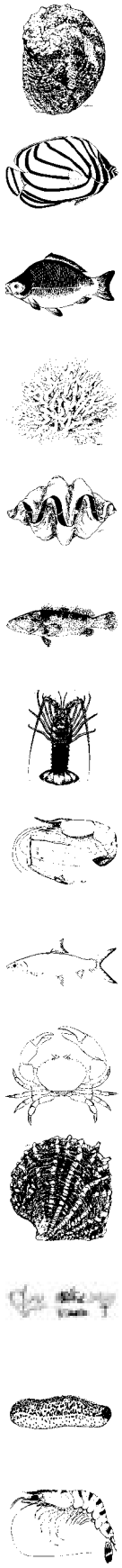
Profiles of high interest aquaculture commodities for Pacific Islands countries



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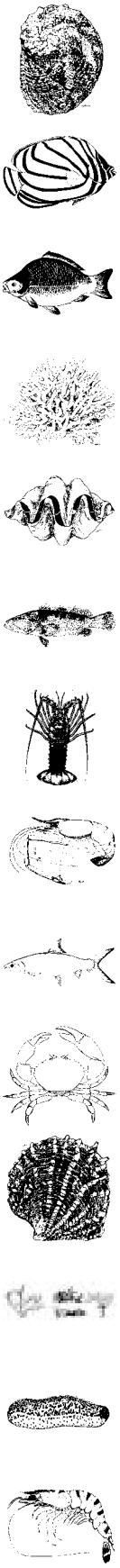

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August 2003

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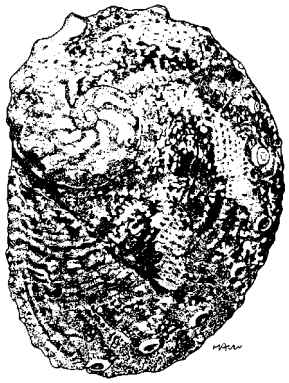
Abalone

Name of species/group

Haliotis asinina (Mollusca: Gastropoda).



Primary potential

Aquaculture for sale of meat, primarily live, canned or frozen.

Attributes for aquaculture/stock enhancement

- Broodstock conditioning, spawning and larval phase uncomplicated and may be conducted all year round.
- Nursery phase is intensive but now well understood.
- Grow-out phase is achievable either on formulated feeds or on seaweed.
- Grow-out methods range from intensive land-based tank culture to sea-based barrel or cage culture and so are suited to a variety of situations.
- Short grow-out cycle of between 10 and 18 months.
- Low disease risk although some countries have been affected by the import of parasites.
- Low environmental impact.
- Ready market for product in a variety of forms.

Culture methods

- Broodstock for tropical abalone are available all year round, have a high fecundity, and can be conditioned to spawn through temperature manipulation and food availability.
- Spawning is induced by temperature and use of UV-irradiated water or hydrogen peroxide.
- Larval cycle is simple as no feeding is required.
- Metamorphosing or 'ready to set' larvae are transferred to a nursery area and either induced to set by the presence of particular algal species or chemically set with GABA (gamma-aminobutyric acid).
- Nursery culture varies: some nurseries conduct intensive production of benthic algae or powdered feeds; others encourage settlement of naturally occurring diatoms, particularly *Nitzschia* and *Navicula* spp.
- Grow-out methods for abalone vary considerably in style, depending on the species under culture and the type of food used. *H. asinina* is unlikely to be very different from the other tropical abalones. If being fed on seaweed, barrel or cage culture on long lines or in deep land-based tanks is common. If being fed artificial food, the tanks consist of either deep tanks with removable hides in them or shallow systems with a high water exchange rate.

Current production status

- Production of all species of abalone with the exception of *H. asinina* has moved rapidly from the research to the development phase, with production of most species set to increase exponentially.
- There are two distinct markets for abalone: a low price one for tropical species and a high price one for temperate species. The market distinction is on size, texture and taste.
- Aquaculture production of abalone totals approximately 8000 tonnes, with both China and Taiwan producing over 3000 tonnes each. Other countries in or beginning to enter the production phase include the USA, Mexico, Chile, South Africa, Australia, Korea, Thailand and Indonesia.

Marketing

- Marketed live, canned, fresh frozen, parboiled, pouched, dried or in value-added forms such as soups. Most tropical abalone is sold live.
- Sales are primarily to Asia through existing, very competitive, buying groups.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- The technology is readily available; hatchery and nursery technology is very similar to trochus.
- Growth rates are very high, and so the turnover time is fast and risks are lower. Grow-out methods can vary widely in capital requirements.
- Suitable for polyculture with seaweed farms.
- Good option where canneries or other seafood processing facilities are already in existence.
- Low environmental impact.

Disadvantages

- Risks with poor availability of live airfreight.
- Capital requirements of land-based farms.
- Necessary to achieve relatively large exports to achieve economies of scale and be attractive to the market.
- Highly competitive nature of the alternative suppliers to the market.

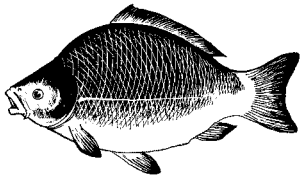
Carp

Name of species/group

This group includes common carp (*Cyprinus carpio*), Chinese carps (silver carp, bighead and grass carp, mud carp, etc.), Indian carps (rohu, catla and mrigal, etc.), barbels (such as Thai silver barb) and some other species of cyprinids. Carps can be described by mode of feeding: there are foraging carps (common carp and grass carp, etc.) and filter feeders (silver carp and bighead).

Primary potential

Low input, low cost aquaculture production of protein food for domestic consumption and cash income.



Attributes for aquaculture/stock enhancement

- Carp farming for consumption dates back to more than 2000 years ago in China. Nowadays, carp culture is widely practised in East Asia, Southeast Asia, South Asia, Israel, Central Asia and some Eastern European countries.
- World carp production from aquaculture in 1999 was 14.9 million tonnes, which was 44.7% of the world total aquaculture production in the same year. Eight of the top 10 aquaculture finfish in single species production are carps (the other two are tilapia and Atlantic salmon). In many industrialised countries, like Australia, carps are regarded as pests. In many populous counties in Asia they are the strategic species for securing rural livelihood and national food security through freshwater aquaculture.
- The carp species for aquaculture are generally low in the food chain in an aquatic ecosystem. Being low in the food chain is desirable in the sense that they can be grown with less costly feeds. Silver carp and bighead can be grown by fertilising the water so that the plankton for their food proliferate.
- Foraging carps may be herbivorous (grass carp) or omnivorous (common carp). Foraging carps readily accept artificial pellet feeds in culture conditions.
- Among filter feeders, silver carp feed mainly on phytoplankton and bighead feed mainly on zooplankton. In water bodies with high organic matter content, such as fish ponds, organic particles colonised with bacteria may contribute up to one third of the growth of the filter feeders in addition to planktons.
- It is possible to integrate carp culture with crop farming and/or animal husbandry, as widely practised in some Asian countries. This reduces production cost, makes efficient use of land and water and reduces disposal/discharge of waste materials into the environment.
- In reservoirs that supply water for domestic or urban use that have high nutrient content or algal bloom problems, filter feeding silver carp and bighead stocked or cultured in cages help the removal of nutrients from the water, resulting in better water quality. Minor benefit is the production of food fish without feed input.

- Hatchery technologies for the common carp and carp species found in South Asia and Southeast Asia are well established and relatively simple. As well as mass-scale hatchery operation, these species are also suitable for small-scale hatchery operators.
- Chinese carps do not spawn naturally in captivity and require hormonal treatment. Hatchery technology for seed production of Chinese carps is well developed and established. Chinese carps are more suitable for mass-scale hatchery operation because of their reproductive characteristics, i.e. relatively larger maturation size and age.
- Nurseries for carps are mostly earthen pond-based. Preparing the natural food organisms (zooplanktons) through balanced fertilisation and proper water management of these ponds requires some skills. Supplementary feeds are used. Carp nursery techniques are well established in Asian countries like China and India.
- Carp are less demanding of animal protein for food. For grow-out, compound feeds with mainly plant ingredients and with 30–40% crude protein are commonly used. In major carp producing countries there is a well established commercial carp-feed industry that supplies both ordinary hard pellets and floating pellets.
- Diseases are not a major problem in extensive to semi-intensive culture systems. Additional input is required for disease control in intensive farming. Grow-out period is 6 months to 1 year in tropical conditions. In cold water, it takes 1–2 years.

Culture methods and current production status

- Most carp farming is pond-based with several species stocked in the same pond (polyculture). Tilapia and sometime catfish are stocked together with carp. Single-species culture, or monoculture, is rare except in flow-through systems and cage culture of common carp in streams or canals.
- There are different stocking models for polyculture, depending on the availability of the main source of feed. If grasses (aquatic or terrestrial) are abundant, grass carp can be stocked as the major species. The leftover feed and grass carp excreta would sufficiently fertilise the pond water for the growth of filter feeders.
- Pond-based carp culture has been traditionally integrated with crop farming (mulberry, fruit, vegetables, etc.) and animal husbandry (ducks, swine, chicken, etc.) in China. The practice has been widely introduced to many other parts of the world with some modifications to fit into local conditions. (The NACA Secretariat and the Freshwater Fisheries Research Centre in Wuxi, China, offers a 3-month training course in integrated fish farming each year for overseas trainees with funds to cover all expenses in China. South Pacific countries could participate for the cost of the air fare.)

- There is a varying degree of intensity of pond carp culture from extensive to intensive:

  Extensive

  - Low stocking; more fertiliser than feeding; more filter feeders than foraging species. (Organic fertilisation alone could support fish weight gain of 15 kg/ha/day with filter feeders and common carp.)

  Intensive

  - High stocking density, more commercial feeds than fertilisation or even no fertilisation, foraging species as main species and filter feeders as minor species for cleaning water. (Aeration is required if the targeted production exceeds 10 tonnes/ha/year.)
  - Small-scale farms operate in ponds of 0.1 to 0.5 ha in size. Large commercial farms operate in ponds of about 1 to 2 ha in size. Deep ponds (2–3 metres) are desirable.

- Net cage and pen culture of carp in freshwater lakes, reservoirs, rivers and canals have been well established in some Asian countries. Supplementary feeds or commercial feeds are often used. This requires reliable supply of reasonably large fingerlings from pond-based nursery farms.
- Carp culture in paddy field (for nursing or for grow-out) is successful in many Asian countries where pesticides are not used. Paddy fields need modification with a deep ditch for fish as shelter. (In China in 2000, 2.5 million ha of paddy field was utilised for grow-out of fish, mostly carps, and 0.25 million ha for fingerling culture. National average yield of food fish from paddy field was 487 kg/ha/year.)
- Carp fingerlings are released into inland open waters for fishery resource enhancement in many Asian countries.

Marketing

- Among major producers, almost the entire production of carp is for the domestic markets for local consumption.
- Carp are marketed in live, fresh, chilled and frozen forms, depending on the location, season and local consumer preference. In some Buddhist countries in Asia, consumers only buy dead fish. Live carps are preferred in China and among Chinese communities in Southeast Asia.
- In countries where carp consumption is new, it may take some time to educate or train the people on how to eat carps that have a lot of intermuscular bones. Proper cooking, such as deep-frying and fish meat balls, can overcome this. Carp are well suited to Chinese and Indian cuisine.
- The head of bighead carp (one third of the body weight is in the head) is often sold separately in China, and fetches higher prices because it is meaty and good for soup. In the Philippines, on the other hand, the head is removed and the body is sold at a higher price.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- Some carp species have been introduced to South Pacific countries with some degree of acceptance by local farmers and consumers.
- Carp could be integrated with other farm activities in Pacific Islands countries to reduce overall production costs and bring greater economic and environmental benefits.
- Some large Pacific countries with extensive river systems have poor freshwater fish fauna, or only small species, and careful introduction of some carp species could enhance the supply of edible freshwater fish (but see also under Disadvantages below).
- Filter feeding carps, silver carp and bighead are suitable for low cost aquaculture production and for culture-based inland fishery resource enhancement. Grass carp, as a voracious feeder, could be introduced to utilise both aquatic and terrestrial grasses.
- In many Pacific Islands countries there are no major rivers. Even if Chinese carps, which require strong turbulences in the spawning ground, spawn naturally in the rivers, the eggs will be flushed into the sea before well they are developed. Hence, the threat to local fish species is considered to be minor.

Disadvantages

- Carp species might pose a threat to indigenous fish when introduced, primarily through habitat modification/degradation.

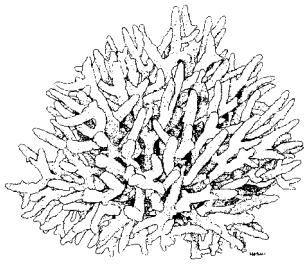
Coral

Name of species/group

Scleractinian corals.

Primary potential

Aquarium and curio coral trades, coral reef restoration, and enhancement of snorkelling trails for ecotourism.



Attributes for aquaculture/stock enhancement

- Aquacultured corals qualify as 'captive bred' and are exempted from CITES regulations, but only if they are certified as grown from second generation cultured stock.
- Coral seed is readily available in the wild. However, wild stock should only be relied on in the selection of fragments for culture into mother colonies.
- Selection for colour, growth form, disease resistance, attachment and growth rate should be done in initial trials before culture into mother colonies.
- Coral culture is a central component of the 'green certification' process for the aquarium and curio trades, a plan for phasing out the wild coral harvest over time.
- High rates of survival (close to 100%) when coral seed are handled properly.
- Fast production (3–12 months for aquarium corals, 1–3 years for curio corals).
- Retail prices for cultured corals are higher than for wild collected corals.

Culture methods

- Corals can be grown in shallow water in the field with relative ease without the use of scuba, as long as the culture site has (1) good water flow but is sheltered from waves; (2) consistently high quality seawater; and (3) abundant shelter for herbivorous fish, which are important for cleaning the frames.
- Underwater culture tables for holding the culture frames of coral fragments are constructed of 12 mm ($^1/_2$ inch) metal bars wired together with baling wire (similar to WorldFish Center clam culture tables). Extra bars can be attached to form 2 or 3 layers.
- Culture frames are made of 1 X 1 cm galvanised wire mesh, painted to prevent rusting. Dimensions may vary but must be sufficient to allow for overlap and stability on the culture table.
- Bases for culture can be made of concrete disks, rock or shell.
- 3–5 cm coral fragments serve as seed. A 14 kg (30 lb) breaking strain monofilament line holds the seed fragment tightly to the base and the base to the frame. A single frame can hold about 50 fragments for culture, and 10–12 frames per culture table.

- Corals can be grown at high densities, lessening negative impacts on reef environments.
- Coral fragments can also be cultured directly on clean rubble beds, with each fragment tagged to establish its cultured nature.
- Mother colonies can be cultured on lines stretched between the culture tables, attached to concrete blocks, or directly on clean rubble.
- Each coral farm should have an associated restoration or reef enhancement site, for receiving unmarketable corals (misshapen, partly dead or broken).

Current production status

- Much research remains to be done to improve methods.
- Pilot-scale production is occurring in several places in Fiji (Walt Smith and Foundation for the South Pacific) and in the Philippines and Palau using different methods and requiring scuba.
- Commercial production took place in Marau Sound, Solomon Islands, in 1998–1999, but most of this activity was curtailed by ethnic unrest in 1999–2000.

Marketing

- Well established, long-standing international demand.
- Domestic demand by the tourism industry for small bleached or coloured corals, estimated at up to 50,000 aquacultured colonies per year in Fiji Islands alone.
- Opportunity to develop a local product of high value, and for use with communities for conservation, to build conservation awareness, and as a restoration incentive.
- Potential for culture and marketing of medical-grade corals for bone grafts.
- Cultured corals have multiple markets, so farmed corals are less vulnerable to fluctuations in market demand. Can be used in reef restoration.
- No competition with other aquaculture or fisheries products.
- For eco-labelling purposes, corals are identified as of aquacultured origin by incorporation of monofilament line deep within colonies and by skeletal overgrowth onto bases. Establishing that corals are grown from cultured mother colonies, without negative impacts and linked to conservation, will require third-party certification.
- Aquarium corals (live) must be kept in well oxygenated seawater for air shipment, while curio corals (dead) have an indefinite storage life and can be shipped by sea.
- For purposes of restoration or snorkelling trail enhancement, transport of corals is possible for several hours out of water if regularly sprayed with water and shaded.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific:

- Simple, low cost technology and easy management. Suitable for small-scale operations and for self-employment of rural women and youth.
- Coral farming should best be introduced as part of a wider reef awareness and management context, and as an economic incentive for conservation.
- Coral culture should be done in the field. The culture of corals in greenhouses in developed countries not only produces tonnes of greenhouse gases but is a violation of indigenous property rights, as outlined in the UN Convention on Biodiversity.

Risks to field culture

- *Stegastes* 'farmer fish' can move onto culture tables and establish algal farms, killing the corals.
- If herbivorous fish are absent, algae can overgrow the cultured corals.
- Bleaching during warm water events can kill the corals, but can be prevented by covering the coral farm with shade cloth.

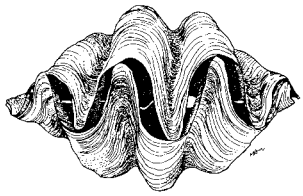
Giant clam

Name of species/group

Giant clams *Tridacna gigas, Tridacna derasa, Tridacna tevoroa, Tridacna squamosa, Tridacna maxima, Tridacna crocea, Hippopus hippopus, Hippopus porcellanus.*

Primary potential

Aquaculture for sale of various products.
Aquaculture for stock enhancement.



Attributes for aquaculture/stock enhancement

- Methods for all phases of aquaculture have been developed and are readily accessible in manuals and through experienced personnel.
- Broodstock of many species is available in most of the Pacific region.
- Techniques for rearing larvae, often the most technically difficult phase of aquaculture, are relatively simple. Survival may be low but the very high numbers of eggs available from broodstock spawnings compensate for this.
- Relatively simple and inexpensive facilities, compared to many other shellfish and finfish, are required.
- Feed input is only needed at the land nursery stage. Afterwards no feed inputs are required.
- Commercial size for the aquarium trade can be reached in about two years.
- Giant clams are not prone to diseases.
- Giant clams are sold for very high retail prices in the USA (e.g. Harbor Aquatics advertises prices from USD20 to USD300) and probably in Europe and Japan, where tropical aquaria are popular. (Constraints may be access to suitable international air transport for rapid transport of live clams and the extent to which current markets are satisfied.)

Culture methods

- Juveniles are not available from the wild so hatchery production is needed.
- Low environmental impact at all stages of production.

Juvenile production

- Gonad ripeness is easily visible.
- Spawning is induced by heat shocks or serotonin injection.
- Large numbers of eggs are produced (millions to hundreds of millions).
- Larval phase is short at less than 10 days. Hatchery production is technical and requires trained personnel and specialised equipment.

- Microalgal food for larvae involves standard, but technical, production methods. For simplicity, microencapsulated diets may be used.
- The land nursery phase for juvenile growth is relatively long (6–8 months) but only requires clean seawater and some additional soluble nutrients.

Ocean nursery production

- Juveniles are transferred to simple mesh cages in the sea at 15+ mm shell length.
- With some reduction of stocking densities the ocean nursery phase can be carried through to market size, thereby reducing mortality from large predators.
- To reduce mortality from predatory snails and flatworms, regular simple husbandry in relatively shallow water is required.
- Wide variability in growth rates both within and between species ensures a steady flow of market size animals.
- The ocean nursery phase utilises simple, inexpensive technology.
- Husbandry can involve all members of a family group.
- Where larger clams are required, involving longer periods of growth, when the clams reach a size where they will be free from predation they may be spread out on the substrate. They require virtually no husbandry at this stage: it is equivalent to forestry.

Restocking

- Individuals large enough to be essentially free from predation can easily be placed in suitable positions on the reef.
- Lack of mobility makes it easy to monitor mortality, growth and reproduction.
- Age to sexual maturity in larger species can be 10+ years, so long-term vigilance is required to prevent poaching before reproductive capacity is achieved.
- Restocking is expensive for the number of clams involved. Regulation is far cheaper where there are significant existing stocks.
- Restocking has been successfully achieved in the Philippines and probably in some Pacific Islands countries where clam species were reintroduced as quarantined juveniles, reared and subsequently introduced into the environment. In the Philippines, some restocked clams have been used as broodstock to produce at least one further generation of clams.

Current production status

- Generally very limited, pilot-scale hatchery, nursery production and grow-out culture in the Philippines, Solomon Islands, Vanuatu, Tonga, Fiji Islands, Cook Islands.
- Commercial companies in Hawaii and Micronesia selling to at least the USA tropical marine trade (probable sources of clams for trade). There are no readily available values for the commercial value of these operations.

Marketing

Aquarium and shell trade

- Established aquarium market for wild giant clams makes marketing aquarium size cultured giant clams easy.
- The smaller clams needed for the aquarium trade have a high value-to-weight ratio and a short growing period to commercial size (2 years and less).
- Due to CITES listing there are some transport difficulties for F1 generations in or through some countries. Using F2 generations overcomes this problem.
- Cultured clams are perfect for eco-labelling due to lack of reef degradation and employment of coastal communities.

Clam meat production

- Lucrative market for adductor muscle from large wild clams, but no large established market for meat from smaller individuals.
- Best price is for sashimi-grade meat, which means clams need to be shipped live.
- Transport difficulties due to limited air transport networks in the Pacific, the heavy weight of larger animals and limited shelf life (30 hours maximum) due to the need to keep the animals alive.
- High value product can be shipped as shucked meat but needs specialist handling and swift transport to markets.
- Domestic markets are very low volume due to the high production costs, thus limited mainly to specialist restaurants and the tourist trade.
- Transport and holding problems restrict the shelf life for low-volume domestic consumption.

Shell trade

- Giant clam shells are valuable and don't need rapid transport. There is much worldwide trade in illegal clam shells, some of which command high prices at the retail level.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- Broodstock widely available throughout their geographical distribution.
- Relatively simple hatchery technology.
- Very fecund animals producing millions of eggs.
- Low cost growing methods.
- Ocean nursery grow-out in shallow coastal areas makes tending easy.

- No adverse environmental effects, so good for eco-labelling.
- All members of the community can become involved in the grow-out phase.
- At the rural level, a small number of clams can produce a reasonable livelihood.
- Aquarium clams are high value and easy to transport. More brightly coloured species/individuals can be selected for the aquarium trade.
- More robust and quicker growing species (*T. derasa* and *T. gigas*) are more suitable to meat production due to higher survival and faster weight gains.
- Shells are valuable for legitimate shell trade.
- Stock enhancement is easily monitored.

Disadvantages

- Some species are extinct/becoming extinct in some regions.
- Need hatchery production of juveniles. Hatchery survival can be very variable.
- Very susceptible to predation at ocean nursery phase in some regions, so need constant husbandry.
- Great variability of growth rates between and within some species. Highest value species are the slowest growers.
- Work needed in developing the markets for food, aquarium trade and shells (although all are potentially lucrative).
- Very perishable, need to be shipped live or very fresh.
- Some meat market clams are heavy. If they need to be airfreighted live and whole, transport costs are high.
- Relatively poor and expensive air links to the Pacific region make transportation difficult.
- Improper handling by airline ground-staff often leads to mass mortalities.
- Stock-enhanced areas are easy targets for poachers.

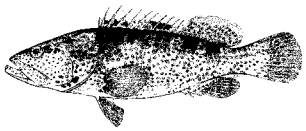
Grouper

Name of species/group

Groupers (family Serranidae, subfamily Epinephelinae).

Primary potential

Aquaculture.



Attributes for aquaculture/stock enhancement

- High demand in export markets.
- High value.
- Rapid growth rates (depending on species).
- Sedentary / territorial.

Culture methods

Seedstock

- Most grouper seedstock is still supplied through wild capture of juvenile fish. Juvenile fish are collected using a range of methods, such as push nets and traps and fish aggregating devices.
- Hatchery production of groupers is still low and irregular. Larvae are difficult to rear because of their specific feed and environmental requirements. Survival is generally less than 5% to juvenile stage. A few hatcheries have improved survival of some grouper species (barramundi cod *Cromileptes altivelis* and tiger grouper *Epinephelus fuscoguttatus*) to around 40%. Viral and bacterial diseases also cause mortalities in hatcheries.

Grow-out

- Groupers are generally grown out in net cages. Some coastal species can be grown out in ponds.
- Specific requirements for grow-out are:
  - Suitable water quality, particularly temperature 26–32°C and salinity 20–35 parts per thousand.
  - Suitable sites for cages: sheltered areas, moderate currents, depth at least 10 metres, sand or mud substrate.
  - Supply of feed, preferably compounded (pellet) feed.
- Grouper is well suited to small-scale operations, and is cultured in small (2 X 2 X 2 m to 5 X 5 X 5 m) cages in Asia.
- Successful management requires a good knowledge of finfish aquaculture, as well as technical support, particularly for disease (viral, bacterial, parasitic) diagnosis and treatment.
- Opportunities for employment of women in daily maintenance, including feeding, harvesting and packing.

Current production status

- World aquaculture production of groupers is around 6000–7000 tonnes per annum, valued at about USD60 million, the bulk of production from wild seedstock.
- Production is constrained by the numbers of seedstock available from the wild and from limited hatchery production.
- Availability of feed (trash fish or pellets) is another constraint to grouper grow-out.
- Taiwan is the leading producer of hatchery reared grouper seedstock. Taiwan exports grouper seedstock throughout the Asia-Pacific region.
- Translocation and health testing are important issues associated with the import of grouper seed.

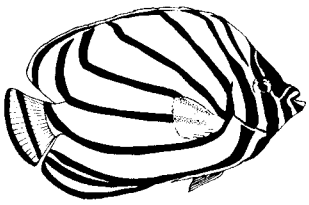
Marketing

- Many high value grouper species (such as coral trout) are sold to the Hong Kong live fish market, where they bring high prices.
- Live groupers can be shipped using airfreight or live fish transport vessels. If airfreight is used, direct flights to Hong Kong are preferred to prevent offloading, which often results in long delays and loss of product.
- There may be small-volume local markets (hotels, restaurants, Chinese communities) in South Pacific countries.
- There is currently an effort under way to introduce a voluntary code of practice for live reef fish. This may lead to certification and eco-labelling of sustainably produced live reef fish.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

- Marketing infrastructure is important — either direct flights for airfreight or the availability of live fish transport vessels. Live fish transport vessels require a substantial quantity of product, e.g. 15 tonnes or more, to make a trip worthwhile.
- A source of feed needs to be established. Compounded (pellet) feeds are preferable, since they are more cost-effective and less environmentally damaging than the use of trash fish.
- Grouper aquaculture is set to expand in Asia. Asian producers may have a competitive advantage due to location close to the major markets, seedstock supplies, etc.

Larval fish



Name of species/group

Postlarval coral reef fish species of value to the live fish trade for food or ornamental (aquarium) species. The food trade deals principally in serranids from the genera *Epinephelus* and *Plectropomus*, but also includes the Napolean wrasse (*Cheilinus undulatus*). Thousands of small brightly coloured species are sold in the ornamental trade, including some valuable crustaceans such as tropical spiny lobster and coral shrimp. Key families for this market include the angelfish (Pomacanthidae), butterflyfish (Chaetodontidae), surgeonfish (Acanthuridae), damselfish (Pomacentridae) and wrasses (Labridae).

Primary potential

Aquaculture for cash income. Potential for capture, culture and release for stock enhancement if wild stocks are severely depleted.

Attributes for aquaculture/stock enhancement

- Relative ease of capture of wild postlarvae at settlement, if appropriate collection areas are accessible.
- Research work in Solomon Islands has identified a number of species that are relatively hardy, easy to feed, show good survival rates and are marketable.
- Disease has not been a problem so far, although fish have not been kept in high densities. More work is planned to investigate this factor.
- Capturing wild juveniles for grow-out results in genetically fit stock.
- If excess fish are captured or if local stocks are depleted, then juveniles can be safely released back to the wild after being nursed through the high mortality period.

Culture methods

- Postlarval coral reef fish and invertebrates are collected from the wild using light traps or crest nets. Both methods target presettlement fish recruiting to reefs from the plankton at night. Light traps employ a light to attract photo-positive species. Crest nets are small mesh nets with a mouth area of less than 2 square metres. They are fixed on shallow reef crests facing the open ocean so that fish recruiting over the reef crest are caught. An adaptation of the crest net system has potential as a cost-effective, easy to implement harvest device.
- Most postlarval individuals are robust and still planktivorous, enabling them to be transferred to small sea cages after collection.
- Sea cages should be kept in semi-sheltered areas with some current to enable natural feeding.
- Feeding can be supplemented with fish roe, chopped fish and commercially available flake diet.

- A WorldFish Center project in the Caribbean has devised a 'plankton pump' which uses a light at night to attract zooplankton. This is then pumped into the fish cages. This may have application in the Pacific if capture and rearing of postlarval fish becomes established.
- In French Polynesia, a commercial operation uses specially formulated pellet food.
- Village participants in the fishery will require an exporter to purchase their fish but will be able to capture and rear the fish with no outside intervention.
- Suitable for men, women and adolescents.
- Minimal start-up capital.
- Environmentally friendly and biologically sustainable.

Current production status

- The French Polynesian commercial operation (AquaFish Technology) uses state of the art capture and rearing facilities requiring high capital input and expertise. They are presently exporting a range of fish to aquarium hobbyists in France. No estimates of production are available.
- The three-year ACIAR funded Solomon Islands research pilot project is aimed at establishing the feasibility of a low technology, low cost fishery to be implemented at village level. No production figures are available. Trials have shown that target species can be caught, grown and sent to markets at very low cost. The project has also captured and successfully reared lobster and shrimps.

Marketing

- Markets for ornamental fish exist in developed countries, notably in North America, United Kingdom, Europe, Japan and Australia.
- There is unlikely to be a Pacific domestic market.
- International air transport must be available in reasonable proximity to the aquaculture sites (no more than one day's travel). Export routes already exist for Pacific nations with an established fishery for adult ornamentals.
- An experienced export company is a necessity. Packing and freight of live fish for the long air journeys to overseas markets requires specialist expertise and equipment.
- The establishment of a fishery based on postlarvae would further enhance the good name the Pacific currently holds for aquarium fish, since cyanide is not used in the region. Certification by the Marine Aquarium Council (MAC) or eco-labelling is guaranteed for fish caught and raised in the manner described. They represent an excellent product as they have been caught using environmentally friendly and biologically sustainable methods, then raised in captivity. On export and sale they are healthier and less stressed than

animals removed from the wild as adults and sold immediately to be placed in an aquarium.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

- Some Pacific areas will be constrained by unsuitable reefs or insufficient postlarval fish supply.
- In Asia, a great many people are involved in the harvest and cage grow-out of millions of grouper postlarvae, fry and fingerlings for the live food trade. In the Pacific, postlarvae of valuable *Epinephelus* species have so far not been collected in sufficient quantities to indicate that a similar industry could be established.
- Capture and culture of postlarval ornamental reef fishes cannot be expected to replace the current trade based on adult individuals but can provide an extra option as a sustainable fishery that may also supply some niche markets.
- The techniques developed for this fishery in Solomon Islands research and the French Polynesia commercial operation will be well suited to Pacific conditions.

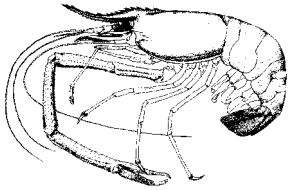
Macrobrachium shrimp

Name of species/group

Macrobrachium rosenbergii (Crustacea: Palaemonidae).

Primary potential

Aquaculture for cash income.



Attributes for aquaculture

- Larval cycle is uncomplicated, up to 20 days duration.
- Hatchery technology for mass seed production is standardised and well established.
- Juveniles are hardy and easily transported.
- In countries like Australia, annual mass migrations of juveniles occur. Captured juveniles could be used to conduct pilot grow-out trials, thereby avoiding the need to build an expensive hatchery initially.
- Neither juveniles nor adults are prone to diseases under culture conditions.
- Diet is less demanding than for marine prawns.
- Grow-out period is 6 months, allowing two crops per year. Selective harvesting could be done every two weeks after 4 months of culture.
- In some countries, macrobrachium fetches a higher price than marine prawns.
- Macrobrachium is best sold live or fresh chilled.

Culture methods

- Both clear and green water larval culture systems could be used for juvenile production. Low technology backyard and commercial hatcheries have been operating successfully for a number of decades.
- Grow-out production is pond-based. Pond sizes of 0.1–1 ha are suitable for production. The grow-out system is simple.
- Integration of prawn and farm animal production has been successfully applied in many Asian countries. Such low technology and low cost production systems could be readily adopted by Pacific countries.
- Marine prawn production systems have been successfully modified for intensive macrobrachium culture, with production of 2–5 tonnes/ha/year achievable.
- The farming system generally has low impacts on the environment. More intensive systems will have greater impacts on the aquatic system, but the fresh water could be re-used for watering terrestrial crops, and prawn waste accumulated in the bottom of ponds could be removed for fertilising land crops.

- Integrated macrobrachium and animal farming could be environmentally benign.
- Both hatchery and grow-out operations could involve women and family units.

Current production status

- Both hatchery and grow-out production systems are very well developed.
- Extensive, intensive and integrated farming of *Macrobrachium* species is conducted in many countries in Southeast Asia.
- World aquaculture production probably exceeded 130,000 tonnes in 1999, and is growing. The production from China alone was 79,000 tonnes in 1999 and 97,000 tonnes in 2000.

Marketing

- Frozen shrimp are easier to transport but this product is still not well accepted by many Asian countries (dead shrimp fetch only 50–70% of the price for live product of the same size in Thailand and China).
- The best practical option for many Pacific Islands countries is to sell fresh chilled, blanched if needed.
- The opportunity for export of processed shrimp is low because of the higher head/tail ratio than marine prawns and the loose meat texture that results from autolysis (enzymatic self-digestion) of body tissues.
- The shrimp is specially suited for cuisines where lots of spices are used in cooking. Many from Europe love the shrimp as it cooks extremely well with a variety of wines.
- Freshly grilled shrimp is popular in Southeast Asia and among tourists. Despite its freshwater origin, it is displayed in seafood restaurants in aerated aquaria and sold at USD10/kg. There are some 'shrimp-fishing' restaurants in Southeast Asia.
- Opportunity for local value-adding is limited.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- The species is established in the Indo-Pacific region. Where successful introductions have taken place, the shrimp has proved to be benign and has been well received by the local communities.
- Suitable for culture in smaller ponds. This is an advantage in many of the Pacific countries that have small land masses.

- Hatchery and seed production techniques are relatively easy, established and could be low technology.
- Suitable for extensive and intensive farming. Very successful species suitable for polyculture — for example, rice and prawn farming.
- Well developed market. The meat has an established niche market.

Disadvantages

- Some Pacific nations need to translocate the broodstock from their neighbours.
- *Macrobrachium rosenbergii* is not endemic to the countries in the Pacific, although other species of *Macrobrachium* are. However, it is believed that *M. rosenbergii* has been introduced into Guam, Fiji Islands, French Polynesia, Micronesia, New Caledonia, New Zealand, Palau, Solomon Islands, Vanuatu and Samoa during the past thirty years. No negative impacts have been reported in these translocations.
- Being a freshwater species, it may spread throughout the river systems within an island but there is little threat of it spreading between islands.

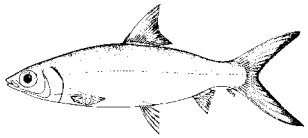
Milkfish

Name of species/group

Chanos chanos Forsskal (Osteichthyes: Chanidae)

Primary potential

Aquaculture for human consumption; juveniles as tuna bait.



Attributes for aquaculture

- Milkfish is a warm water species. It prefers water temperatures 20–33°C.
- Unlike many other large saltwater fish it is herbivorous and feeds on cyanophyta (*Lyngbya* spp.), diatoms and other similar food items.
- Larvae eat zooplankton. Juveniles and adults eat cyanobacteria, soft algae, small benthic invertebrates, and even pelagic fish eggs and larvae.
- Can be grown in monoculture or in polyculture with other finfishes and crustaceans.
- Wild fry occurs in the tropical and sub-tropical seas of the Indo-Pacific region and extends to the Red Sea, the East Coast of Africa, South California and the West Coast of Central America.
- Technology for broodstock development and hatchery for large scale seed production is already established.
- Technology for nursery and grow-out in ponds, pens and cages in fresh, brackish and marine environment is developed.
- Juveniles can be grown to maturity (broodstock size) in 5–7 years in ponds, tanks and cages under proper management.
- Artificial feeds for intensive farming have been developed.
- Fingerlings (25 g) are also used as tuna bait.
- Recommended as biomanipulators to produce greenwater for environmentally friendly intensive shrimp farming.
- No known occurrence of disease outbreak in aquaculture.

Culture methods

- A typical milkfish farm comprises nursery and transition ponds representing about 10–15% of the total farm area. The rest of the farm is rearing ponds and canal system.
- Pens or floating netcages may be used instead of ponds for grow-out.

Fry

- Milkfish spawn only in fully saline water. Females spawn up to 7 million epipelagic eggs (1.1–1.2 mm diameter), which hatch in about 24 hours. Spawning and fertilisation take place at night. Frequency of spawning is unknown. Eggs and larvae are pelagic up to 2–3 weeks. The larvae seek out clear coastal and estuarine waters warmer than 23°C with salinity 10–32 parts per thousand and abundant phytoplankton.
- Incubating eggs and newly hatched larvae are transported to the shore by currents,.
- Older larvae migrate onshore and settle in coastal wetlands (mangroves, estuaries) during the juvenile stage, or occasionally enter freshwater lakes.
- Under natural conditions, larvae and fry migrate inland, seeking tidal pools. They settle in them for 1 month until they become juveniles, then migrate into lagoons, lakes and shallow waters. When they reach adolescence (24–45 cm fork length) they return to the sea for further growth and sexual maturation.
    - Larvae for aquaculture can be collected from brackish waters such as shallow sandy areas, mouths of rivers, and lagoons.
    - Intensive milkfish farming depends heavily on hatchery bred fry.
    - Hatchery production technology is well developed. A mature female can produce 1–7 million eggs after about 5–7 years of rearing. Survival rate of 35% has been attained from Day 0 of fertilized egg to Day 21 (fry)
    - Significant survival rate of 70% has been attained in nursery operation after 30–45 days of culture. Stunted milkfish fingerlings reared from 6 months to 1 year in transition pond attain 50–60 % survival at an average body weight of 35–50g.

Fingerlings

- Nursery ponds are prepared by sun drying, liming and application of organic and inorganic fertiliser to enhance growth of benthic algae (*lab-lab*).
- Supplemental feeding with rice bran and other feedstuff is often done.
- Wild or hatchery bred fry are available all year round with peak in April–June and again in October–December
- Fry are stocked in 1–5 hectare nursery ponds, at the rate of 30–40 fry per square metre, for 30–45 days. Densities are reduced as the fish grow. Some are directly stocked in grow-out ponds and the rest go to transition or stunting ponds at 15 fingerlings per square metre for 6 months to about a year. Bigger sized fingerlings (40–80g) are preferred for pens and floating netcages.

Fingerlings

- Non-aerated ponds:
  - *Shallow water culture.* In the traditional culture method, milkfish are cultured in shallow (40–60 cm) brackish water ponds of 2–50 hectares. Water exchange is tidal. The growth of benthic algae is encouraged through photosynthesis and fertilisation. Other natural foods like filamentous algae (lumut) maybe resorted to, but yield is less compared with lab-lab. Stocking rate 2,000–3,000 fingerlings (5–10 g) per hectare; 1–2 croppings per year; yield 1.5–2.0 tonnes per hectare per year.
  - *Deep water culture.* Also known as the plankton method. Milkfish are cultured in ponds, with a depth 80–110 cm and area 1–10 hectares. Water exchange is tidal. Production: 1–2 croppings per year; yield 1–2 tonnes per hectare per year.
  - *The modular system* allows 6–8 crops per year with yield of 2–4 tonnes per hectare per year. The growing fish are moved through three adjoining ponds of increasing sizes, at the ratio of 1:2:4 or 1:3:9. Ponds are prepared by the lab-lab method of growing natural food. Water exchange is tidal. The program involves pond preparation, stocking, transfer and harvest in regular intervals. To sustain year-round production, an inventory of milkfish fingerlings, organic and inorganic fertilisers, and organic pesticides needs to be maintained.
- Aerated ponds:
  - Increased productivity can be gained through culture in deep ponds (0.1–1.5 m) using paddle wheel aerators, feeding machine and water pump to increase primary productivity. At the minimum stocking density of 8,000–12,000 fingerlings per hectare, production of 4–6 tonnes per hectare per year can be attained. At the highest density of 30,000 fingerlings per hectare, yield is 12–15 tonnes per hectare
- Floating netcages:
  - Fingerlings (40–60 g) from the nursery ponds are reared to marketable size in netcages. Stocking density of 40–100 fish per cubic metre can produce 20–45 tonnes per crop.
- Pens
  - Fingerlings (40–60 g) from the nursery ponds are reared in fish pens, 5,000–10,000 square metres in size constructed in shallow water, with a stocking density of 30,000–40,000 per hectare. Fingerlings forage for natural food from the bottom or plankton. Supplemental feeding is needed if there is depletion of natural food. Production of 15–20 tonnes can be attained.

Current production status

- Culture of this species is well developed in Asian countries, especially the Philippines, Indonesia and Thailand. Currently Hawaii, Kiribati and Fiji Islands are the only Pacific Islands countries culturing milkfish.

- Milkfish production in Fiji Islands was worth approximately AUD30,000 per year for 1996–1998, with total pond area of about 80 ha.
- Hatchery-reared juveniles in Kiribati are exported to Fiji.
- Few other Pacific Islands countries are culturing milkfish, and production levels are uncertain.
- Large-scale commercial hatchery and nursery operations have been established in the Philippines, Indonesia and Taiwan.
- Current Philippines price of milkfish fry is 1 cent a piece. A 2–3 cm pre-fingerling size costs 1.75–2 cents a piece.

Marketing

- In general, milkfish operations are market oriented. Milkfish commands reasonable prices at population centres.
- Milkfish is marketed fresh, fillet, deboned, smoked, canned and frozen.
- Processing increases the commercial value and palatability of milkfish.
- Processing provides additional employment opportunities.
- Cultured juvenile milkfish (25 g) are excellent bait fish for tuna longline fishing. This market is the driving force behind the development of the milkfish industry in Fiji.
- Introduction of intensive culture has led to an increase in demand for fingerlings.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- Widely distributed in the Indo-Pacific region. Wild milkfish fry has been reported throughout the Pacific region in countries such as Palau, Kiribati, French Polynesia and nearby countries.
- Broodstock maybe developed as possible source of hatchery bred fry in the region for possible large-scale seed production operation.
- A continuous supply of seedstock can be guaranteed from hatchery technology.
- Employment potential for fry gatherers, and in post harvest and processing activities.
- Milkfish is low in the food chain (a herbivore/detritivore), and so food inputs are relatively simple.
- Feeding technology is well established.

- Potential for development of feed manufacturing, input supplier, broodstock supplier, seed production and marketing enterprises.
- International market available. Exported from Philippines.

Disadvantages

- Environmental problem from effluents from intensive culture ponds.
- Overcrowding of pens and floating netcages leads to environmental pollution that eventually triggers fish kills.

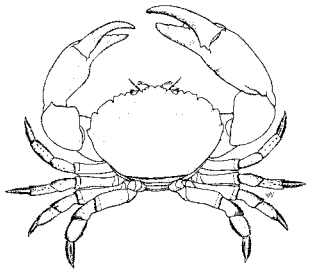
Mud crab

Name of species/group

Mud or mangrove crabs (*Scylla* spp.).

Primary potential

Aquaculture. There is some scope for stock enhancement.



Attributes for aquaculture/stock enhancement

- In many areas throughout Southeast Asia juvenile mud crabs are collected from the wild and stocked into ponds or enclosures for grow-out.
- Once mud crab are through their larval stage they appear to have robust health. If ponds are stocked at appropriate densities survival through grow-out is high.
- Mud crabs can grow from juvenile to adult size in 4–6 months, dependent upon species and water temperature, providing the potential for two crops per year.
- Live mud crabs fetch market prices of around AUD10 per kg. Higher prices can be obtained for smaller soft-shell mud crab of 100–150 g in Asian markets. For crabs picked for crab meat for canning, a price of around AUD3 per kg is common. Premium prices, of around AUD20 per kg, can be obtained for hard shell crabs in excess of 1 kg for the banquet market in restaurants, with particularly high prices during the New Year and Chinese New Year periods.
- In Indonesia and Philippines the price paid for crablets for farming is rising every year as the supply situation from the wild worsens.
- Mud crabs are quite hardy organisms. Little is known of disease problems in the juvenile or grow-out phase of their culture. It is only during larval culture that susceptibility to bacteria has been identified.
- Mud crabs (*S. serrata*) have a high fecundity, producing several million eggs per individual. They are easily bred in captivity, which means that selective breeding (e.g. for rapid growth) can be introduced in the near future.
- Broodstock husbandry is simple.
- Mud crabs are easily transported either as larvae in water, or dry once they have reached the crab stage.

Culture methods

- Juveniles/seed can be collected from the wild or be produced in the hatchery.
- Seedstock for most mud crab farms in Southeast Asia is harvested from the wild. Hatchery production has only recently started to contribute to seedstock production. The future of the industry is in hatchery produced seedstock, as wild seedstock will always be a limiting factor.

- Issues for grow-out include scope for using simple, low cost technology, suitability for small-scale operations, ease of management, possible environmental impacts and opportunities for employing women.
- In Southeast Asia, mud crab grow-out takes place either in ponds (with or without mangroves) or in enclosures within mangrove forests.
- Some pelletised feeds are available, but little research has yet gone into their formulation. Trash fish and agricultural wastes (in some areas) are currently used as feeds for mud crabs.
- In Australia the grow-out of mud crabs in mangrove enclosures by Aboriginal communities is seen as a farming practice that can complement traditional fishing and gathering activities. The husbandry of mud crabs in the enclosures is seen as an activity in which women can play an important role.

Current production status

- There are active mud crab fisheries in Africa, through Southeast Asia and into the Indo-Pacific.
- Mud crab farming is a significant industry in the Philippines, Vietnam, Indonesia, Sarawak and elsewhere in Southeast Asia.
- The main constraint is the reliable supply of crablets. Larval rearing of mud crabs on a commercial scale has proven to be more difficult than for some other crustaceans. Larvae are particularly sensitive to bacteria and related water quality parameters.
- Whilst many groups are still working to develop reliable commercial mud crab aquaculture systems, commercial production of crablets for farming has already commenced in Vietnam and the Philippines on a relatively small scale.
- In Australia, crabs from hatchery production have been grown out in a commercial prawn farm on an experimental basis, and government institutions together with the private sector are working on commercialisation of their technology.

Marketing

- The international market for crabs is generally strong.
- Most Pacific nations have a significant domestic demand for mud crabs. In many countries, overfishing of mud crabs has left depleted stocks, which cannot meet local demand.
- Mud crabs are reasonably tough animals and can be transported live, packed dry in boxes. This makes marketing and transportation much simpler than for many other organisms.
- In addition to the live mud crab trade, there is also a market for soft-shell crab (particularly in Southeast Asia).

- Niche markets can be developed for 'egg crab' (females with eggs), all male crabs (as they grow faster and larger, with bigger claws than females) and for crab meat. Special markets exist for banquet size mud crabs (over 1 kg), which have their highest demand around New Year and Chinese New Year celebrations.
- There is also a market for crablets for farming throughout Southeast Asia.
- Throughout Southeast Asia considerable effort is being put into the development of environmentally friendly production systems based on simple enclosures being constructed in existing mangrove forests (or revegetated mangroves) to culture crabs. It may be feasible for such crabs to obtain eco-labelling.
- Development of mud crab farming will have spin-offs, as associated with most seafood enterprises. There will be an increased demand for transport/freight services, packaging, processing (if the product is cooked or meat picked) and feeds, all of which will provide employment and business development opportunities. Processing of blue swimmer crab meat from wild fisheries has led to considerable investment in processing plants in Indonesia and the Philippines. The market for pasteurised, canned crab meat is very large. One US company alone, Phillips, has a need for 30,000 US tons per annum.
- Farmed production of mud crabs can meet market demand outside of seasonal catches from mud crab fisheries and provide a better continuity of supply to the market. Similarly, harvesting from farms can be timed to meet peak demand.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- Countries in the region can benefit from investment in this species already undertaken elsewhere. Technology can be transferred.
- There are good local markets for mud crab in most Pacific Islands countries.
- Many Pacific Islands countries have extensive mangroves that can be used for farming crabs in simple enclosures. Tending/operating a mud crab farm in mangrove enclosures requires minimal technical training.
- Some Pacific Islands countries have good links to significant markets such as Hawaii, Guam, New Zealand, Australia and the USA.
- Hatchery production of mud crab can be used for restocking of wild mud crab fisheries. Income developed from mud crab farming can assist in poverty alleviation.
- Mud crab farming (and fishing) can complement and provide a secondary source of income from mangrove silviculture.

- There is already an established marketing network in many countries for mud crab from fishing.
- Harvested stock can be stored without refrigeration.

Disadvantages

- Airfreight options and capacity may be limited, making it difficult to take advantage of live trade.
- Many Pacific Islands countries have limited land area available for pond-based farming systems.
- Technical staff will need to be trained or recruited to run hatcheries to support mud crab farming.
- If crablets are moved between islands without adequate health checks, there is the risk of spreading disease.
- If fisheries enforcement is not effective, there may be a temptation to collect juvenile crabs from the wild for farming, which will be contrary to current best practice management for mud crab fisheries.
- In some Pacific states, international trade in mud crabs is controlled by legislation, as part of their wild fisheries management control. This would have to be amended to allow product to be exported, perhaps by a marking system to make them distinguishable from wild stock.
- If pond culture is utilised, discharge will have to be well managed to avoid harm to fragile coral ecosystems.
- If ranching or restocking of wild stocks is attempted, professional genetic advice will be required to ensure genetic diversity is maintained and genetic contamination from non-local stock does not occur.

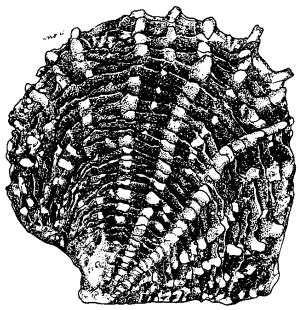
Pearl Oyster

Name of species/group

Pearl oysters (Pteriidae).

Primary potential

Aquaculture.



Attributes for aquaculture/stock enhancement

- Culture techniques well established and relatively simple.
- No feed input (nursery and grow-out) so reduced environmental impact.
- Possible to collect culture stock (adults and juveniles) from the wild.
- Well established markets.
- Range of products (shell, half and round pearls, meat).
- High value product.
- Ease of product storage and transport.

Culture methods

Juveniles/seed

- *Wild:*
  - Spat (seed) can be collected from the wild using spat collectors.
  - Spat collectors can be made from a variety of materials (e.g. shade cloth, tree branches, onion bags).
  - Spat collectors are immersed to coincide with major recruitment periods.
  - Spat are removed from collectors at a time to maximise size but minimise predation.
  - Spat collection uses simple low cost technology, is easy to manage and is suitable as a small-scale operation.
  - Income could be generated by selling spat to pearl farms.
  - Spat collection has low environmental impact and is suitable for women.
  - The major disadvantage is reliance on natural recruitment which can be unreliable.
- *Hatchery:*
  - Reproductively mature broodstock can be obtained from wild or culture stock.
  - Broodstock are induced to spawn using thermal stimulation. Eggs and spawn need to be combined for fertilisation within 60 minutes of spawning. Fertilised eggs are incubated, 30–50 per ml, in lightly aerated 1 micron filtered seawater for 24 hours. Incubation tanks are drained and larvae are retained on sieve mesh.

- Larvae are stocked at a density of 1–2 per ml into culture tanks containing well aerated 1 micron filtered seawater.
- Larvae are fed cultured microalgae at a density of 1000–20,000 cells per ml, depending on age. Amount of algae is increased with increasing larval size.
- Water in larval culture tanks is changed (fully or partially) every 2 days.
- Larvae large enough to be retained on a 170 micron screen are removed to settlement tanks containing spat collectors. Larvae are recruited to collectors and retained in settlement tanks for a further 2 weeks.
- Settlement tanks receive daily feeding and daily partial water change.
- Spat collectors are removed to the ocean where they are left until the juveniles are large enough for removal (around 3 months of age).
- Hatchery culture is costly, technically demanding and unsuitable for small-scale operations.
- Advantages include year-round production, independence from natural recruitment events and genetic manipulation. The latter may be important for developing oysters to produce larger pearls or pearls with 'niche' colours.

Grow-out

- Pearl oysters are cultured using simple low cost technology, which is suitable for small-scale operations and village based production.
- Major management issues are regular checks for predators, cleaning of bio-fouling, and upgrading of net size as oysters grow.
- The simplicity of pearl oyster grow-out results primarily from the fact that oysters feed on natural plankton so feed input is not required.
- Lack of feed input considerably minimises environmental impacts relative to other aquaculture species. However, large areas dedicated to pearl oyster culture do represent some navigational hazard.
- Considerable potential for employing women directly in pearl oyster culture and in value-adding activities.

Current production status

- Commercial production in French Polynesia, Cook Islands. French Polynesia is currently producing 11 tonnes valued at USD165 million.
- Small-scale production in Solomon Islands, Fiji Islands, Marshall Islands, Tonga, Federated States of Micronesia. Research in Kiribati, Tonga (half pearls or mabe).
- Production problems include disease (through poor husbandry), predation (primarily by *Cymatium* spp. gastropods) and lack of trained personnel and technical expertise.

Marketing

- There is considerable international potential, and domestic potential for countries with significant tourist industries.
- Pearls are an ideal export commodity, being small and lightweight yet of high value with no specific storage or transport requirements.
- Large increase in production of black pearls in French Polynesia has seen their value decrease from an average of USD77 per gram in 1986 to around USD13 per gram in 2000.
- Quality control efforts in French Polynesia are likely to help stabilise the price and the market for cultured black pearls.
- There is clear opportunity for niche markets for unusually coloured pearls. Given current competition, new entrants to the pearl market will need to maintain a high quality product.
- There appears to be potential for mabe pearl (from *Pteria* sp.) production in the Pacific.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

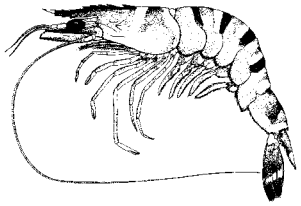
Advantages

- Limited resources required for pearl oyster culture.
- No food input required, minimising environmental impacts and costs.
- Well established markets and culture protocols.

Disadvantages

- Reliance on specialised technicians for pearl seeding.
- Overproduction or increased production may depress product value and impact potential market and profits.
- Lack of appropriate technical expertise in many Pacific nations.

Penaeid prawn



Name of species/group

Several species of marine prawn are commercially farmed in various parts of the world. The most important of these are giant tiger prawn (*Penaeus monodon*), western white prawn (*Litopenaeus vannamei*), western blue prawn (*Litopenaeus stylirostris*), Chinese white prawn (*Fenneropenaeus chinensis*), Indian white prawn (*Fenneropenaeus indicus*) and Japanese kuruma prawn (*Marsupenaeus japonicus*). Two species, *P. monodon* and *L. stylirostris*, have been found suitable for aquaculture in the Pacific.

Primary potential

As it is still at a preliminary stage of development in Pacific Islands countries, marine prawn is recommended for aquaculture only. Stock enhancement is too costly and a lot of effort is demanded due to poor survival after release into the wild. The nursery habitat for penaeid prawn species is brackish water and estuaries, and the absence of this environment in many Pacific Islands countries suggests that the potential for stock enhancement is likely to be limited.

Attributes for aquaculture/stock enhancement

Penaeus monodon

- Giant tiger prawn can be grown to a large size (40–60 g) to fetch a higher price in international markets (price is often size-related).
- Culture and hatchery techniques are not as simple as for *L. stylirostris* (below).
- Suitable for aquaculture only in countries such as Fiji Islands, Solomon Islands and Papua New Guinea where it is native. Other countries may face problems of chronic shortages of wild broodstock and high risk of importing virus-infected animals or non-reliable broodstock (due to its difficulty in domestication).
- Captive breeding is difficult and hatchery survival is low (20–30%).
- Farms should be located in brackish water areas or coastlines with available freshwater supply throughout the year. These conditions are not commonly found in the region.
- This species is only suited to intensive culture, which requires high investment and intensive care.

Litopenaeus stylirostris

- *L. stylirostris* is nearly identical to *L. vannamei* in origin, appearance, biology, culture and hatchery techniques; the techniques for both species are less sophisticated and require less intensive care than for *P. monodon*.
- *L. stylirostris* is able to breed in captivity with high survival in hatchery conditions (50–60%).

- Although it is an exotic species for Pacific Islands countries, it is easy to maintain captive broodstock in ponds or tanks for long periods. Development of pathogen-free and pathogen-resistant strains is also possible. Therefore this species is more suitable for countries which have to rely on import of broodstock.
- Growth rate is uniform and fast in the early stages but slows down after 3–4 months (18–20 g).
- As it can tolerate higher salinities than *P. monodon* or *L. vannamei*, closed-system culture using full strength seawater is possible; this would have the added advantage of assisting in the control and prevention of viral diseases.
- An advantage of this species is that it may be cultured in various ways and at a range of costs, from low cost extensive culture to medium cost semi-intensive culture to high cost intensive culture.

Culture methods

- Culture techniques for both species are similar.
- In order to avoid shortages and delays in supply, postlarvae (PL) should be produced from local hatcheries, which may be either low investment outdoor or high investment indoor facilities.
- If they are not available in the wild, disease-free broodstock may be imported, but this should occur only if strict quarantine procedures are followed.
- In the initial stages of penaeid aquaculture development, low maintenance semi-intensive culture (5–10 PL per square metre) in large ponds (5–10 ha) should be adopted. This will allow acquisition of local skills in penaeid aquaculture and the training of local staff.
- At these moderate densities the amount of feed required will not be high; this will be an advantage in areas where feed is not produced locally.
- Production is also moderate: 600–1000 kg/ha.
- In sustained production, as a precaution in case of virus disease outbreak the trend of farm design is toward smaller (0.5–2.0 ha), more intensive farms (30–50 PL per square metre with production of 1,200–5,000 kg/ha), using a closed system or water recycling system if possible.
- Infrastructure and equipment should be improved for hygienic purpose.
- In Asia, in every country the pilot farms have been large scale with high investment, covering hatchery, processing plant and export enterprise. This makes it feasible to import and adapt technologies to suit local conditions, as well as to train local staff. Later, small-scale farms run by trained personnel will follow if government and banks can provide them necessary infrastructure and source of funds.

Current production status

- Due to its high profitability, penaeid shrimp farming has been the focus of commercial development in several Pacific Islands countries over the past 30 years, with varying degrees of success.
- Development has been slow due to the lack of suitable technologies, traditional skill in aquaculture, capital, infrastructure and R&D support from governments.
- In 1999, 39 and 13 tonnes of *Penaeus monodon* were produced for the export market in Fiji Islands and Solomon Islands respectively. Currently, there are three grow-out farms and hatcheries in Fiji while two farms in Solomon Islands still rely on seeds imported from Australia.
- In 1999, 1,906, 43 and 25 US tons of *Litopenaeus stylirostris* were commercially farmed in New Caledonia, French Polynesia and Guam, respectively. These large enterprises mainly applied technology developed in France and Tahiti. Penaeid farming technology is sufficiently well developed that Pacific Islands countries can adopt from other countries the most appropriate technologies for the region.

Marketing

- To avoid high competition from the major prawn producing countries where production and shipping costs are less, Pacific Islands countries should focus on producing high value eco-labelled, clean and green products.
- *L. stylirostris* is tolerant of high salinities, and is therefore suitable for eco-labelling because its farm sites can be located outside mangrove areas, where the farm effluent discharges will produce lower organic loads because of the stronger flushing effects in more exposed open waters.
- The freshness of green products could be promoted locally for the tourist market.
- A market for live prawn in domestic Chinese restaurants can double the price, and this should be developed where possible.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

Penaeus monodon

- Rapid growth to a large size.

L. stylirostris

- Can tolerate high salinities, and therefore does not require brackish conditions, which are scarce or absent in many Pacific Islands countries.
- Culturing in seawater may avoid some of the problems with viral infection that occur in brackish water culture.

- Can be grown at a range of costs and intensities (low to high) to suit the local technical expertise and financial resources.

Disadvantages

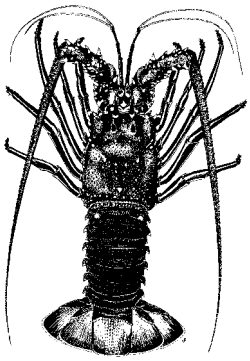
Penaeus monodon

- Supply limitations in areas outside its native range.
- Difficult to breed and maintain in hatchery conditions.
- Requires brackish conditions, which are limited in availability, or absent, in many Pacific Islands countries.
- Best suited to intensive culture, which requires high investment and care, and which may cause eutrophication problems in the oligotrophic conditions of the coral reef habitats of many Pacific Islands countries.

L. stylirostris

- None identified.

Rock lobster



Name of species/group

Spiny rock lobster (*Panulirus* spp.). The dominant and most widespread species in the Pacific is the pronghorn or golden rock lobster, *P. penicillatus*. Other common species are the painted lobster, *P. versicolor*, the striped leg lobster, *P. longipes femoristriga*, and the ornate lobster, *P. ornatus*. All are large (total length more than 25 cm as adults, up to 50 cm for *P. ornatus*) and actively fished for by hand or spear.

Primary potential

The primary potential is for aquaculture for cash income.

Attributes for aquaculture/stock enhancement

- High value species with excellent local and potential export markets.
- Juveniles easily captured but may be of limited availability.
- Lobsters are robust and easily cultured from juveniles to market size (800 g or more) within 18 months on natural or pelleted feeds.
- Capital investment for on-growing of the lobsters need not be high. Ideal for subsistence farming or scaling-up to more intensive forms of production.

Culture methods

- Hatchery production of spiny lobster seed is not yet developed. Even if successful, seed production will be very difficult technically, and prolonged (4 months or more), making it high risk.
- Seed lobsters recruiting into shallow near-shore reefs and structures are easily caught using fixed crest nets or trolled lampara nets, or by collecting aggregations of lobsters by hand from natural or man-placed collection sites.
- The abundance of recruiting seed in Pacific Islands countries is not well documented but is likely to be comparatively low.
- Captured lobster seed of more than 25 mm total length (TL) is easily on-grown. However, overcrowding and poor handling of the seed, and particularly of non-pigmented post-pueruli, can result in high mortality (more than 30%) in the immediate post-capture period.
- In Vietnam, where culture production of *P. ornatus* amounts to 1000 tonnes annually, lobsters are cultured in floating or fixed net sea cages in protected bays or lagoons that have a good tidal flow. Seed lobsters of about 25–30 mm TL are stocked (100 to 200 per cage) in small floating net cages (typically about 2 m square and about 2–2.5 m deep; 2.5 mm square aperture) and grown to a size of about 50 g (10–12 cm TL). At this size, lobsters are placed (100 per tank) into larger grow-out cages, typically about 4 X 4 m or 4 X 6 m and 5 m deep (at high tide), with net aperture of 10–15 mm square. Small lobsters are fed a mixture of shellfish (oysters, crabs) and fish, with more fish and less shellfish given as the lobsters grow. Lobsters are sorted into same-sex groups after reaching

300–400 g: males grow faster than females. Lobsters attain a typical harvest weight of 1 kg within 18 months from initial stocking. Survival of lobsters from stocking into grow-out cages is typically 90%. Surprisingly, no hides or shelters are provided for the lobsters in the Vietnamese cages but sand is frequently added to provide a bottom substrate. A serious disease problem of caged lobsters occurred in Vietnam in August 2001 with losses as high as 20–30% of the cage in one week. The disease was attributed to pollution and poor water quality predisposing the lobsters to fusarium and/or vibrio infections.

- Research in Australia is examining on-land and in-sea culture systems, and pelleted dry lobster diets are under development as an environmentally more sustainable alternative to fresh foods.
- Lobsters in Vietnam are sent live to Tokyo and Hong Kong markets, where they fetch prices of USD21–28/kg depending on size. Even though the demand for seed is high and prices are accordingly high (USD5–10 per piece, depending on size) lobster culture is very profitable, with operating profit in the order of 100%.

Current production status

- On-growing of wild-caught seed lobsters is widely practised in Vietnam, the Philippines, India and Indonesia. Farming is typically on a subsistence scale (limited by the availability of seed) although the magnitude of production in Vietnam is collectively very large (1000 tonnes annually).
- In Australia and New Zealand, lobster seed cannot be taken for aquaculture except under strict and limited pilot licence conditions. However, there is some in-sea and on-land holding of legal-size lobsters for weight gain and/or more favourable (niche) marketing.
- There is considerable research investment in Australia and New Zealand to develop hatchery propagation and optimal grow-out culture and feed technology for spiny lobster aquaculture.

Marketing

- All marine lobsters are highly regarded by people of all cultures as fine table food and thus are in high demand.
- Most wild lobster fisheries are overexploited, with many stocks having already collapsed or catch rates closely regulated to sustain the wild fishery.
- For these reasons, lobsters fetch high prices. The highest price is paid for live product, chilled or frozen products bring much lower prices (at least by half).
- Aquaculture offers the only prospects by which lobster supplies can realistically, and sustainably, be increased.
- Major market for Pacific Islands countries would be local, supplying hotels and restaurants. It appears that the wild lobster catch (about 300 tonnes/year collectively for Pacific Islands countries) is unable to satisfy local demand.

- Considerable export potential exists for live product to Southeast Asian markets. This would require lobsters to be cultured close to major centres that have international air services.
- Packing and transport conditions for live shipment of lobsters are well developed and would not be a problem.
- Development of a successful export market would require both continuity of supply and a reasonable volume of production.
- There is very little known about the lobster stocks of Pacific Islands countries and whether aquaculture production would be sustainable if recruiting seed was taken in large quantities for aquaculture.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

- Aquaculture offers the only real prospects by which lobster supplies can be sustainably increased.
- In the short term, and until successful and economically viable propagation of spiny lobsters is achieved, aquaculture will depend on the availability and sustainability of captured wild seed.
- The faster growth rate of tropical *Panulirus* spiny lobsters compared to the cold water *Jasus* species is a strong competitive advantage for lobster aquaculture for Pacific Islands countries. Although hatchery propagation of spiny lobsters is still far from becoming a commercial reality, the more rapid larval development of tropical species is a distinct biological advantage over that of the temperate species.
- Since the rate of recruitment of seed to the adult wild fishery is low, with perhaps only 5% (and probably less) ever attaining adulthood, the capture of a modest proportion of wild seed for aquaculture on-growing (e.g. 0.5 million pieces from a total recruitment likely to be in excess of 10 million annually) would enable an aquaculture industry of 300 tonnes per annum without detriment to the sustainability of the wild fishery in Pacific Islands countries.
- However, before contemplating aquaculture on this scale, research is warranted to better determine the stock structures of spiny lobsters in the Pacific region and to estimate recruitment patterns and survival rates. Such research would enable responsible fishery management polices to be put in place (e.g. quotas on captured seed and collection sites, restocking of a proportion of the on-grown catch) to ensure sustainability of the wild fishery stocks.
- Similarly, appropriate controls to regulate the number of cages and culture sites may be necessary to minimise environmental impacts to the adjacent reefs and waterways.
- By way of a cautionary note, attempts in the late 1970s and again in early 1990s to establish large-scale intensive aquaculture of spiny lobsters in the Philippines collapsed within a few years of establishment when seed supplies became insufficient to support the venture.
- Low intensity aquaculture of spiny lobsters for the ornamental or food markets could be a very profitable domestic and/or export industry in some parts of the Pacific. However, the Philippines experience of going too intensive too quickly should not be forgotten.

Sea cucumber

Name of species/group

Tropical sea cucumbers, particularly sandfish (*Holothuria scabra*).

Primary potential

Aquaculture, stock restoration and enhancement.

Attributes for aquaculture/stock enhancement

- High value and demand.
- Easy to harvest, process and store.
- Widespread distribution.
- Feeds low on food chain (e.g. bacteria) so there is the potential for simple feeds.
- Restricted to inshore habitats and relatively sedentary.
- Low cost, low technology hatchery production.
- Potential fast growth, high density.
- A traditional commodity, so there is local knowledge of ecology and habitats for restocking.

Culture methods

- Broodstock collected from the wild can be induced to spawn, year-round depending on latitude, using temperature and transport shock. Acclimated broodstock in tanks can spawn all year round on a lunar cycle at low latitudes.
- Larvae are reared on a mix of microalgae and settle on diatom-conditioned plates after two weeks.
- Juveniles are reared on hard substrates till 20 mm long then on sand.
- Can be reared to a size suitable for release (~20 to 100 mm) on low cost diets and in low cost tanks or ponds.
- Small wild juveniles are not generally available and recruitment is highly variable.
- Grow-out to market size is in enclosures or ponds. Sea cucumber may be grown in polyculture with prawn.
- Indications are that it will take two years to grow to market size.
- Successful stock restoration and enhancement will require better management than is now practised, but possible environmental impacts are believed to be low.
- Women are traditional harvesters and processors of beche-de-mer in many small island developing states.

Current production status

- Hatchery production of sandfish juveniles is now routine at the experimental level and is being undertaken in India, Indonesia, Australia, Vietnam and New Caledonia among others. Pilot-scale production of juveniles en masse is being undertaken for use in release experiments to test the most appropriate size, time and habitat of release. Companies in Southeast Asia and Australia have proposed commercial hatchery production but none are, to our knowledge, in production.
- Fattening of wild-caught sub-adults is practised in Indonesia and India in enclosures within estuaries or calm waters using low cost feeds such as agricultural byproducts.
- The bottleneck to hatchery production is survival at or shortly after settlement. Control of copepods can be a problem.
- High density cultures of newly settled juveniles have highly variable growth.
- Little is known about the growth of juveniles over 100 mm in length and the density in which they can be successfully grown to market size.
- To date few experimental releases have been made with hatchery-produced juveniles in fully replicated trials. No long-term reseeding trials have been conducted and no tagging method is yet available.

Marketing

- Traditionally a 'boom-and-bust' fishery in small islands developing states.
- The demand for the dried body wall product beche-de-mer is high (some suggest insatiable), mainly through markets in Hong Kong, Taiwan, Singapore and into mainland China.
- Estimates suggest the production of tropical sea cucumbers is USD90 million annually but detailed statistics are difficult to obtain.
- High quality sandfish fetches up to USD100 per kg at the retail level in the bigger markets.
- There are established buyers in most small island developing countries offering lower prices to local collectors.
- Product quality can be a problem. Sandfish are harder to process than other sea cucumbers. Training can lead to better product and better prices.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- The depletion of stocks, which can take 50 years to recover, has led to increasing prohibition or restrictions on the taking of sea cucumbers leading to support from indigenous people for a solution.

- Aquaculture works on three levels: (1) restoration of depleted stocks, (2) enhancement of existing stocks above historical levels, (3) aquaculture in ponds or enclosures, thus multiplying the advantages.
- A traditional product, collected by hand. Does not require large retraining, capital, or changes to traditional practices. Benefits should flow directly to the village level.
- Hatchery requirements for sea cucumbers are similar to other species such as pearl oysters and giant clams.

Disadvantages

- Small island developing states could probably afford only one centralised hatchery.
- Culture and stock enhancement is not a quick fix and will not work without more research into release strategies and, most importantly, an effective enforcement of harvest regulations, probably administered at the village level.
- Genetic differences between stocks at a local scale necessitate culturing with separate broodstock groups from different areas.

Seaweed

Name of species/group

Eucheuma, cottoni (*Kappaphycus alvarezii*), lumi wawa, ogonori (*Gracilaria* spp.), lumi cevata (*Hypnea* spp.), tosakanori (*Meristotheca procumbens*), nama, seagrapes (*Caulerpa racemosa*), limu tanga'u, mozuku (*Cladosiphon* sp.).

Primary potential

Aquaculture.

Attributes for aquaculture/stock enhancement

- Primary producer (lowest possible trophic level, so does not require feeding).
- Vegetative propagation (asexually from cuttings) so hatcheries are not necessary.
- Low technology, simple cultivation methods.
- Comparatively low inputs required for aquaculture, simple equipment.
- Seaweed for industrial raw material markets can be dried in the sun, so no need for post-harvest refrigeration.

Culture methods

- Seedstock is obtained from cuttings retained after each harvest.
- Grow-out can be on rope lines and stakes ('off-bottom' method) or IN nets in shallow back-reef areas or on floating rafts (e.g. bamboo) in lagoons.
- Technology is low cost and requires only simple equipment and methods.
- This type of aquaculture is well suited for small-scale operations, by 'grassroots' people running a seaweed business at a household level.
- All of the seaweeds on the above list occur naturally in the Pacific Islands region, except kappaphycus, which is an introduced species. No scientifically rigorous study of the environmental impacts of kappaphycus introductions has yet been made. However, experience so far suggests that impacts, if they exist, are fairly benign (provided that quarantine procedures are adequate).
- Seaweed farms of whatever species have at least two beneficial impacts: they can increase local fish populations by providing shelter and food for herbivorous fishes (especially siganids), and they act as 'nutrient sinks' that take up inorganic nutrients (ammonia, nitrate, phosphate) from the water column.
- Seaweed fisheries are traditionally the domain of women in many Pacific Islands countries, so it is a natural progression for women to be involved in seaweed farming.

Current production status

- Kappaphycus farming is well established in Kiribati, with production routinely around 1000 dry tonnes per annum. It is now re-established in Fiji Islands after a stop-start history of development.
- Seaweed Both Tonga and Vanuatu are poised for development of their own kappaphycus industries.
- Seaweed Kappaphycus production problems include epiphytic filamentous algae (EFA), ice-ice disease, and herbivore damage (mainly by siganid fishes). Growth is highly site-specific, so test-plot surveys are necessary to find the best grow-out locations. Transportation from outlying islands to a major port for containerisation is also a disadvantage.
- Seaweed *Cladosiphon* sp. aquaculture is at an advanced stage in Tonga, which had already developed a lucrative but seasonal fishery for this seaweed. Aquaculture will allow increased production and a prolonged growing season.
- Seaweed Aquaculture of *Meristotheca*, *Gracilaria*, *Hypnea* and *Caulerpa* species is at an experimental stage. Some culture trials having been completed but development has been halted owing to either technical constraints or lack of a ready market.

Marketing

- Seaweed Markets for kappaphycus seaweed are virtually guaranteed.
- Seaweed The farming technology is well known, so kappaphycus is the top candidate for seaweed aquaculture development in the Pacific region.
- Seaweed Once production reaches a certain level, there is a big opportunity to add value locally by construction of a processing factory here in the region.
- Seaweed Gracilaria and hypnea are sources of industrial phycocolloid, but no buyers are immediately apparent. They have value in domestic markets as food species, and traditional fisheries exist for these two seaweeds in Fiji Islands and in other places. It is worth noting that both gracilaria and hypnea are suitable food species for use in trochus and green snail aquaculture, so this alone could justify some limited aquaculture production of these two seaweeds.
- Seaweed Meristotheca and caulerpa are edible species in high demand in Japan, but the former is scarce and difficult to cultivate while the latter is perishable and difficult to transport over long distance. Cladosiphon is also in high demand in Japan as a food species, and is already being successfully marketed there by Tonga.
- Seaweed All seaweed aquaculture products are suited for eco-labelling, as they are essentially organically grown with nothing (food, chemicals) added into the water column apart from the seaweed plants themselves.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

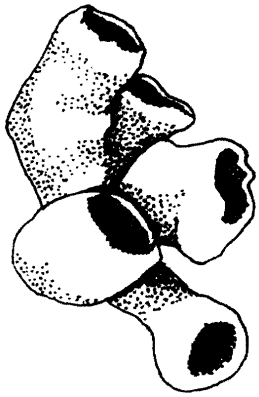
Advantages

- Most seaweed farming is low technology and suited to the lifestyles of rural villagers who may have few other income generating opportunities.
- The activity is suited for both men and women.
- There are huge areas of sheltered and unpolluted waters suitable for seaweed farming in many Pacific Islands countries. Impacts of seaweed farming appear benign or even beneficial.
- The products can be sold fresh or dried, and are suited for eco-labelling.

Disadvantages

- One drawback is long distances for transportation, firstly from outer islands to the main port and secondly from the main port to European, North American or Japanese export markets.
- The main drawback for kappaphycus aquaculture is that the farm-gate price must be sufficient, and payments be made on a sufficiently regular basis, to maintain grower interest compared with returns from other rural income sources like fishing or copra.

Sponge



Name of species/group

Bath sponges (*Spongia matamata, S. manipulatus, Coscinoderma mathewsi, Rhopaloides odorabile*). Many sponge species have some potential for fine chemical and pharmaceutical production.

Primary potential

Aquaculture of individual species for either bath sponge or chemical production, eliminating wild harvesting of commercial sponge species.

Attributes for aquaculture/stock enhancement

- Sponge aquaculture is ideally suited to remote island communities. The level of infrastructure required is much lower than for food species aquaculture. In-sea culture means no requirement for artificial energy and nutrient input.
- Wild sponges are harvested initially to provide seed stock for cloning. Clones are then used for subsequent culture.
- Growth rates are high in tropical waters but seasonally variable in temperate environments.
- The value of the product is highly variable, depending on size and quality (species dependent) and marketing strategy (bulk wholesale or valued-added niche markets).
- Post-harvest processing utilises natural, biological and physical processes ('rotting' to remove living tissue, drying in wind and sunlight).
- No necessity for refrigeration for storage or transport of product.

Culture methods

- Sponges can grow from cuttings so wild stock is necessary only for initial clone production. Subsequent crops utilise increasing proportions of cultured stock.
- Grow-out methodologies are grouped into two basic methods, horizontal or vertical support structures, primarily dictated by farm location and topography. On shallow-lagoon farms, sponges are attached by line to horizontal rope support lines (Pohnpei). On deeper-water farms, sponges are attached by lines to vertical ropes weighted at the bottom and held up in the water column by floats (Australia) or multi-compartment vertical lanterns, weighted at base and floated at top, are hung off backbone rope for commercial production (New Zealand).
- The technology is simple and low cost (weights, ropes, floats). The structures are serviced by boat from the surface. Scuba is required for original set-up and wild seed collection.
- Sponge farming is an idea small-scale community cottage industry

with full participation of women (two persons minimum plus canoe for harvest and maintenance of lines plus extension service and set-up assistance).

- Environmental impact potential is small but may include depletion of food for other filter feeders down-current from farms, gene pool alteration with imported wild stock, potential pollutants from gurry (rotting tissue), disease outbreaks in monoculture production.

Current production status

- Pohnpei (Federated States of Micronesia): Pohnpei Natural Products is at the commercial production stage with two species in culture (general purpose sponge *Coscinoderma mathewsi* and cosmetic sponge *Spongia matamata*). There have been problems reaching production targets, with cancellation of market contracts.
- New Zealand: Pilot-scale production of bath sponges (*Spongia manipulatus*) with private industry and Maori participation (National Institute of Water and Atmospheric Research, NIWA). Active R&D programme supporting bath-sponge culture and other fibre uses.
- Australia: Sponge farming is under research and development as an industry ideally suited for economic development by indigenous communities of Queensland (Department of State Development) and the Northern Territory. The Australian Institute of Marine Science (AIMS) is providing scientific support.

Marketing

- The international bath sponge market is buoyant with demand currently outstripping supply, and an increasing demand for 'natural' products generally. Current world market would be several million units, with a wide range of prices depending on market strategy adopted, in addition to size and quality.
- Small local tourist market, but with value-adding using attractive and informative packaging and development of innovative products such as gift packs can expect high retail price.
- Unfortunately the wholesale market gives poor returns. A number of sponge trading houses (mostly in Greece and Florida) buy minimal-processed, dry sponges in bulk. They process (clean, soften, lighten) to customer specifications and on-sell for a range of applications (bath, cosmetic, personal hygiene, artists, painters, car detailers, decorative). Wholesale prices range upwards from AUD1, depending on size and quality. Retail prices range from AUD2 to more than AUD40. High-technology research and development of new fibre applications, as well as pharmaceutical applications, has the potential to increase returns even further.
- Sponges, being light, robust, compressible and non-perishable, are ideal products for remote locations with sporadic transport infrastructure.

- Cultured sponges need to compete with wild-harvested product initially, but wild harvests will decline as a result of overfishing and environmental restrictions.
- Bath-sponge aquaculture is environmentally sustainable and friendly. Eco-labelling will promote these features and increase retail price.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- New species with new characteristics that rival Atlantic species, romance and exoticism of the pristine pollution-free Pacific, and production by indigenous people through community outreach are marketing advantages to tourists and European markets. Attractive packaging of sponges can draw together all of these positive associations, enhancing their value.

Disadvantages

- Acceptance of new species over, or in addition to, traditional sponge species by dealers.
- Remote farming locations can be a problem for communication, transport to markets and prompt extension assistance with problems.
- Communities may have limited knowledge of business practices and market demands for consistent quality and on-time delivery of product.

Tilapia

Name of species/group

Tilapia.

Primary potential

Aquaculture. Stock enhancement (but requires approval for wild release of exotics, for example in Papua New Guinea).

Attributes for aquaculture/stock enhancement

- Hardy, easy to breed and high survival.
- Fast growing, multiple harvests per year.
- Ease of production (feeding regime, management approach).
- Disease resistant.
- Able to be transported live.
- Improved strains are available.
- Moderate to high economic value.
- Potential for export.

Culture methods

Seed

- Hatchery production required to maintain stock quality.
- Simple low technology hatchery design.

Grow-out

- Amenable to multiple production systems, from small subsistence pond production to semi-intensive, commercial and high intensive systems (e.g. raceway, recirculation systems).

Current production status

- Fiji Islands has commercial and subsistence production which is rapidly expanding.
- Other Pacific Islands countries have attempted to introduce tilapia for aquaculture but with limited success to date. This is probably due to a lack of staff trained in tilapia culture practices and technologies and limited resource availability.

Marketing

- Domestic market potential in Fiji is high and expanding rapidly. There is potential for export markets. Trial shipments have been made to the USA and Australia.
- Tilapia is sold either whole or as fillets, live or frozen for the domestic market, frozen for the international market.

- There is limited opportunity for value-adding (perhaps smoking).

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- Acceptable as a food fish in most locations. On large islands, it can be an important protein source in inland regions. Improved strains are available.
- Easy species to culture and very hardy.
- Production systems are relatively cheap.
- Short culture cycle and amenable to low input systems.
- Feed technology is advanced.
- Women are commonly involved in production systems.
- Primarily freshwater but there is potential for brackish water culture.
- Colour variants are available (e.g. red strains).
- Potential for integrated farming and polyculture.

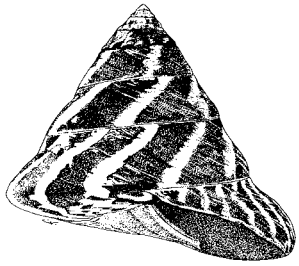
Disadvantages

- Limited cold tolerance (culture requires temperature above 20°C).
- Poor stock management may produce stunting.
- Potential for hybridisation among stocks, which can reduce productivity. Likely escape into natural river systems, and impact on native fish and other species.

Trochus

Name of species/group

Trochus niloticus (Mollusca: Gastropoda).



Primary potential

Stock enhancement. Potential in aquaculture (selling small juveniles to the aquarium trade as 'cleaners').

Attributes for aquaculture/stock enhancement

- Hatchery technology for mass seed production is easy and standardised.
- Large-scale production of small juveniles (1–2 mm) is economical under Pacific conditions.
- Broodstock are readily available in certain localities in the Pacific and large adults are highly fecund (0.5–1 million eggs).
- Spawning is readily induced without the need for specialised equipment.
- The larval cycle is simple and larvae do not require feeding during the planktonic larval phase.
- Hatchery operations are relatively disease free.
- Juveniles and adults are easily transported for stocking.
- Trochus could be grown in polyculture with other molluscs, e.g. giant clam.

Culture methods

Juvenile production

- Juveniles for stock enhancement and culture are not available from the wild and need to be produced in the hatchery.
- Hatchery technology is simple and the techniques for mass production of small juveniles are standardised and cost-effective.
- Heat treatment (2–3°C increase in water temperature, and change of water) is used to bring about spawning.
- The planktonic larval phase is simple, short and non-feeding.
- Settlement plate/substrates are prepared with benthic diatoms such as *Navicula* and *Nitzschia* spp. for larval settlement about 5 days after fertilisation.
- Benthic diatoms for feeding are maintained with soluble commercial fertiliser such as Aquasol.
- Juveniles reach 1–2 mm diameter 4–8 weeks after settlement.

Seeding and stock enhancement

- Methods for transporting juveniles in 'moist' atmosphere have been developed.

- Methods for seeding juveniles on reefs have been established.
- Seeding for stock enhancement is a low cost and low technology operation that could be conducted on a small-scale or on a commercial basis.
- Seeding activities are suitable for women and artisanal fishers.
- Seeding for stock enhancement is environmental friendly and supports species diversity of the reefs. Where translocation to a new country is considered, potential environmental and species diversity issues need to be considered. However, more than 50 years of trochus translocation have produced few recorded instances of adverse impacts in the Pacific (there are reports of reductions in abundance of *Turbo setosus* at Aitutaki Atoll, Cook Islands, following introduction of trochus there in 1957, although *T. setosus* is known to be relatively common there at present).

Current production status

Juveniles

- Hatchery production is well established.
- Production of 1–2 mm size juveniles is economical but seeding with large juveniles (10–40 mm) may only be suitable and economic for establishing broodstock populations in new areas and not for general stock enhancement release.
- Large juveniles can be produced in sturdy cages fixed to reefs.

Marketable product

- Previous releases of adult broodstock have successfully produced viable trochus fisheries in the Pacific, but not all releases are successful. Recent ACIAR funded research has showed that broodstock can be used to enhance juvenile recruitment.
- Stock enhancement using hatchery-produced juveniles is still being refined. Recent research has shown that numbers could be enhanced but survival rates would have to increase to make it economic.
- 'Predator swamping' by releasing mass number of juveniles has been suggested as a method of enhancing juvenile survival in stock enhancement.

Marketing

Juveniles

- No known competitor in the aquarium trade.
- No marketing has been done for juvenile trochus for the marine aquarium trade.

Marketable product

- The market for trochus shell is well established.
- Shells are easily transported and non-perishable.
- Price of shells is subject to fluctuation. The high prices achieved in the early 1990s have come under severe pressure due to the downturn in price of mother-of-pearl shells (*Pinctada maxima*).
- Trochus meat has been reported to fetch a very high price in the Japanese market (especially in Okinawa); USD50–90/kg has been reported in the Okinawa fish markets. However, export of the meat is not economic due to the limited production of trochus meat for processing in the Pacific. Further, no marketing has been done on the acceptability and price of trochus meat from the Pacific to Okinawa.
- Processing of trochus meat for export has yet to be developed although it is believed that the methodology is relatively simple.
- Potential for selling the meat as a 'green and clean' product from the pristine environment of the Pacific region.

Comparative advantages/disadvantages (risks) of producing the species in the Pacific

Advantages

- The species is well established in the Indo-Pacific region. Where successful introductions with broodstock have taken place, the animal has proved to be benign and has been well received by the communities.
- It is a 'forgiving' and a good aquaculture 'training' species.
- Hatchery and seeding techniques are relatively easy and established.
- Recent ACIAR funded research has showed that broodstock can be used to enhance juvenile recruitment.
- Trochus hatchery and seeding work could involve the whole community and provide employment to women and youth.
- There is a well developed market for the shell product and the meat is readily acceptable and eaten by the people.
- Trochus can be value-added by making into button blanks and other shell jewellery.

Disadvantages

- Some Pacific nations need to translocate the broodstock from their neighbours.
- Methods of stock enhancement using hatchery-produced juveniles need to be refined. Recent research has showed that stock numbers could be enhanced but survival has to be increased to make it economic.
- Where enhancement is carried out, sustainable management practice needs to be put in place to ensure long-term viability.