restaurants throughout Samoa, particularly in Apia.

Redclaw has been previously introduced to Samoa, along with the yabby *Cherax destructor* in 1993 and in 1995. Both species were cultured in freshwater ponds in the Solaua area. Despite the reported success of culture trials with redclaw (excellent survival and growth), the project was abandoned soon after. One major problem was the inability of the ponds to retain water due to crayfish (most likely *C. destructor*) burrowing through the banks.

Following the recommendation in the initial report (Rimmer *et al*. 1999a), a trapping survey was undertaken in the Falefa river system (Solaua, Sauniatu, Falefa) to determine whether there were any surviving redclaw from the Solaua aquaculture venture. The survey was undertaken with a view to more widely distributing redclaw if remnant populations existed in the Falefa river system. Two three-day trapping expeditions were undertaken which covered sections of the Falefa river system from Solaua down to Falefa falls. No redclaw or yabbies were found during this survey.

Future aquaculture trials

Mud crabs

Despite the problems encountered during the present study, we still feel that there is good potential for mud crab culture in Samoa. Because of the available area and likely mud crab resources in Samoa, this is likely to remain a relatively small-scale sector, based on the capture of small mudcrabs that are then grown out to a larger size before being sold.

Any future trials of mud crab aquaculture should involve an individual or a smaller group of villagers, such as a family or church group, rather than the whole village. The family or group that takes on the responsibility of the venture must also be responsible for security of the crabs.

There may be opportunities to undertake additional mud crab grow-out trials under the auspices of the IUCN 'Samoa – Marine Biodiversity Protection and Management' project. These trials could be conducted in the Saanapu – Sataoa Conservation Area, or in other areas in Safata Bay, at sites identified as suitable in Rimmer *et al*. (1999b).

We recommend that additional mud crab grow-out trials be undertaken in conjunction with private individuals, families or small groups to assess the biological and economic viability of mud crab farming in Samoa.

Shellfish

The translocation trials undertaken with *Asaphis*, *Anadara* and *Gafrarium* under the Samoa Fisheries Project demonstrated that it is possible to translocate these shellfish to new areas and achieve survival and growth at the translocation site. However, these trials also showed that there are significant constraints to the successful translocation of shellfish, including predation, and the suitability of sites in terms of substrate and water quality.

The resourcing of these trials under the Samoa Fisheries Project was, of necessity, limited. A full assessment of the translocation of these shellfish would require significant resourcing to allow design of replicated experimental plots, purchase of shellfish, and consistent intensive sampling of both naturally occurring and translocated populations. Because of these resourcing requirements, it would be preferable to have a small dedicated research project on shellfish translocation. Fisheries Division should seek funding from regional research providers (SPC, ACIAR, etc.) for such a project.

We recommend that further translocation trials be undertaken with the shellfish *Asaphis*, *Anadara* and *Gafrarium* and that these trials assess in more detail the impacts of predation and site suitability (including substrate and water quality) on the survival, growth and reproduction of the translocated shellfish.

Note: the following recommendations relate to the re-introduction of species already trialed in Samoa. All the species listed below have previously been introduced to

Samoa with no evident negative environmental impacts. In most cases, introduced species were rapidly harvested to extinction once culture activities ceased, which indicates their susceptibility to over-harvesting and supports the lack of environmental impact associated with their introduction. Any introductions should be carried out in an environmentally responsible fashion, with the agreement of the Samoa Department of Lands, Surveys and the Environment, Division of Environment and Conservation, and in accordance with the ICES Code of Practice on the Introductions and Transfers of Marine Organisms 1994 (ICES 1995) and the FAO guidelines for responsible aquaculture practices (FAO 1997).

Oysters

Oyster culture could not be trialed under the Samoa Fisheries Project because of the limitation of using only local species for aquaculture development. However, there are excellent opportunities for the development of an oyster aquaculture industry in Samoa. As noted in the Market information section (p. 15) there is a high demand for oysters which is currently being met by imports, mainly from New Zealand. One importer estimated that he was importing 400 dozen oysters each week. Based on this single estimate of demand, at SAT$1 per oyster the existing demand for oysters is around SAT$250,000 per annum. Since there are several oyster importers in Apia, demand is likely to substantially exceed this figure. An added advantage for the development of an oyster aquaculture industry in Samoa is that it would provide import replacement, with associated economic benefits to Samoa.

Previous trials with oysters have demonstrated the suitability of the Safata Bay area for oyster culture. Diploid and triploid Pacific oysters *C. gigas* were imported from the United States in 1990 and trialed using rack culture in Safata Bay. Although survival was low (attributed to gastropod predation), the trial demonstrated the suitability of Safata Bay for oyster culture.

Based on the outcomes of the 1990–91 trials it seems likely that improved culture techniques could improve oyster survival and allow a better assessment of the potential for oyster culture at Safata.

There are two options for re-introduction of Pacific oysters:

1. Introduction of triploid oysters. Triploid oysters are generally sterile, and thus there is theoretically little chance of triploid oysters establishing self-maintaining populations. However, no population of triploid organisms is ever 100% triploid; there is always a number of diploid animals present which have potential to breed and establish reproducing populations. Also, a few triploid individuals will spawn, although the spawnings are usually very small in size. A disadvantage of triploid oysters is that new oysters will have to be introduced each year from a hatchery, which will add significantly to the cost of the aquaculture venture. A major advantage of triploid oysters is that they grow more rapidly than diploid oysters under the same environmental conditions.
2. Introduction of diploid oysters. Because diploid oysters are capable of reproduction, populations may be allowed to reproduce and the spat collected for grow-out. This reduces the reliance on hatchery provision of spat. However, it is quite possible that the oysters will develop self-maintaining populations in the wild. This is certainly the case with *C. gigas* which has established wild

populations in a range of geographic areas and habitats in tropical to temperate areas throughout the world.

Triploid oysters are readily available from Taylor Shellfish, Kona, Hawaii, United States (e-mail: taylor@ilhawaii.net). The company advises that, based on previous experience freighting oyster spat in the South Pacific, the major cost of importing oyster spat would be the freight cost to Apia. Taylors would require the purchaser to organise pick-up and dispatch of the spat to Samoa.

The major environmental impact of introducing Pacific oysters is likely to be competition with the local oyster species. These have not been accurately identified but likely include *C. echinata* and probably several additional tropical species (S. Lindsay, pers. comm.). Previous experience with *C. gigas* in many countries is that it will outcompete native oyster populations. However, as with others species introduced to Samoa, it is likely that harvest pressure will prevent the widespread proliferation of the *C. gigas*.

In summary, we feel that there is excellent potential for the development of oyster culture in Samoa, based on:

- high local demand for oysters;
- previously successful trials at Safata Bay.

We recommend that further assessment trials be undertaken with triploid oyster spat imported from Hawaii to minimise the risk of wild populations of *C. gigas* becoming established in Samoa. Subsequent to these assessment trials, a decision can be made as to whether to continue to import triploid oysters or whether to establish self-maintaining populations of *C. gigas* for natural spat production, or whether to establish an oyster hatchery. Two sites have been identified with high potential for oyster culture using different techniques: Safata Bay on Upolu (rack culture) and Asau Bay on Savai'i (raft culture).

As noted in the initial report (Rimmer *et al*. 1999a), many filter-feeding molluscs, particularly oysters and mussels, are associated with a range of human health issues, such as accumulation of heavy metals, accumulation and transmission of human health pathogens, and accumulation of toxins. The accepted methodology for dealing with these issues is depuration of molluscs in filtered clean seawater, usually using a recirculation system fitted with ultraviolet sterilisation. An assessment of the aquaculture potential of Pacific oysters should also include an assessment of the need to provide depuration of these oysters in cooperation with the Health Department.

Mussels

There is also good potential for the development of mussel aquaculture in Samoa, as demonstrated by trials with the Philippine green mussel *Perna viridis* in the 1980's. *P. viridis* from Tahiti were successfully grown in raft culture trials in Safata Bay on Upolu and Asau Bay on Savai'i. The mussels grew well, although survival was poor on some rafts (attributed to poaching) and a natural spatfall was recorded in 1984 in Asau Bay. A number of additional batches of spat were imported to Samoa, the last in 1987. The trials ceased when Cyclone Ofa devastated much of Asau Bay in 1990, and the mussel beds that had developed as a result of the spatfall in Asau Bay were soon harvested to extinction.

There is some question over the continued suitability of Asau Bay for mussel culture, since the bay was dramatically altered by the destruction of the airstrip by Cyclone Ofa. It has been suggested that the changes in the hydrology of the bay may have made it unsuitable for mollusc culture. However, we feel that Asau Bay is still suitable for mussel farming by virtue of its deeper water, productivity and consistently high salinity (unlike Safata Bay). Consequently, we recommend that any future trials with mussels be undertaken in Asau Bay.

As with oysters, market data (albeit limited) suggest that there are good local markets for mussels that are currently being met with product imported from New Zealand. An assessment of the potential of mussel aquaculture by the Trade and Investment Promotion Unit (TIPU) of the Department of Trade, Commerce and Industry, Government of Samoa (TIPU 2000), includes an assessment of the markets for mussels in Samoa. In September 1999 green mussels without shell from New Zealand were being landed in Samoa at a cost of SAT$13–17 per kilogram CIF, and were being retailed at around SAT$18–19 per kilogram. TIPU estimated the total quantity of imported mussels at 7–10 tonnes (without shell) per annum, with perhaps another 2–5 tonnes per annum being brought to Samoa by returning residents and visitors carrying gifts for relatives (TIPU 2000). These data suggest a total market of 9–15 tonnes per annum valued at SAT$117,000–255,000.

TIPU also recognised a potential export market to American Samoa of 4–6 tonnes per annum, and a substantial export market to adjacent countries such as Fiji and Tonga.

TIPU undertook an economic assessment based on a production facility utilising ten rafts constructed from bamboo, and production of 500–1,000 kg of mussels per raft every eight months (based on Fisheries Division data). Total capital costs for such a project would be around SAT$400,000. The assessment predicted a total net profit of around SAT$95,000 over the first five years of the project (TIPU 2000).

A major problem with initiating culture trials with *P. viridis* is finding a suitable source of spat. The earlier source of *P. viridis* spat (the IFREMER hatchery in Tahiti, French Polynesia) apparently no longer produces this species. There are no hatcheries producing spat of *P. viridis* in the Philippines – aquaculture of this species there relies on natural spat-fall (J. Toledo, pers. comm.). In the absence of a reliable source of spat that could be readily imported, developing mussel aquaculture in Samoa would be difficult and potentially expensive.

We recommend that Fisheries Division monitor the availability of *P. viridis* spat in the South Pacific with a view to undertaking culture trials with this species should a source of spat become available.

Trochus

Trochus niloticus is valued for the inner nacreous layer of the shell, which along with that of the pearl oysters, is used for the manufacture of 'mother-of-pearl' buttons. It is commercially one of the most important shellfish in the Pacific Islands. Its flesh is a good source of protein. In some South Pacific countries, the harvest of trochus is a small but significant source of revenue and employment and is becoming increasingly so because of the steadily increasing demand for, and price of, trochus shell on the world market. The predominant opinion in the fashion industry is for a slight to moderate increase in the use of trochus buttons.

Trochus now occurs in all but four of the twenty-two Pacific Island countries. Twelve countries actually harvest trochus with six countries (Solomon Islands, Papua New Guinea, Fiji, New Caledonia, Vanuatu and the Federated States of Micronesia) producing 87% of the total. In recent years the annual harvest from the Pacific Islands region is estimated to have about 2,300 tonnes or about 59% of the world's total production of 3,900 tonnes. The present export value of the annual trochus harvest is approximately US$15 million.

T. niloticus does not occur naturally in Samoa. Another species, *T. pyramis,* does occur in Samoa but does not have the quality of shell that is required for commercial use. A total of 128 trochus *T. niloticus* was introduced from Fiji in 1990 in an attempt to establish trochus in Samoa. Eighty trochus were released on reefs on Namu'a and Nu'utele Islands and the rest maintained at the Fisheries Division facility at Apia. The status of the released trochus is unknown, but the remaining trochus at the Apia facility either died or were pilfered and eaten.

We agree with Amos' (1996) recommendation that trochus be re-introduced to Samoa. *T. niloticus* has a history of introduction in many island countries in the South Pacific. While precise data on environmental impacts are not available, it appears that the introduction of this species has not been associated with significant negative environmental impacts. Indeed, there is a history of over-harvesting being one of the main management problems with trochus, suggesting that it is unlikely to over-populate reefs.

One issue with the re-introduction of *T. niloticus* is the impact on the endemic *Trochus* species, *T. pyramis*. Widespread introduction of *T. niloticus* should consider potential impacts on *T. pyramis*. However, given that the major problem with both *Trochus* species in Samoa seems to be harvest pressure, there seems to be little potential for *T. niloticus* to replace *T. pyramis* to any significant extent.

Dr Chan Lee (Fisheries Western Australia) is currently developing an ACIAR-funded research project to examine trochus reseeding in Australia, Vanuatu and Samoa. **We recommend that Fisheries Division discuss with Dr Lee options for trochus reseeding in Samoa, with a view to undertaking trochus reseeding as part of the proposed ACIAR project.**

Future use of the Fisheries Division hatchery at Toloa

Privatisation

The Government of Samoa has requested that all government departments assess their activities and infrastructure with a view to privatising activities where possible. One of the Fisheries Division areas identified for possible future privatisation is the Giant Clam Hatchery at Toloa.

Naturally, there are advantages and disadvantages to privatising the hatchery, and these are discussed below:

Advantages

- ✓ Lower overall operating costs for FD – FD would save on costs associated with operating the hatchery (electricity, maintenance, etc.), travel costs for staff to travel to and from the hatchery and staff time.
- ✓ Promote commercial aquaculture development in Samoa – privatisation would promote the development of commercial aquaculture in Samoa through the need to establish culture facilities for the clam seedstock produced at the hatchery.

Disadvantages

- ✘ No access to hatchery facilities for FD – unless the hatchery was partially privatised, in which case FD could lease back some tanks and raceways for its own use.
- ✘ Reduced aquaculture skills and expertise in FD – without access to the hatchery, the skills and expertise acquired by FD staff under the Samoa Fisheries Project and associated training (e.g. JICA postgraduate scholarships) would be rapidly lost.
- ✘ Fewer opportunities to participate in regional aquaculture research and development projects – for example, the proposed ACIAR trochus broodstock enhancement project will probably require use of the hatchery for quarantine of trochus broodstock, and possibly for production of seedstock for additional stocking.
- ✘ Lack of a quarantine facility for any introductions of potential marine aquaculture species to Samoa – as recommended in this report, there is considerable potential for aquaculture development in Samoa based on the re-introduction of several marine species. However, responsible reintroduction of these species requires initial quarantine in an isolated facility prior to their reintroduction to natural waterways.

Cost-recovery

An alternative to full or partial privatisation of the Toloa hatchery is the introduction of cost-recovery. Under this scenario, the hatchery would continue to be operated by Fisheries Division. However, instead of clams (and any other organisms cultured at the hatchery) being given to villages, the clams would be sold on a cost-recovery basis. An analysis of the operating costs of the hatchery, based on a production of 70,000 clams per annum, indicates a cost-recovery figure of SAT$0.81 per clam. If the production level were to increase to 100,000 clams per annum, the unit cost would decrease to SAT$0.57 per clam (Lindsay *et al*. 2001).

Technical Limitations of Toloa Giant Clam Hatchery

The Fisheries Division Giant Clam Hatchery at Toloa, constructed with AusAID support under the Samoa Fisheries Project, is limited in its application to only a few species. In its current format, the hatchery can support the culture of giant clams and trochus, neither of which require microalgae during their larval stages. For the development of other species that we have recommended for aquaculture development in Samoa, the hatchery would need to have an algal culture facility added to it.

The culture of microalgae is fundamental to the operation of mollusc, crustacean and finfish hatcheries. The microalgae (typically 2–10 µm in diameter) are cultured in plastic bags or tanks and are then fed to the larval stages being cultured. In the case of finfish hatcheries, the microalgae are fed to zooplanktonic prey (such as rotifers) that are in turn fed to the fish larvae. However, a microalgal production facility is relatively expensive to establish and maintain, and requires substantial additional training in techniques such as sterilisation of media and equipment, axenic culture techniques, etc. The addition of a microalgal production facility to the Toloa hatchery would be a major financial commitment by Fisheries Division, both in terms of capital (for the construction of additional undercover and enclosed facilities, and the purchase of additional equipment) and operating (particularly labour) expenses. Considerable additional staff training would be necessary to operate a facility of this type.

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Appendix 1 – Terms of reference

Aquaculture: Assessment of Local Species Consultant

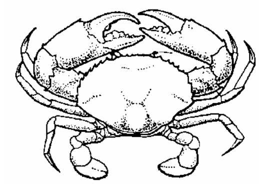
The Specialist will strengthen the capacity of the Division of Fisheries with regard to the identification of opportunities for diversified aquaculture based on species other than clams and tilapia. The Specialist will work with counterpart staff and the Aquaculture Adviser to assess and run pilot trials on the aquaculture of selected species. The Specialist is expected to play a key role in the transference of specialist skills to the staff of the Fisheries Division.

Duties:
Specifically, the Specialist, in collaboration with the Aquaculture Adviser and counterparts from the Division of Fisheries, will be responsible for:

- The assessment of the potential of Samoa’s marine and freshwater aquatic flora and fauna for aquaculture (initial input).
- The design and implementation of culture trials of selected species at the Division’s aquaculture facility or other site, where the assessment provides reasonable justification.
- The review of trialed species for broad-scale culture, and the capacity of the Division to realise the potential of selected species.
- Ensure that nominated counterpart(s) are in a position to take over the appropriate tasks within 2 years and provide on-the-job training.
- Completing reports and documents as detailed in the Project Inception Report.
- Undertaking other duties as requested by the Project Team Leader.

Appendix 2 – Selected Species Profiles

Common Name: Mud crab / Mangrove crab
Scientific Name: *Scylla serrata*
Local Name: Paalimago
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.

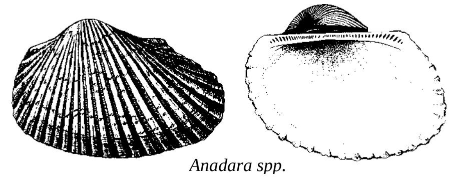
Ongrowing (Culture) Techniques	Crabs are grown out in ponds or in enclosures in ponds or rivers. Stocking rates range from 0.05/m^2 for extensive culture, 1.5/m^2 for ponds, and up to 5/m^2 for enclosures. Crabs can reach about 400 g in 3–5 months, depending on the initial stocking size. Survival is 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 & Postharvest Handling	Mangrove crabs can be readily transported live to markets. Live mangrove crabs are commonly found in the Apia fish market.
Cost effectiveness of each Stage	Unproven – production technology remains largely experimental.
Markets (current)	Fisheries Division statistics list the total weight of crabs sold in the Apia Fish Market and other outlets in Samoa at 38.5 tonnes (valued at SAT$649,954) in 1996-97 and 6.6 tonnes (valued at SAT$52,870) in 1997-98. A large crab may sell for about SAT$30 in the Apia Fish Market. The main market avenues in Samoa are the Apia Fish Market, restaurants and hotels.
Markets (potential)	Export of mangrove crabs could be possible. They are a popular species, and can be readily transported live.
Status of Species	*Scylla serrata* is endemic to Samoa. Local stocks believed to have declined. It is illegal to sell berried female mangrove crabs and the legal minimum size limit is 150 mm.
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.
Suitable site availability	Numerous sites in Samoa suitable for construction of fixed cages.
Remarks	Mangrove crab aquaculture currently depends on wild-caught seed to supply stock. Hatchery techniques have been developed but are still largely experimental.
References	Brown (1993), Richards (1994), Bell and Ropeti (1995), Keenan and Blackshaw (1999)

Common Name: Ark shell, Venus shell

Scientific Name: *Anadara, Gafrarium*

Local Name: Pae, Tugane

Status: Endemic



Anadara spp.

Description	Small bivalves utilised for subsistence/artisanal purposes by some villages. Have become locally extinct in some areas, and villages have requested re-introduction.
Spawning (Natural)	*Anadara* greater than 20-mm in length have visible gonads and presumably are sexually mature. *Anadara* probably spawns throughout the year. Sexual differentiation in *G. tumidum* begins at a shell length of 20-mm with first spawning occurring at 24-mm. In New Caledonia, fully mature *G. tumidum* individuals were found throughout the year with the period September to March as the main sexual maturity period.
Spawning (Hatchery)	
Settling/Rearing (Natural)	
Settling/Rearing (Laboratory)	
Ongrowing (Natural) Techniques	*Anadara* and *Gafrarium* occur in localised areas in brackishwater lagoons. *Anadara* is patchily distributed from below the low water mark, mostly in *Zostera* beds. Studies of *Anadara* in Fiji found that density varied from 0.2±0.8 to 2.2±3.1 individuals/m^2, and abundance was greater where both sand and mud were present, although larger specimens were found in muddy areas. *Anadara* are not evenly distributed, but form aggregations of variable numbers. *Anadara* may grow from settlement to 20-mm in length in less than a year, and from 20 to 40-mm in 8 months or less, but may require another 4 years to reach 65-mm.
Ongrowing (Culture) Techniques	Farmed *Anadara granosa* in Thailand reached about 40-mm in length in 24-g in weight after 18 months.
Food Supply	Naturally-occurring phytoplankton. *G. tumidum* is a suspension-feeding bivalve.
Disease	
Water Quality Issues	May have specific substrate requirements that limit their

	distribution. The general habitats for *Gafrarium* are sheltered areas, lagoons, mangroves and brackish-water.
Harvest & Postharvest Handling	Sold live by the bag / small basket for *Gafrarium* while *Anadara* are usually sold in bundles.
Cost effectiveness of each Stage	
Markets (current)	Fisheries Division statistics for 1997-98 list 2,660 bags landed, worth SAT$13,300.
Markets (potential)	Limited to local market.
Status of Species	Endemic. *Gafrarium* forms subsistence / artisanal fisheries in certain villages, e.g. Vaimoso, Vaiusu / Vailoa and Fusi Safata.
Investment requirement	Minimal. Reintroduction to local areas only.
Suitable site availability	Because of apparent specific substrate requirements, site availability would have to be assessed on a small-scale basis.
Remarks	Potential for re-introduction of these species to areas where they were formerly abundant, but have now disappeared.
References	Baron (1992), Richards (1994), Bell and Mulipola (1995)

Common Name:	**Trochus**
Scientific Name:	***Trochus niloticus***
Local Name:	**Aliao**
Status:	**Introduced from Fiji**
Description	A large (up to 15-cm diameter) gastropod, trochus is found in tropical and subtropical waters of the eastern Indian and western Pacific Oceans. Since the 1950's, trochus has been successfully introduced to nearly all island groups of Polynesia. Trochus is harvested for its mother-of-pearl shell that is used to make buttons for high-quality garments.
Spawning (Natural)	Spawning occurs throughout the year at low latitudes, but only during the warmer summer months towards the southern limit of its range. Most spawning activity occurs around full or new moon. Females spawn about every 2–4 months. Spawning is preceded by movement to high points on the reef, and trochus may form aggregations at these points. Female trochus in the 86–100-mm basal diameter range can release an average of 1 million oocytes, while females in the 130-mm basal diameter range can produce up to 3 million eggs.
Spawning (Hatchery)	Spawn readily in captivity.
Settling/Rearing (Natural)	Hatching occurs 11–13 hours after fertilisation, producing a free-swimming trochophore. Larval settlement occurs at 50–60 hours in the presence of suitable substrate, i.e. a primary algal film or coralline algae. In the absence of suitable substrate, settlement may be prolonged to 10 days.
Settling/Rearing (Laboratory)	Techniques well developed. Trochus larvae are lecithotrophic and do not need to be feed during the short larval phase. Hatchery procedures are relatively simple and giant clam hatchery can also be used to rear trochus.
Ongrowing (Natural) Techniques	Released into wild for stock enhancement. Optimal size-at-release yet to be determined, but survival of small trochus is often very low (<1%). *T. niloticus* generally inhabits the windward margin of coral reefs and lives in the intertidal and shallow subtidal zones, and feeds on the fine epilithic algal turf which grows on bare coral in this part of the reef. Trochus show relatively rapid growth during the first 3–4 years, the rate being determined by environmental conditions. Trochus achieve a basal diameter of 8-cm after 3 years, but subsequent growth is much slower: basal diameter of 11-cm is achieved at 5–8 years.

Ongrowing (Culture) Techniques	Growth rates reportedly too low for intensive culture.
Food Supply	Naturally occurring feeds. Trochus is herbivorous, grazing on attached algae.
Disease	No / little information.
Water Quality Issues	N/A.
Harvest & Postharvest Handling	Harvested by hand. Meat is edible and comprises 15% of the live weight. Shell traditionally used for buttons and other 'mother-of-pearl' applications.
Cost effectiveness of each Stage	Major issue is optimal size-at-release to allow adequate survival of juvenile trochus.
Markets (current)	Meat of local species, *T. pyramis*, consumed. Shell unsuitable for button manufacture.
Markets (potential)	Shell used for manufacture of high-quality buttons. The present export value of the annual trochus harvest is approximately US$15 million. There are markets in South-east Asia for fresh, frozen, dried and canned trochus meat.
Status of Species	Not endemic. FAO introduced 128 live trochus from Fiji in 1990. Status of introduced trochus is not known. Minimum legal size in Samoa: 75 mm
Investment requirement	May require hatchery to supply suitable numbers of juveniles to establish this species in Samoa. The proposed clam hatchery would be suitable for hatchery production of trochus.
Suitable site availability	Suitable habitats for trochus transplantation: • well-developed reef area with abundant corals, showing topographic complexities with depressions and elevations frequently exposed at low tide, and having rich flora of microscopic algae on the limestone substrates; • reefs with reasonable water movements and currents, without extreme dilution of sea water by freshwater runoff, and without pollution; • reef flat in the intertidal zone with suitable microhabitats for juveniles; • gentle reef slopes and terraces up 10 meters in depth, providing wide area for adult habitat. Site suitability for releases assessed in 1996. Generally, a major portion of reefs in Samoa would be suitable for trochus.
Remarks	Original importation attempted to introduce adult trochus to

	Samoa. This appears to have been unsuccessful. Generally, reintroducing adult trochus appears to have been more successful than reseeding with hatchery-reared juveniles to areas that have been overfished. Either replenishment strategy needs to be accompanied by measures to reduce harvest pressures. Although the value of the trochus fisheries is not large when compared to the industrial fisheries of the region such as that for tuna, the impact is substantial. Because it is one of the few resources from which cash income in rural locations may be derived, it is worthy of special attention by Pacific Island governments and the regional fisheries organisations.
References	Nash (1993), Richards (1994), Bell and Ropeti (1995), Amos (1996)

Common Name: Pacific Oyster
Scientific Name: *Crassostrea gigas*
Local Name: Tio
Status: Introduced from USA

Another species, probably *C. echinata*, occurs naturally in a few lagoons in Samoa, particularly Asau and Safata Bays and supports a small subsistence fishery there.

Description	A marine oyster that is widely cultured in tropical and temperate waters throughout the world, and has been introduced to many areas for aquaculture.
Spawning (Natural)	No naturally occurring populations of *C. gigas* in Samoa. In other tropical areas, there is an extended spawning season throughout most of the year, with peaks usually before and after the rainy season. A mature female can spawn 50–100 million eggs. The larval phase lasts for about 2–3 weeks.
Spawning (Hatchery)	Hatchery techniques well developed, but not widely used because of reliance on natural spat-fall. Hatchery required to produce triploids.
Settling/Rearing (Natural)	Spat can be collected on a range of substrates, including bivalve shells. Spatfall tends to be variable in both space and time, and a range of areas needs to be monitored to find the best locations for setting spat collectors. Settlement densities of up to 128 spat per shell have been reported for *C. gigas*. Larvae grow best at 19–27 ppt salinity.
Settling/Rearing (Laboratory)	Techniques well developed. Farming of faster-growing triploid oysters relies on hatchery-reared larvae for spat. Triploid oysters are generally sterile
Ongrowing (Natural) Techniques	Shell growth is greatly influenced by factors such as water temperature and salinity, currents and gestation. It is generally fastest in the spring and autumn and tends to slow in the spawning season over summer.
Ongrowing (Culture) Techniques	Grown out using a variety of methods, including: stakes, lattice, racks, rafts, long-lines, trays, etc. Marketable size of *ca*. 7–8 cm shell height is reached generally within 7–8 months to 1 year. Single trial carried out in Samoa in 1990-91 demonstrated growth to 120 mm (diploids) and 160 mm (triploids) in 9 months. Survival was only 10%, which was mainly attributed to gastropod predation.
Food Supply	Naturally-occurring phytoplankton.

Disease	Cultured oysters are subject to a range of diseases, parasites and predators. Because of the relatively long history of oyster culture, these are generally well documented, although less so for tropical than temperate regions.
Water Quality Issues	Similar to those for other sessile filter feeders. Adult *C. gigas* grow equally well over salinities ranging from 15–45 ppt. Sites should be free of sewage and heavy metal pollution, as well as toxic dinoflagellate blooms.
Harvest & Postharvest Handling	Usually partial harvested to ensure steady supply. Individual oysters are separated and cleaned of biofouling organisms. Oysters may be depurated for several days.
Cost effectiveness of each Stage	Hatchery: expensive, requiring specific microalgal culture capacity. Thus spat would need to be imported, at least for initial stockings.
Markets (current)	There is a small fishery for the local oyster species (*C. echinata*?) in the Asau Bay area. These are sold locally. At least SAT$20,000 worth of oysters are imported into Samoa per annum, the main supplier being New Zealand.
Markets (potential)	Variously estimated at 50,000 to over 250,000 oysters (per annum), locally at SAT$10 / dozen.
Status of Species	Not endemic. Introduced in 1990 for culture trials: 4,500 diploids and 56,000 triploids. Will require importation of seedstock, at least for initial stockings, or on-going importation of triploids.
Investment requirement	Low capital investment required for grow-out. Culture techniques can be easily adapted to use local materials. However, a hatchery may be required to produce the required numbers of spat.
Suitable site availability	Previous trial at Safata Bay demonstrated the suitability of this site for oyster culture. Asau Bay and Saleaula (Savai'i) are other potential sites.
Remarks	Spat would need to be imported. Triploid *C. gigas* are available from a commercial hatchery in Hawaii. Importation of diploid oyster seeds would lead to establishment of breeding stocks. Comparison of diploid and triploid performance in previous (and future?) trials to evaluate growth of diploid vs importation of triploid.
References	Walne and Spencer (1971), Mann (1979), Quayle (1982), Bell and Ropeti (1995), Joseph (1998)

Common Name: Philippine Green Mussel
Scientific Name: *Perna viridis*
Local Name: Maso
Status: Introduced from Tahiti

Description	One of many mussel species cultured throughout the world, *Perna viridis* is cultured throughout the Asia-Pacific region.
Spawning (Natural)	No naturally occurring populations in Samoa. Natural spatfall recorded in Asau Bay in 1984 from earlier introductions to Samoa.
Spawning (Hatchery)	Hatchery techniques for mussels well developed, but not widely used because of reliance on natural spat-fall. Spawning can be easily induced by lowering salinity. Larval rearing require specific culture of algae and thus expensive and requiring specialised expertise.
Settling/Rearing (Natural)	Free-swimming larvae require a firm substrate for settlement and for subsequent byssal attachment throughout juvenile and adult life. Spat can be collected on a range of substrates. 'Christmas tree' rope method used in New Zealand is effective.
Settling/Rearing (Laboratory)	The larval phase lasts for 3–4 weeks. Farming would require hatchery-reared larvae for spats only if breeding stocks are not established.
Ongrowing (Natural) Techniques	*P. viridis* inhabits estuarine or coastal waters that are rich in plankton, warm (26–32°C) and of high salinity (27–33 ppt).
Ongrowing (Culture) Techniques	Grown out using fixed (poles or racks) or suspended (grow-out ropes from floats, rafts, racks, frames or long-lines) techniques. Marketable size of *ca*. 5–7 cm shell length is reached generally within 6–7 months to 1 year. Earlier trials carried out in Samoa in 1980's demonstrated growth to 8.5 cm in 9 months. Survival was generally low due to poaching and predation.
Food Supply	Naturally-occurring phytoplankton.
Disease	Good management practices important to reduce the impact of diseases, parasites and predators. Principally, these involve regular thinning of mussels, and removal of biofouling.
Water Quality Issues	Similar to those for other sessile filter feeders. Prefer high productivity area, such as enclosed bays. Sites should be free of sewage and heavy metal pollution, as well as toxic dinoflagellate blooms.

Harvest & Postharvest Handling	Usually partial harvested to ensure steady supply. Individual mussels are separated and cleaned of biofouling organisms. Mussels may be depurated for several days.
Cost effectiveness of each Stage	Hatchery: expensive, requires micoalgal culture capacity. Limited available sites precludes a local hatchery.
Markets (current)	Locally produced mussels could replace imported mussels, currently valued at about SAT$7,000 annually (probably an under-estimate).
Markets (potential)	Limited to local market.
Status of Species	Not endemic. Several trial introductions undertaken in 1980's, with spat originating from Tahiti. Although mussels introduced to Asau Bay were able to reproduce naturally, these were eventually fished out after the culture trials there. Thus no breeding population has been established in Samoa.
Investment requirement	Low capital investment required. Culture techniques can be easily adapted to use local materials.
Suitable site availability	Trials at Safata Bay and Asau Bay demonstrated the suitability of these sites for mussel culture. The continued suitability of Asau Bay, post-Cyclone Ofa (in 1990), has been questioned.
Remarks	Seed of *P. viridis* is no longer available from Tahiti.
References	Bell and Ropeti (1995), Joseph 1998

Common Name:	**Redclaw Crayfish**
Scientific Name:	***Cherax quadricarinatus***
Local Name:	**Ula vai vaematua mumu**
Status:	**Introduced from Australia**
Description	A freshwater crayfish native to the Gulf of Carpentaria drainage system of northern Queensland. Only the male crayfish have the red claws that give this species its common name. Redclaw crayfish are now farmed in northern Australia and in parts of South America.
Spawning (Natural)	Spawns naturally in ponds. Spawns during spring and summer months and females may carry two or more broods of eggs per season. A female redclaw can hatch 300-1000 juveniles.
Spawning (Hatchery)	Technology available, but generally not used because of the ease of natural breeding.
Settling/Rearing (Natural)	Fertilised eggs are carried by the female, attached to the pleopods. The eggs hatch after 6–8 weeks, and the hatched juvenile crayfish remain attached to the pleopods for an additional 1–2 weeks. After this time, the juvenile crayfish detach from the pleopods, but they remain in the vicinity of the female for about another week before they become entirely independent.
Settling/Rearing (Laboratory)	Hatchery not necessary – juvenile crayfish carried by female.
Ongrowing (Natural) Techniques	Redclaw crayfish can be grown-out extensively in freshwater ponds. Supplementary feeding is not necessary if stocking densities are low.
Ongrowing (Culture) Techniques	Grown out in freshwater ponds, generally 0.1 – 0.2 ha in area. Can be cultured at low densities without supplementary feeding, or at higher densities if supplementary feeds are used. Without supplementary feeding, redclaw ponds yield around 100–300 kg per hectare. Previous culture in Samoa indicated that survival was excellent and that crayfish could be harvested after 9–10 months.
Food Supply	Naturally-occurring zooplankton and detritus, with supplementary feeding using pellets preferred.
Disease	Relatively few diseases affect crayfish.
Water Quality Issues	Tolerant of relatively poor water quality, particularly low dissolved oxygen levels and moderate turbidity.

	C. quadricarinatus will tolerate salinities up to 12 ppt.
Harvest & Postharvest Handling	Raw flesh recovery ranges from 14.5 to 36.9% (mean 22.2%) of body weight. Crayfish can easily be transported and sold live, or alternatively sold cooked whole, or as cooked tails.
Cost effectiveness of each Stage	Cheap to produce: does not require expensive hatchery facilities; does not require supplementary feeding.
Markets (current)	Local market unknown.
Markets (potential)	Possible local market for restaurants/hotels. Possible to export if needed volume can be attained.
Status of Species	Not endemic. Three or four separate introductions of redclaw (*C. quadricarinatus*) and yabbies (*C. destructor*) were made to Samoa in 1993 and 1995. It is not known whether any remnant populations in the Falefa River.
Investment requirement	Major capital investment is in ponds and water distribution (supply and drainage) system. Culture techniques require little infrastructure.
Suitable site availability	Previous introductions of *Cherax* spp. have indicated the availability of suitable sites for this species in Samoa, e.g Solaua. There are also many natural fresh- / brackish-water lakes that are suitable for stocking redclaw to establish a new freshwater subsistence fishery.
Remarks	Consideration of species for crayfish culture should be limited to *C. quadricarinatus*. This species has the best overall attributes for aquaculture and the technology for small- or medium-scale production is straightforward and inexpensive.
References	Jones (1990), Bell and Ropeti (1995)

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Appendix 3 – Report on Mangrove Crab Farming Trial at Sataoa

Background

Sataoa village is one of the two villages chosen for the first farming trials of mangrove crabs. This was because of the interest expressed during the assessment for aquaculture by Fisheries as requested by DEC, the availability of suitable mangrove areas during surveys of sites for aquaculture in Samoa and as expressed by the village in their Fisheries Management Plan.

Visits

Upon the arrival of the Project's Aquaculture Adviser, Mike Rimmer, to set up the trials, contacts were made with Sataoa concerning the trial. A visit was made on 6 October, to determine the actual site for the fence/pen for the trial. A second visit was made on 11 October, 2000 to dig a hole in the selected site to test water retention in the area planned for the trial, while actual construction of the fence was planned for Friday, 13 October, 2000. However, during the visit on 11 October, the village informed that they has decided to postpone the construction to the following Thursday 19 October, 2000.

During these meetings, it was explained to the village that their contributions would include labour to construct the fence, supply of posts, supply of small crabs, maintenance of fence, security as well as feeding the crabs on a daily basis.

The Fisheries team went to Sataoa on Thursday 19 October, 2000 with all the material required to construct the fence. Upon arrival, only the *Pulenuu* and another *matai* were there. The Fisheries Assistant (Extension) advised that it would be better not to construct the fence as the village's interest is indicated by the number of people showing up. [The day before the visit, the village had a *galuega* and prepared posts for the fence]. We then had a discussion with the *Pulenuu* and the *matai* present, concerning the project. The discussion involved collaboration between the Fisheries and the village on the project. Since the village's commitment to the project was not known as shown by the absence of *taulelea* to assist in the construction of the fence, it was agreed that construction be held off until the *Pulenuu* meets again with his committee and decide whether the village is committed to the project. The *Pulenuu* will then report to the office and discuss the project with the Extension.[1]

Recommendation

It is difficult at this stage to assess the village's commitment to the undertaking. The *Pulenuu* explained that a possible reason the *taulelea* did not show up was that they were probably too tired from catching *palolo*. Even the *matais* that showed up with *ava* during our first 2 visits did not show up this time, i.e. when it's time to do work.

Given the above, it is suggested that a different site be selected as a second site for the initial trials.

[1] The Pulenuu and committee have expelled Palusalue who was the most active and probably reliable member.
During both visits, a 'usu' by some matai was made. These matais were not present when the team came to construct the fence.

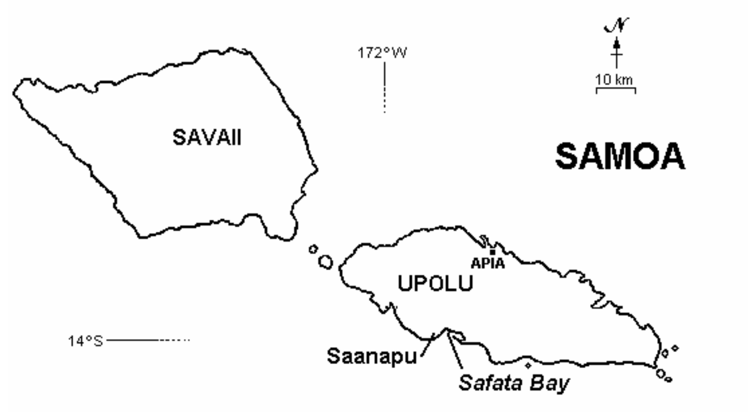
Another village earlier recommended is Matafaa, which does not have any other extra undertakings.

Private individuals at 2 sites have expressed interest in the trials. One of these sites, Moataa, has been visited (see separate report). This site, if chosen, will be a collaborative effort of some families in the area with Leilua Richard Mariner (Customs) as the leading person.

Another site to be surveyed is also in Moataa with Mr Seve Imo as the leading contact.

Appendix 4 – Site reports for sites assessed for mud crab grow-out trials

Site
Saanapu Safata



Date visited
Various: September 1999, October 2000

Description
Large lake system, freshwater and marine water sources. Mangrove fringed.

Water
Clean. 25–26^{o}C; 9–11 ppt.

Substrate
Mud / sand.

Depth
ca. 1 m.

Species already established / introduced
Range of naturally occurring marine and estuarine species.

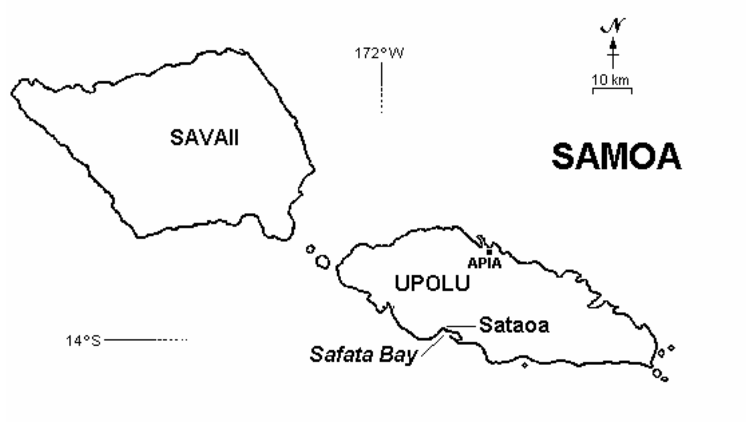
Suitability
Flat, unvegetated area near the road crossing / culvert suitable for mud crab culture. Much of this area is exposed at low tide, covered at high tide. Recommended location for grow-out trial.

Additional comments
Department of Lands, Surveys and Environment was approached by the villages of Saanapu and Sataoa regarding the development of aquaculture in association with the Mangrove Conservation Project being carried in those villages. Specific request to develop tilapia and marine shrimp aquaculture.

Meeting on 6 September 1999 attended by Tony Mulipola (Acting Assistant Director, Fisheries), Lui Bell, Pouvave Fainuulelei, with Sailimalo Pati Liu (Assistant Director for Environment, Project Manager, Department of Lands, Surveys and Environment), plus representatives of villages of Saanapu and Sataoa. Discussion of problems associated with developing shrimp aquaculture (lack of seedstock, possibility of viral disease introduction, environmental impacts, lack of feeds). General agreement that shrimp aquaculture was not suitable for this area. Tilapia aquaculture to be progressed, preferably using ponds away from the conservation area. Interest in proposal to trial mangrove crab farming at Saanapu.

Site
Sataoa

Date visited
Various: September 1999, October 2000



Description
Mangrove-lined brackishwater estuary.

Water
Clean. 27^{o}C; 20–30 ppt.

Substrate
Mud / sand.

Depth
Shallow areas near bank, deepening rapidly to *ca*. 1 m.

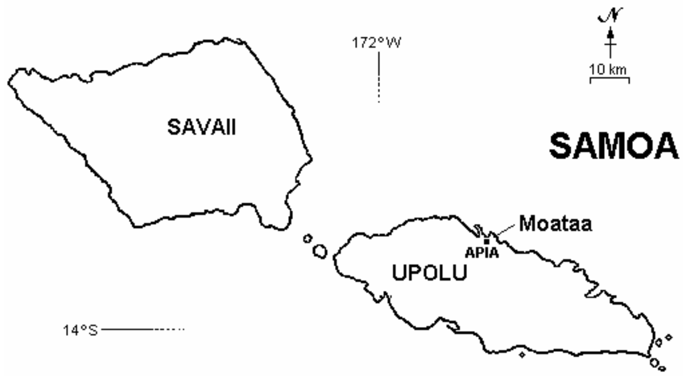
Species already established / introduced
Range of naturally occurring marine and estuarine species.

Suitability
Flat area near estuary mouth is suitable for mud crab culture. Substrate is exposed at low tide, with several pools remaining. Test holes showed that substrate has good water retention properties. Recommended site for grow-out trial.

Additional comments
As for Saanapu.

Site
Moataa (1)

Date visited
20 October 2000



Description
Area visited is mangrove forest behind the property of Mr Richard Mariner. The area is covered in small (2–3 m high) mangroves. There are several clear areas that would allow construction of a mud crab grow-out pen (150 m^2) without damaging the existing mangroves.

Water
Low salinity (2–5 ppt at low, incoming tide). Several freshwater springs in the area reduce the salinity. Temperature 28.0–28.5^oC.

Substrate
Mud.

Depth
About 1 m at high tide. Most of the area exposed at low tide.

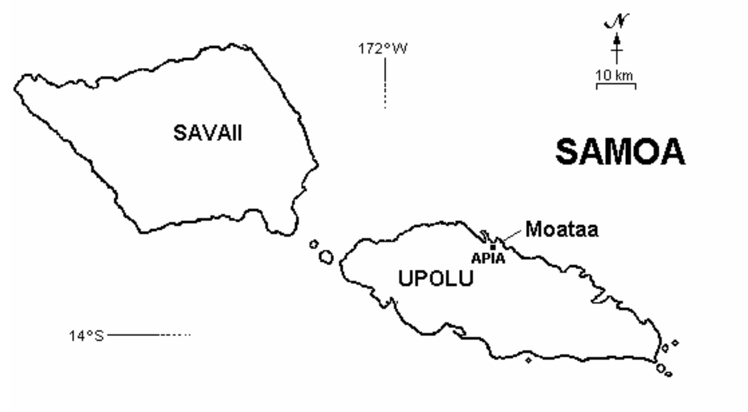
Species already established / introduced
A range of naturally occurring estuarine / marine species, including mud crabs, mullet and perch. People from other villages and neighbouring families trap mud crabs here.

Suitability
Suitable for mud crab grow-out trial. Enclosure could be constructed to incorporate some unvegetated areas, plus some existing small stands of mangroves.

Additional comments
Mr Mariner has discussed the possibility of undertaking a mud crab grow-out trial with his neighbours, and they are supportive of the concept. Fisheries would need to discuss further with all parties the precise arrangements to be undertaken during the trial, including who would feed the crabs (Mr Mariner's neighbours may be willing to do this) and what financial compensation could be arranged (possibly allocation of the profit from the sale of the harvested crabs).

A major advantage of this site is that it is close to Apia and can be regularly monitored by Fisheries at low cost. Security is a concern, but Mr Mariner feels that because his neighbours are usually at home during the day, they will be able to monitor the trial.

Site
Moataa (2)



Date visited
24 October 2000

Description
Area visited is mangrove forest near the small bridge. The area is covered in small (1–2 m high) mangroves, and a shallow brackish water stream runs through it. There are several clear areas that could be partly incorporated in a mud crab grow-out pen (150 m^2), although the pen should include some mangrove areas as well.

Water
Brackish water (8–10 ppt at low, outgoing tide). Temperature 29^{o}C.

Substrate
Solid substrate, with some muddy areas.

Depth
Most of the area exposed at low tide, except for stream. Mangrove area covered at high tide. The stream is only about 0.3–0.5 m deep at low tide.

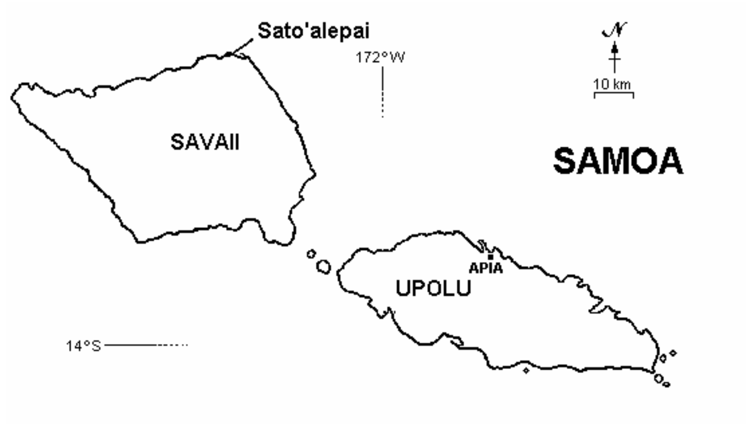
Species already established / introduced
A range of naturally occurring estuarine / marine species, including mud crabs and mullet. Local kids trap mud crabs here and catch up to 10 crabs per night.

Suitability
Suitable for mud crab grow-out trial. Enclosure could be constructed to incorporate some unvegetated areas, plus some existing mangroves.

Additional comments
A major advantage of this site, as with the other Moataa site, is that it is close to Apia and can be regularly monitored by Fisheries at low cost. Contact for this area is Mr Seve Imo.

It is recommended that this site be chosen for the second mud crab grow-out trial, assuming that the trial at Sataoa will now not go ahead. This site is preferred over Moataa (1) because of the higher salinity and easier access to the site.

Site
Sato'alepai



Date visited
1 September 1999

Description
Vary large brackish-water lake, >1 ha. Rocky, uneven bottom makes lake hard to harvest. Open to sea at bottom end, although this has been largely blocked by the construction of the coastal road. Freshwater springs upstream.

Water
Turbid. 5–7 ppt.

Substrate
Mud / rock.

Depth
Mostly *ca*. 1 m.

Species already established / introduced
Range of naturally occurring marine / estuarine species: mullet, garfish, trevally, barracuda, magrove crabs.
Oreochromis mossambicus introduced in 1950's – *O. niloticus* introduced recently. Tilapia are harvested by net and handline. A string of 3 large Nile tilapia (averaging about 30 cm in length) have been sold for WS$10.

Suitability
Good site to run a mangrove crab fattening trial. This village has one of the best records for looking after clams, and are likely to look after a mud crab fattening trial as well.
Redclaw crayfish.
Mullet, rabbitfish, milkfish, freshwater eel.
Trochus on reef flat.

Culture Method
Mangrove crab culture in pens. Redclaw released into lake.
Finfish in cages – possible polyculture with crabs.
Trochus to be released to the wild.