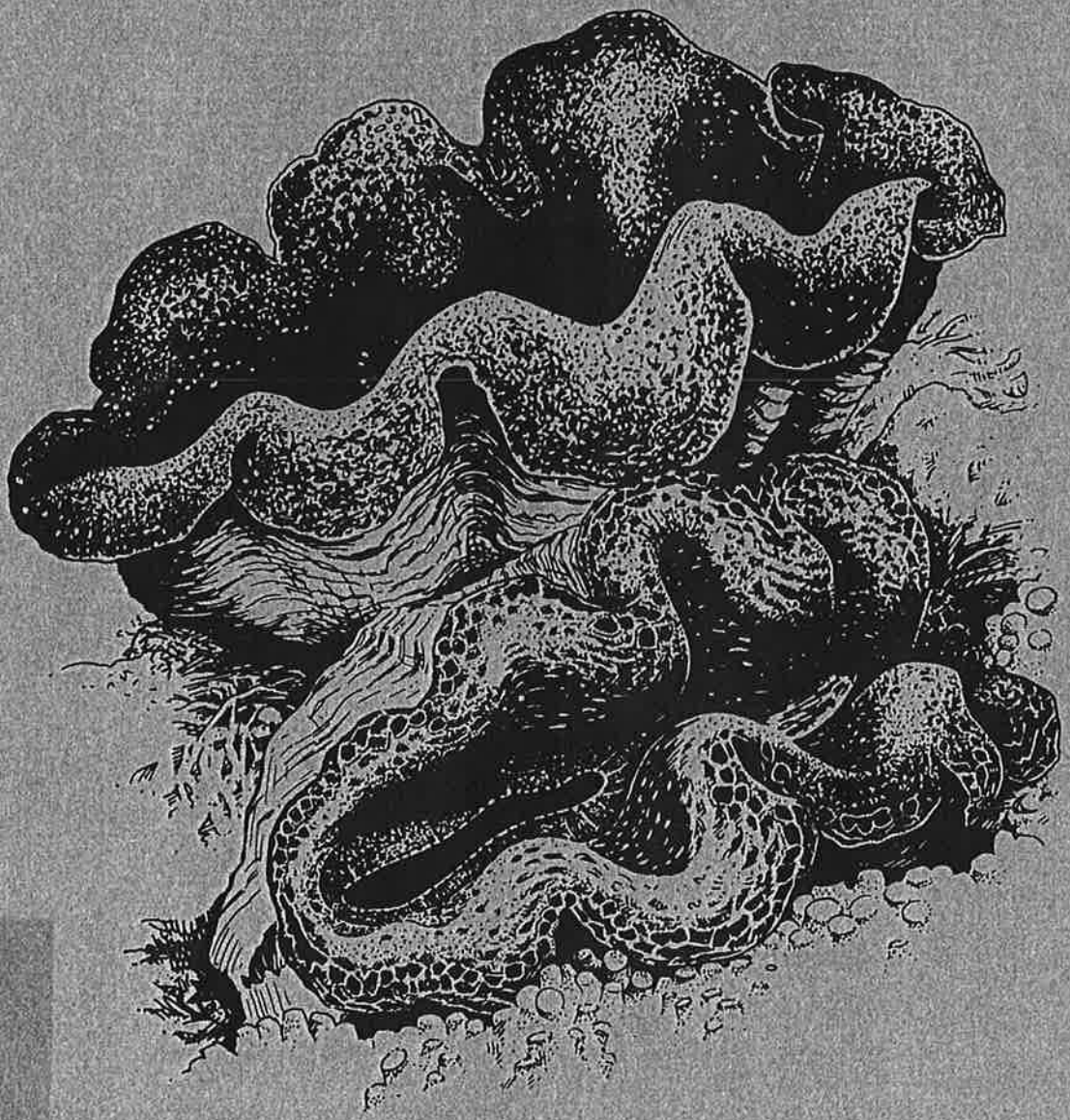
The Status of Species in Trade

Giant Clams: Status, Trade and Mariculture, and the Role of CITES in Management



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GIANT CLAMS: STATUS, TRADE AND MARICULTURE, AND THE ROLE OF CITES IN MANAGEMENT

by

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research
BFAR	Bureau of Fisheries and Aquatic Resources, Philippines
CAC	Coastal Aquaculture Centre, Solomon Islands
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CTSA	Center for Tropical and Subtropical Aquaculture, Hawaii
FAO	United Nations Food and Agriculture Organisation
FFA	Forum Fisheries Agency
FSM	Federated States of Micronesia
ICLARM	International Center for Living Aquatic Resources Management
IUCN	The World Conservation Union
JCU	James Cook University, Australia
MMDC	Micronesian Mariculture Demonstration Center, Palau
PNG	Papua New Guinea
SPREP	South Pacific Regional Environment Programme
SSC	Species Survival Commission (of IUCN)

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PREFACE

In 1984, the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) initiated the CITES Significant Trade project to identify species included in Appendix II of the treaty that may be traded at levels detrimental to their survival. The IUCN Species Survival Commission provides technical support to this project, in the form of biological and status information on species believed to be in "significant trade" and, through the offices of its Wildlife Trade Programme, in the form of supporting information to assess the extent to which exploitation for trade might be detrimental to the survival of these species.

In 1988, giant clams (Tridacnidae) were brought to the attention of the CITES Animals Committee and it was suggested that these species be examined in greater detail in order to determine whether trade levels might be a problem for wild populations. Although this suggestion was not followed up by the Animals Committee at the time, the Trade Specialist Group began efforts in 1990 to secure funding to undertake such a study in collaboration with the SSC Mollusc Specialist Group. The 1994/1995 Significant Trade Review identified the Tridacnidae as one group of species that the CITES Animals Committee would consider in 1995. A draft of the present report formed the basis of the submission to the Animals Committee on these species (IUCN/TRAFFIC/WCMC, 1996)

The report to the Animals Committee synthesized the information on the status and trade of wild populations of giant clams with that on mariculture and markets for mariculture products.

An assessment of the trade in wild-caught giant clams cannot be undertaken without examining trade in mariculture specimens. In addition, the conservation and management of giant clams in the wild cannot be divorced from the enormous efforts being directed towards the culture of giant clams as a sustainable development option in the South Pacific. A second objective of the report was to highlight the shortcomings of CITES in controlling trade in

giant clams, in order to ensure that CITES facilitates trade in mariculture products and improves regulation of trade in wild-caught animals.

This subsequent report incorporates comments received on an early manuscript which could not be included into the version of the report to the CITES Animals Committee (IUCN/TRAFFIC/WCMC 1996). It also takes in to account changes in the IUCN threatened species categories for giant clams, and the publication of a number of new reports and reviews. Giant clam trade and mariculture is a rapidly evolving field, and it is recognised that some of the data in this document may already be slightly out-of-date. However, it is felt that the general conclusions and recommendations are still valid. The report should assist those involved in mariculture to understand CITES, and equally those involved in the regulation and monitoring of the international wildlife trade to understand the conservation requirements of giant clams and the potential role that mariculture may play.

EXECUTIVE SUMMARY

1. Introduction

Giant clams are the largest bivalves in the world and live in tropical seas in the Indo-Pacific, generally either on or in the vicinity of coral reefs. There are seven species in the genus *Tridacna* (*T. gigas*, *T. derasa*, *T. tevoroa*, *T. squamosa*, *T. maxima*, *T. crocea*, *T. rosewateri*) and two in the genus *Hippopus* (*H. hippopus*, *H. porcellanus*).

2. Status in the wild

Eight of the nine Tridacnidae species are on the IUCN Red List of Threatened Animals (IUCN 1996). Several species have been introduced outside their natural ranges, or re-introduced to areas where they are now depleted or extinct, although in all cases bar one, populations have not become established in the wild. Wild stocks of the larger species (*T. derasa* and *T. gigas*) have declined dramatically in recent years as a result of over-exploitation for their meat and shells, and populations have become extinct in many areas.

Abundant populations of *T. gigas* (IUCN-Vulnerable) are known only in Australia and the Solomon Islands, although relict populations could still occur in Palau, Papua New Guinea (PNG), Marshall Islands, Kiribati, Myanmar, and on the west coast of Thailand. This species is extinct in Fiji, Guam, New Caledonia and the Northern Marianas and has been eliminated from most of Japan, Taiwan, Tuvalu, the Federated States of Micronesia (FSM), and Vanuatu. It is extinct in most areas of the Philippines but may still occur in the south.

T. derasa (IUCN-Vulnerable) has a slightly smaller range, with the only confirmed centres of abundance in Palau, northern PNG, Australia, Solomon Islands, New Caledonia, Fiji and Tonga. This species has been widely introduced outside its original range but in only one area (Yap) have wild stocks become established.

T. crocea (Removed from the 1996 IUCN Red List) occurs from southern Japan, south to Australia and east to Palau and is still reasonably abundant. *H. hippopus* (IUCN-Lower Risk: Conservation Dependent) has a similar distribution but populations are greatly reduced in abundance and local extinctions have occurred.

T. tevoroa, *T. rosewateri* and *H. porcellanus* have much smaller ranges: *T. tevoroa* (IUCN-Vulnerable) is restricted to Fiji and Tonga; *T. rosewateri* (IUCN-Vulnerable) has only been described from the Saya de Malha Bank in the Indian Ocean; and *H. porcellanus* (IUCN-Lower Risk: Conservation Dependent) has a very restricted distribution in Indonesia, the Philippines and Palau.

T. maxima (IUCN-Lower Risk: Conservation Dependent) and *T. squamosa* (IUCN-Lower Risk:Conservation Dependent) have the largest ranges and extend from the Red Sea and East African coast across the Indo-Pacific. These two species are still reasonably abundant but their status in the Indian Ocean is poorly known.

3. Subsistance fisheries, domestic markets and international trade

Giant clams have formed part of the diets of Pacific islanders and coastal dwellers in the Australasian region for thousands of years. They continue to be harvested for their meat and shells for both subsistance and commercial purposes and, more recently, for live specimens for use in the aquarium trade. There are no detailed figures on current subsistence use but it has

been estimated at about 200 tonnes of meat a year. There are small, largely unquantified, domestic markets for meat (for local consumption) in most countries within the distribution range of giant clams. There is a substantial fishery for some of the small species, mainly *T. crocea*, in southern Japan for local sale and consumption as sashimi and sushi; the most recent figures are for 1987 when 91 tonnes were harvested. Between eight and 47 tonnes of giant clam meat are sold a year locally in Fiji. Local markets for shells are also poorly documented, although clam shells are sold in many countries to tourists. In Indonesia, crushed shells are used to make floor tiles and at least 10-20 tonnes of shells were being used every two weeks in the late 1980s. There are local markets for giant clam aquarium specimens in Japan and Australia.

The international trade in giant clam products is dominated by meat (adductor muscle) destined for Taiwan, with a smaller amount going to Japan, and shells and live specimens destined for the curio and aquarium trades in the USA, Japan, Australia and Europe. There is an estimated annual demand of 300 tonnes for clam adductor muscle in Taiwan, much of which is thought to have been obtained illegally by Taiwanese fishing vessels from the territorial waters of South Pacific nations. Some meat is also imported by Taiwan, but details are scanty: Indonesia, PNG, the Maldives, Fiji, and Palau, for example, have all supplied meat at some point, but information on regular sources and trade routes is not available. A locally operated fishery in Fiji supplied clam meat (mainly *T. derasa*) in the 1980s to Taiwan and several other countries prior to the 10 year moratorium on clam harvesting for export; annual exports varied from about 7-40 tonnes. The decline in supplies of local clam meat in southern Japan, has led to exports to this country principally from the Philippines (a reported 66 tonnes in 1993).

The international shell trade has been dominated by exports from the Philippines. 1.5 million shells, nearly 350,000 carvings and over 252 tonnes of shells were exported in 1990, but exports dropped to just over 374,000 shells and nearly 70,000 carvings in 1992. Until 1992, exports were dominated by *H. hippopus*, *T. squamosa* and *H. porcellanus*. Exports of clams from the Philippines, except for *T. crocea*, became illegal in 1990/91, but there were considerable problems enforcing this legislation. In 1996, export of all species of tridacnids from Philippines was banned. The main importer of giant clam shells is the USA, which accounted for 57% of Philippine exports in 1991. Other major importers in recent years have been European countries (particularly the UK), Japan and Australia.

The demand for live giant clams for aquaria has grown considerably. Figures for the extent of this trade are patchy and fluctuate considerably between years. The Philippines has been a supplier of wild-caught live specimens. Mariculture operations in Solomon Islands, Seychelles, Australia and the Marshall Islands now supply much of the aquarium trade which is focused in the USA, Europe and Japan.

There are a number of difficulties in extrapolating trade data on giant clam products to numbers of specimens harvested, but some rough estimates are available. Subsistence catch might represent about 200,000-600,000 clams annually. The Taiwanese meat trade at the beginning of the 1990s could have represented 300,000-900,000 clams annually. Philippine meat exports to Japan could represent 250,000-500,000 *T. crocea*. The shell trade could have represented about one million specimens in 1992. Wild caught specimens for the aquarium trade are difficult to estimate, but may have amounted to 5,000 in 1991. These figures provide a rough total estimate of 1,500,000 and 2,500,000 wild caught clams involved in international trade annually in the early 1990s.

4. Mariculture

The discovery that clam mariculture is technically feasible, that the growth rates of some species are much faster than previously believed (up to 10cm/year for *T. gigas*) and that their symbiotic relationship with algae makes them the world's first self-feeding farm animals, has led to considerable research interest and expenditure. Pioneering research has been carried out on the mariculture of giant clams by James Cook University (JCU) in Australia, Micronesian Mariculture Demonstration Center (MMDC) in Palau, and the Coastal Aquaculture Center (CAC) in the Solomon Islands. In the Pacific nations, with their limited land and freshwater resources, clam mariculture is seen as a way of diversifying narrowly based economies, of providing food and employment for small-scale farmers and fishermen, of earning foreign exchange, and of providing clams to restock depleted coral reefs and increase populations of the rarest species.

CAC and Reefarm (Australia) are now the two main hatcheries, but at least 22 countries and territories have one or more small-scale hatcheries and grow-out facilities. The majority are in the Pacific, (with one in Japan). Rapid advances in technology have meant that costs of production have become cheaper and the economics of giant clam farming have changed quickly. The initial emphasis was to produce meat from the two largest species for subsistence use, local markets and the export trade but hatcheries have had greatest commercial success rearing small specimens for the aquarium trade and the Japanese meat trade; the short grow-out phase and thus lower risk of predation provides a better economic incentive. Clam mariculture carries a number of risks such as high mortalities from storms, disease, predators, and poaching.

Many of the hatcheries and village-based grow-out operations also produce clams for restocking depleted reefs. It is too early to judge the success of giant clam "farming" in terms of conservation, but by supplying the Japanese clam meat market and by partially fulfilling demand for aquarium specimens, it may be helping to reduce exploitation of wild stocks. It has undoubtedly been successful in increasing public awareness of the need for sustainable management of giant clams and coral reefs, particularly through the development of village- and community-managed clam farms.

5. Convention on International Trade in Endangered Species (CITES) and National Legislation

All tridacnid species are listed in Appendix II of CITES. However, the effectiveness of this listing is limited by the fact that of the CITES Parties within the distribution range of giant clams, relatively few are involved in international trade in clams and their products. Other range States, e.g. The Solomon Islands, which is involved in the trade are not Party to the Convention. However, CITES Annual Reports provide a useful source of data for the analysis of past trade and for the identification of possible areas of illegal trade. Unfortunately, the significant trade in clam meat to Taiwan is not reported to CITES, since Taiwan is not recognised as an independent state by the United Nations, and is included in the ratification for China.

At least 22 countries have national legislation specifically relating to giant clams, often stricter than that required by CITES. In several countries (e.g. Australia, Indonesia, Philippines, Singapore), clams are fully protected (collection, sale and export of wild specimens banned); in others (e.g., PNG, Fiji, Palau, Tonga) export of wild-caught specimens is prohibited. However, in many of these countries, notably the Philippines, Indonesia, and Palau, this legislation has proven difficult to enforce.

The CITES Secretariat assists Parties in the enforcement of national legislation by regularly issuing `Notifications' informing Parties of national export bans or other relevant domestic legislation. CITES Notifications were transmitted in January and June 1992 and in June 1996, for example, to all CITES Parties urging them to refuse permits from the Philippines for prohibited species and consignments of pre-ban stockpiles of giant clam. An apparent decline in Philippine exports for 1992 may indicate that the first two Notifications at least were to some effect. However, given the delay in the production of CITES Annual Reports, it will be some time before one can judge with any certainty these have had any impact and whether CITES is having any impact on the rapidly increasing trade in aquarium specimens.

Other countries have also been lax in meeting CITES requirements. For example, Australia only permits private or commercial imports of Appendix II listed species when they are bred in captivity, taken under an approved management programme, or declared as 'controlled specimens'. However, in the past, large numbers of giant clam shells have been exported to Australia from the Philippines even though the Philippines does not have a management programme recognised by the Australian Government and is not exporting captive-bred clams for this purpose.

If implemented appropriately, CITES regulations should not impede international trade in farmed giant clams. However, problems have arisen in three areas: 1) interpretation of the definition of "bred in captivity"; 2) obtaining appropriate permits, particularly in non-Party States and; 3) distinguishing farmed from wild-caught specimens. Recommendations are made for resolving these problems.

6. Strategies for giant clam conservation

Management of remaining wild populations of giant clams in their natural habitat must be considered one of the highest priorities.

a) Village-based conservation and management programmes

In many Pacific countries, access to giant clam stocks is controlled by traditional reef tenure systems which have evolved over many years, and clams are subject to traditional fishing rights along with other fishery resources. The support of local people and their involvement at all stages in management is essential for successful management of nearshore fishery resources. Village-run clam grow-out facilities have been set up in the Solomon Islands, the FSM, the Philippines and are being introduced in several other countries.

In several Pacific countries, clams have traditionally been collected and placed in sheltered, protected areas (or clam gardens) close to the village. These are often established as a means of providing emergency food stocks or ceremonial food, but they may also have conservation purposes. In either case, this practice may have a beneficial effect as a clumped distribution can encourage spawning and fertilisation. Clam circles are being established in Tonga as part of community-management projects to manage clam populations.

b) Protected areas

Sanctuaries have been established for giant clams in several countries, and many marine protected areas already exist within the distribution range of giant clams, established for the protection of other marine resources or for the regulation of tourism. An assessment should be made of the extent to which these contain clam populations.

Elsewhere, protected areas containing populations of giant clams should be established (whether through traditional tenure systems, as community-managed enterprises, or as part of government-led marine protected area programmes) for all regions where clams are depleted. Three genetically distinct groups of wild populations have been identified for *T. gigas*, *T. derasa* and *T. maxima*: 1. Great Barrier Reef, Solomon Islands and Philippines; 2. Western Pacific (i.e. Fiji and Tonga); and 3. Eastern Pacific: (Cook Islands, Kiribati and Marshalls). Clam reserves should be established in each of these regions if appropriate protected areas do not already exist.

c) Regulation of exploitation

Several countries have total or partial bans on harvest or export. Further research is required into the potential for introducing other fishery control measures, such as minimum sizes, closed seasons, or annual quotas, to regulate clam collection.

d) Restocking and re-introductions of giant clams

Restocking of reefs with cultivated clams has been carried out in many countries (either as introductions - where a species is introduced to an area outside its original range, or as re-introductions where a species is introduced to an area in which it once occurred). A central database of international translocations is to be maintained at ICLARM.

Translocations of giant clam stocks carry a number of risks, particularly the introduction of disease, pests and predators and the introduction of different genetic stock. Quarantine procedures have been established. Guidelines on introductions and re-introductions and on sound genetic practices for the cultivation of giant clams have been produced, and efforts could be made to ensure that these conform to the IUCN's Guidelines for Re-introductions (IUCN, 1995) where appropriate. A consortium has been initiated, consisting of representatives of various institutions involved in clam mariculture and translocations, to seek funding for the re-establishment of giant clams in the Pacific in a manner which conforms to genetic principles.

1. INTRODUCTION

Giant clams are the largest bivalves in the world and live in tropical seas in the Indo-Pacific, generally either on or in the vicinity of coral reefs. There are seven species in the genus *Tridacna* (*T. gigas*, *T. derasa*, *T. tevoroa*, *T. squamosa*, *T. maxima*, *T. crocea*, *T. rosewateri*) and two in the genus *Hippopus* (*H. hippopus*, *H. porcellanus*). Two species have been described recently: *T. tevoroa* by Lucas *et al.* (1990) (and now considered a probable junior synonym of a fossil species *T. mbulvuana*) and *T. rosewateri* by Sirenko and Scarlato (1991).

The largest species, *T. gigas*, *T. derasa* and *T. tevoroa*, reach up to 100cm, 55cm and 55cm shell length respectively. The other species grow to a maximum size of 30-40cm, with the exception of *T. crocea* which reaches only about 15cm. They reach these large sizes despite living in often nutrient-poor waters, largely because of the symbiotic algae (zooxanthellae), *Symbiodinium microadriaticum*, that live in their tissues. Photosynthetic products of the algae are passed to the clams which appear to gain much of their nutritional requirements from this source. They are also capable of filtering plankton from the sea water like other bivalves. Although filtration was thought to be a minor source of food, Klumpp *et al.* (1992) have found that it is important in small juveniles. The presence of the zooxanthellae means that giant clams are rarely found in turbid, sediment-laden waters and prefer shallow sunlit seas, although *T. squamosa* can live in turbid waters (Mingoa-Licuanan, *in litt.* to S. Wells, 1994). Giant clams are normally found from the intertidal reef crest or flats to depths of about 15m, although some species have been reported from depths of 30m, and *T. tevoroa* is found to 40m depth.

Giant clams are harvested for their meat and shells and are taken live as aquarium specimens. Stocks of the largest species have declined dramatically over the last 10-20 years as a result of excessive exploitation for their meat and shells. The discovery that the growth rates of some species are much faster than previously believed (up to 10cm/year for *T. gigas*) and that their symbiotic relationship with algae makes them almost 'self-feeding', led to considerable research interest and expenditure, resulting in the development of successful technology for clam mariculture.

This report reviews the status of giant clams, the information that is available on their exploitation, the impact that this may be having on wild populations, and summarises the results of mariculture programmes. It analyses the role that the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has played in giant clam conservation, and explains the functioning of this Convention. Many people involved in giant clam mariculture have perceived CITES to be an impediment, not only to efforts to farm clams, but also to the conservation of wild stocks.

2. STATUS IN THE WILD

The IUCN Invertebrate Red Data Book (Wells *et al.*, 1983) provided one of the first reviews of the conservation status of giant clams. This was followed by Munro (1989), who used information gathered from a questionnaire distributed by ICLARM in 1983 and other material. Since then, a large number of reports and publications have come out documenting the status of species in different countries. The most recent general review is Lucas (1994). Further details of the biology, ecology and distribution of giant clams can be found in Rosewater (1965), Copland and Lucas (1988), Munro (1989; 1993a, b), Fitt (1994) and Lucas (1994). Munro and Nash (1985) provide a bibliography of references relating to giant clams up until 1985 and local names used in Pacific countries are listed in Govan (1989).

Using these and other references, Annexes 1 and 2 give details of distribution and status by species and country.

2.1. Distribution

There are still many gaps in our knowledge of the distribution and abundance of giant clams. Most information is available for the South Pacific and Southeast Asia, the regions where the larger and more valuable species occur and, thus, where greatest exploitation takes place. Information for the Western Indian Ocean is sparse. An additional complication is that distribution patterns are becoming confused by the growing number of introductions of species outside their natural ranges (Eldredge, 1993). There is very little information on the extent to which introduced populations have become established in the wild. Many of the introductions listed in Annexes 1 and 2 refer to specimens introduced for mariculture purposes rather than to restock reefs. For example, several species have been introduced to Hawaii, well outside the range of any tridacnid. *T. crocea* no longer occurs there but the fate of the *T. gigas* and *T. squamosa* specimens is unknown. Six hundred clams were introduced into the Caribbean in Bonaire (Netherlands Antilles), Guadeloupe and South Florida from the MMDC for culture and the aquarium trade (Eldredge, 1993). The only place where there is clear evidence of a species being re-established in the wild is in Yap (see below).

The ranges of the larger species are much reduced. *T. gigas* is extinct in at least four of the 20 countries and territories within its original range and possibly extinct in four others. Abundant populations are known only in Australia and the Solomon Islands, but it is possible that relict populations may still occur in Myanmar, Palau, PNG, Marshall Islands, Kiribati, and on the west coast of Thailand. Elsewhere populations are much reduced and there have been many local extinctions. This species is extinct in Fiji, Guam, New Caledonia and the Northern Marianas and has been extirpated from most of Japan, Taiwan, Tuvalu, FSM, and Vanuatu (Munro, 1989; 1993a,b; Calumpong, 1992). Cultivated stocks have been re-introduced to Fiji and the Philippines and introduced to American Samoa, Hawaii, Tonga, Western Samoa and the Cook Islands, but have not become established in the wild (Munro, 1993a,b).

T. derasa has a more restricted distribution than *T. gigas*, and occurs in only nine countries and territories. It extends further east in the south than it does in the north, following the edge of the Western Pacific Plate (Benzie, 1993a). (Munro (1989) suggested that this eastward extension to Tonga could have been due to early seafarers jettisoning clams from bilges of canoes). The only confirmed centres of abundance are in Palau, northern PNG, Australia, Solomon Islands, New Caledonia, Fiji and Tonga. It is extinct in Guam and the Northern Marianas. This species has been widely introduced outside its original range, for example to

American and Western Samoa, the Cook Islands and throughout the FSM, but wild stocks are known to have become established only in Yap (FSM) (Munro, 1989, 1993b; Lindsay, 1994, 1995).

T. crocea occurs from southern Japan, south to Australia and east to Palau (in about 17 countries) and is still reasonably abundant, although it may be extinct in Guam and the Northern Marianas (Munro, 1989). *H. hippopus* occurs from Myanmar, east to the Marshall Islands and south to New Caledonia, and is still found in 19 countries. Populations are greatly reduced in abundance and it is now extinct in several places including Fiji, American and Western Samoa, Tonga and probably Guam.

T. tevoroa, *T. rosewateri* and *H. porcellanus* have much smaller ranges. *T. tevoroa* is limited to a few island groups in Fiji and Tonga covering a total area of about 300 km^2. It is relatively rare at all locations (Sone, 1996) and its deep water habitat may partially protect it from harvesting, but some local exploitation occurs in most areas. *T. rosewateri* has so far only been described from its type locality on the Saya de Malha Bank (Mauritius) in the Indian Ocean. *H. porcellanus* has a restricted distribution mainly in the Sulu and South China Seas (northern Indonesia and the Philippines), with its greatest natural abundance around Sulawesi (Braley, *in litt.* to S. Wells) and Palau.

T. maxima and *T. squamosa* have the largest ranges and these seem to have changed little from the distributions reported by Rosewater (1965). They extend from the Red Sea and East African coast across the Indo-Pacific to the Pitcairn Islands: *T. maxima* has a current range of 45 countries, and *T. squamosa* of 41. Both species are still reasonably abundant (Munro, 1989), although *T. squamosa* may be extinct in Japan and Guam and *T. maxima* is extinct in Hong Kong. However, the status of these species in the western part of their range (the Indian Ocean) is poorly known.

2.2. Threats

Extinctions and declines are due almost entirely to over-exploitation, partly by local people for subsistence purposes and, probably to a greater extent, by commercial harvesting either for the meat or the shell trade, as described in section 3. In some places, where only subfossil shells are known, population declines could be due to ecological factors, but, as yet, no firm information exists to support this hypothesis. Belda *et al.* (1993) have shown that elevated nutrient levels damage shell growth and decrease skeletal strength, which could have long-term consequences for populations in heavily polluted areas. Reef degradation, now recognised as being widespread, could also play a role. Siltation on reefs in some of the larger islands of Melanesia has reportedly affected some populations (IUCN/TRAFFIC/WCMC, 1996).

An additional threat is mass mortalities of populations from as yet unidentified causes. These were recorded at several locations in Australia between 1985 and 1987 (50% mortality of *T. gigas* and *T. derasa* populations at Lizard Island; 25% mortality of *T. gigas* and *H. hippopus* near Cairns). In 1992, a mass mortality affected both wild and cultured populations in the Solomon Islands. Studies have shown that no parasites are involved but the cause could be a pathogen and/or a pollutant (Lucas, 1994).

Natural recruitment rates of *T. gigas* and *T. derasa* are very low despite their enormous fecundity. Giant clams, although hermaphroditic, are not self-fertilising and fertilisation

depends on the presence of other individuals. The eggs of giant clams produce a chemical which induces spawning in adjacent clams and causes a chain of spawning events down-stream of the first clam. The wide dispersal of many of the surviving populations thus makes fertilisation unlikely, because if individuals are too scattered, spawning will not be triggered. Re-establishment of depleted populations thus depends on larvae coming in on currents from other reefs. This could take many years if a reef is isolated or if current directions are unfavourable. A clam population depleted in the Solomon Islands in 1983 had not recovered by 1987; and other areas in this country such as Marovo Lagoon which had commercial fishing in the past still have very low populations compared to areas not subjected to harvesting (Govan *et al.*, 1988; Munro, 1989, 1993b).

2.3. Regional review of stocks

Average stock densities of giant clams vary enormously, probably reflecting their episodic recruitment, combined with the effects of exploitation and unknown habitat preferences (Lucas, 1994). Giant clams are still abundant on much of the Great Barrier Reef in Australia, which probably has the largest stocks in the world (Munro, 1989; Braley, 1993), although some stocks were reduced by poaching in the 1970s when an estimated 69,000 *T. gigas* were taken north of Cairns (Pearson, 1977). Densities of *T. gigas* and *T. derasa* average about five individuals/ha, although up to 100 clams/ha have been recorded. *H. hippopus* averages 30-90 clams/ha. *T. crocea* and *T. maxima* average about 1,390 clams/ha, although exceptional instances of 3,000 clams/ha have been recorded (Munro, 1993a, b).

The second largest populations are found in the Solomon Islands, Palau and Fiji. The Solomon Islands still have some good stocks, even though clams here are regularly consumed for subsistence, and poaching is sometimes a problem (Munro, 1989). Oengpepa (1993) reports that some populations in the Solomon Islands, particularly of *T. gigas* and *T. derasa*, are being depleted at an alarming rate. Substantial stocks may also exist in Palau, and although poaching was a problem in the 1970s (Hardy and Hardy, 1969; Heslinga, 1979), there have been no surveys since the 1970s and early 1980s (Nichols, 1991; Heslinga, 1993). In Fiji, stocks away from population centres are relatively abundant, and population declines may have been less rapid here than elsewhere as clams are considered "high status food" (see section 3.1). However, exploitation in recent years has led to dramatic declines in the larger species near population centres (Lewis *et al.*, 1988; Munro, 1989).

Elsewhere in the South Pacific, the general picture is one of declining populations. In the FSM, all species are under heavy pressure from local exploitation (Munro, 1989) and even the remotest reef areas may suffer from poaching. In PNG, poaching was a major problem in the 1970s and 1980s (Wankowski, 1979). In Kiribati, estimated stocks in the 1980s were found to be low compared with those on the Great Barrier Reef or in PNG (Munro, 1986; Taniera, 1988).

Southeast Asian stocks have been severely reduced. Giant clams are heavily exploited in the Philippines and several species are considered locally endangered; the east, south and west regions are still poorly known but the Luzon and Visayas region was surveyed in the mid-1980s (Alcala, 1986; Juinio *et al.*, 1986; Mingoa-Licuanan, 1993). Undisturbed or only moderately exploited populations of most species are found in eastern Indonesian waters, but elsewhere in this country they are heavily exploited (Munro, 1989). The status of stocks in most other countries is poorly known, although populations on the west coast of Thailand are not heavily exploited (Munro, 1989, 1993b).

2.4. IUCN categories of threat

Seven species of giant clam appear on the IUCN Red List of Threatened Animals (Baillie and Groombridge, 1996). *T. gigas*, *T. derasa* and *T. rosewateri* are listed as Vulnerable, on the basis of the rate of decline of remaining wild stock (although some experts consider that the mariculture programmes are now sufficiently successful that *T. gigas* and *T. derasa* can be categorised as Lower Risk: Conservation Dependent). *T. tevoroa* is also listed as Vulnerable, on the basis of its small and declining 'area of occupancy', although it has also been suggested that it should be categorised as Endangered. *H. hippopus*, *H. porcellanus*, *T. maxima* and *T. squamosa* are listed as Lower Risk: Conservation Dependent, on the basis of the decline and disappearance of many populations. *T. crocea* is not included in the 1996 Red List; it was previously listed as Insufficiently Known.

3. SUBSISTENCE FISHERIES, DOMESTIC MARKETS AND INTERNATIONAL TRADE

Harvesting of wild giant clams falls into two categories: 1) Subsistence collection on an opportunistic basis to supply local demand: meat (both mantle and muscle) for food and fertiliser, and shells for a variety of decorative and utilitarian purposes; and 2) Commercial harvest to supply local and overseas markets: adductor muscle mainly for the Taiwanese market; small live clams for the aquarium trade; shells for the curio and souvenir trade.

There are very few sources of information on quantities harvested, consumed locally or exported. Giant clam products are specified in very few national trade or fishery statistics, one exception being the annual fishery statistics for Fiji. Stanton (1990; 1994) reviewed international trade statistics and found that they provide only limited information as giant clam products are usually included in broad commodity categories for molluscs and crustaceans. The *FAO Yearbook of Fishery Statistics* gives figures for 'clam meat, frozen', but this covers many different bivalve species.

CITES Annual Reports, which Parties are obliged to produce, give information on reported levels of international trade to species level but the figures are difficult to interpret as, at least until 1994, quantities were given in a number of different units: meat as kgs, bags, cartons, boxes and other units; shells as kg, 'shells' (assumed to be single valves), pairs (assumed to be a complete shell), carvings (probably a single valve, polished or otherwise worked to form a bowl), kg of carvings, sets of carvings, and 'skins'. A number of other factors contribute to the difficulty in interpreting the size of the international trade, including the possible inaccuracy of reporting, the fact that a proportion of the international trade between Parties goes unrecorded, and the fact that trade between non-Parties, and between Parties and non-Parties is not recorded.

There is a substantial body of literature on potential markets for giant clam products, as several studies have been carried out with the aim of identifying outlets for farmed products. Shang *et al.* (1990) interviewed seafood brokers in Japan, Taiwan, Hong Kong, Australia and the USA. Market demand for clams for food and for aquarium specimens was evaluated by Shang *et al.* (1992) for Honolulu, Guam, Saipan, Japan (Okinawa) and the USA. Other markets for giant clam products in southern Asia and Japan were reviewed by Compass Consulting Services (1986), Dawson (1986), Dawson and Philipson (1989), Cowan (1991) and in several studies summarised in Tisdell (1992) and Tisdell *et al.* (1994). Some of these publications help to provide an overall picture of exploitation, although many focus more on potential demand and markets.

3.1. Subsistence fisheries

Giant clams have formed part of the diets of Pacific islanders and coastal dwellers in the Australasian region for thousands of years, and the shells are a major component of middens in the region (Munro, 1989; 1993b). They continue to play a role in subsistence livelihoods throughout much of the Pacific and in some South-east Asian countries. All the flesh is edible, except for the kidneys which are bitter. Preparation methods include boiling in coconut milk, pickling in vinegar, drying and salting; clams are also eaten raw. The adductor muscle, which makes up about 10-15% of the flesh, is the most highly regarded part. The shells are used for a range of purposes such as bowls, rainwater containers, drinking troughs for livestock, ornaments, and tools. In the Marshall Islands, the meat of *T. crocea* and *T. maxima* is used to fertilise bread fruit trees (Smith, 1992b).

Like most subsistence fishing, clam harvesting is not carried out in a manner conducive to the gathering of statistics. In most cases, clams are taken opportunistically, in the course of other fishing and reef gleaning activities. Clams are harvested on foot at low tide from shallow reef areas, or are gathered from deeper waters by diving from a small boat, using goggles. In several countries, they are harvested primarily when the weather is unsuitable for other fishing activities from boats. Generally, only the amount required for immediate consumption is taken, although sometimes additional clams are taken and placed 'in store' in shallow water near the beach. When meat is the primary interest, the shells are often left on the reef. In many countries, for example Tonga and Western Samoa, clam meat is sold in preference to being eaten at home because it is a good source of cash (Vuki *et al.*, 1991). The current total subsistence harvest of clams in the Pacific is therefore not known. However, Munro (1993b), using information on mortality rates and stock densities, suggests that about 200 tonnes of meat are taken a year and that this harvest is probably smaller than that from commercial fisheries.

In Fiji, Tonga and Western Samoa, local demand for clam meat is relatively limited (Tacconi and Tisdell, 1992a). In Fiji, it is a 'high status food', used mainly on special occasions or as a reserve food in difficult times; in Western Samoa demand may be limited by supply. In American Samoa, giant clam meat is a traditional delicacy (Killelea-Almonte, 1992). In the Cook Islands, *T. maxima* is the most significant shellfish component of local subsistence diets, but *T. squamosa* is also harvested (Sims and Howard, 1988); harvests of clam meat in 1978/79 were about 100-135 tonnes a year, but may now have declined. In Niue, *T. squamosa* is most commonly consumed, and *T. maxima* is less popular, but both species are considered luxury rather than staple foods (Bell, 1993a; Dalzell *et al.*, 1993). In Kiribati, clams are harvested fairly intensively around populated atolls, particularly *T. gigas*, although *T. maxima* is also taken in smaller quantities (Munro, 1986). Clam meat is also eaten in Vanuatu, the Marshalls (Smith, 1992b), FSM (Smith, 1992a), Tuvalu (Tacconi and Tisdell, 1992c) and Palau (Nichols, 1991).

In the Solomon Islands, all six species of clams present are widely eaten except in Seventh Day Adventist communities. In the outlying islands, such as Sikaiana, Ongtong Java and the Shortland Islands, where it is particularly popular, excess harvest, especially of *T. crocea* and *T. maxima*, is traditionally dried. Traditionally, shells have been used for currency (Anon, 1996); they are now used for jewellery, traditional artefacts and utensils (Govan *et al.*, 1988; Munro, 1989; Skewes, 1990; Hambrey, 1991). A more detailed review of traditional usage of clams in the Solomon Islands is given in Hviding (1993). In Wallis and Futuna, giant clams are not considered a special food but are eaten raw or marinated when available and shells are sometimes used to decorate gardens. There is some subsistence use on the Great Barrier Reef in Australia (Munro, 1989). Pacific island immigrants in New Zealand and Australia also eat clam meat if the opportunity arises (Tisdell *et al.*, 1990; Tisdell and Wittenberg, 1990).

In Indonesia, clam meat (usually dried or salted) has been eaten extensively on the coast (Panggabean, 1987), although this has apparently declined in some areas since a ban on harvesting and the development of seaweed farming as an alternative activity (Firdausy and Tisdell, 1992). The shells are used for a variety of purposes including ornaments and basins (Pasaribu, 1988; Tisdell, 1992). In the Philippines, clam meat is used locally as a supplementary food but is not taken as a major subsistence fishery commodity (Juinio *et al.*, 1987).

Singapore, Thailand and Malaysia are among the few countries in Southeast Asia where clam meat is not eaten in large quantities (Munro, 1989), although it is known to be eaten in Sipadan (Malaysia) (Wood *in litt.* to S. Wells, 1994). It is not eaten in Sri Lanka, although the shells are sold to tourists.

3.2. Domestic markets

3.2.1. Meat

Domestic markets for clam meat are poorly documented and difficult to separate from subsistence use. Clam meat seems to be sold if it is not required for immediate consumption or if there is a specific requirement for cash within the household. Domestic markets are thought to be fairly small in most Pacific countries but information is very sparse. There is a more significant local market in Japan; figures are also available for Fiji.

In Japan, giant clams are fished in the south around Okinawa to supply the local food market in these islands: the only region in the country where clams are easily available and traditionally eaten (this is the part of Japan where coral reefs are found). However, they are also taken more rarely in the Ogasawara Islands (Tokyo Prefecture) for shellcraft, and in the Amami Islands (Kagoshima Prefecture). The industry has been documented by Shang *et al.* (1990, 1992). The most important species is *T. crocea*, followed by *T. squamosa* and *H. hippopus*, although Ishihara (*in litt.* to S. Wells, 1994) reported that *T. maxima* is also taken. Clams are prepared raw as sushi and sashimi, and so are preferred live or fresh (frozen clam meat has a less desirable colour and flavour), although they may also be pickled (Cowan, 1991). The total catch reached a peak of 578 tonnes in 1975, declining to 91 tonnes in 1987 due mainly to overfishing. Ishihara (*in litt.* to S. Wells, 1994) reported that official fishery statistics record annual harvests of only 42-78 tonnes between 1988 and 1992. Prices have consequently risen. In the late 1980s, auction prices for meat ranged from US$2.86 to US$10.71 per kg in-shell, depending on: the size of the clam, as smaller clams were more expensive; the season, as prices were higher in winter and the typhoon season when supplies are low; and the species, as *T. crocea* was more expensive (US$57-71/kg for mantle and muscle (without shell) for sashimi and sushi) than *T. squamosa* (US$21-29/kg) and *H. hippopus* (US$18-21) (Shang *et al.*, 1990).

In Fiji, clam meat is sold in municipal markets and more recently direct to restaurants, supermarkets and other outlets. *T. maxima* is most popular, but small *T. squamosa* and *T. derasa* are also sold (Lewis *et al.*, 1988). Clam meat is expensive (F$2-3/kg) relative to other seafood. Data on local sales are available in the Fiji Fisheries Division annual reports, but are imprecise in that they include a combination of figures for both meat and shell, and meat alone. Data have been analysed by Tacconi and Tisdell (1992a) and by Lewis *et al.* (1988). Quantities fluctuate considerably, but from 1978-1990 between 4 and 14 tonnes of clam meat (cooked or dried) were sold annually through local markets and a further 4-33 tonnes through wholesale and retail outlets (Table 1). In 1987 and 1988 quantities were fairly high, due to an increase in the export of clam muscle (see section 3.3.1.) and the consequent sale of mantle in the local market. Table 1 gives production figures according to the Fisheries Division. Additional details on local markets are provided in Ram (1994).

Table 1. Domestic market and exports of giant clams in Fiji (tonnes)

Data until 1987 from Lewis *et al.* (1988); figures represent mainly weight of mantle and muscle, although in some cases (not specified) shell weight may be included. Data 1988-1990 from Tisdell (1992), extrapolated from Figure 13.1.

	Domestic market	Exports
1979	6.79	0
1980	14.06	0
1981	18.06	0
1982	11.96	0
1983	17.32	0
1984	42.20	7.3
1985	16.50	20.8
1986	19.06	11.42
1987	21.66	10.69
1988	*c*.22.00	38.49
1989	*c*.14.00	?
1990	*c*.11.00	?

Local markets exist in a number of other Pacific countries, but there is little information beyond some data on prices which seem to be variable. In American Samoa, giant clam meat retails at about US$8/kg (Killelea-Almonte, 1992). In the Solomon Islands, clam meat (amounting to about 1 tonne a year) is occasionally sold in local markets for about US$1-2/kg, and there is some demand from restaurants and hotels in Honiara (Hambrey, 1991). There are local markets in the Marshall Islands (*T. maxima, T. squamosa, H. hippopus*) (Smith, 1992b), Niue (Dalzell *et al.*, 1993), and FSM where, in 1990, 3.66 tonnes were sold in the main markets of Chuuk, at a total value of US$8900 (about US$2.2/kg) (Smith, 1992a). In Vanuatu, the main source of clam meat for the public market is north Efate (Bell and Amos, 1993). Clam meat is popular in Tonga. At the time of the study by Tacconi and Tisdell (1992a), data collected over a 10-week period suggested that annual landings for the domestic market might be 639-1,346kg, but it was thought that this might be an underestimate. Bell *et al.* (1994) estimate a total annual harvest of 52.8 tonnes in Tongatapu. There is a local market in Western Samoa but this is sporadic due to supply; clams of 40cm shell length sell for 20-25 WS$ in the Apia fish market (Tacconi and Tisdell, 1992a; Wright *in litt.* to S. Wells, 1994).

In Indonesia, clam meat retailed for about US$1.5/kg (Panggabean, 1987). In Jepara, it is now normally sold dried; the lack of fresh meat may be due to local over-exploitation of stocks, so that meat has to come from more distant fishing grounds, possibly as a by-product of the shell trade for the tile industry (see section 3.2.2) (Firdausy and Tisdell, 1992). In Myanmar, clam meat is marketed fresh for local consumption (Munro, 1989).

3.2.2. Shells

There are small local markets for shells in the Pacific and Indian Ocean islands and other countries where tourism ensures a steady souvenir trade, but this is poorly documented. The shells that are sold are probably often by-products of harvesting for meat. The CAC in the Solomon Islands sells shells and shell products locally, including bowls and jewellery, using shells of all sizes. The MMDC in Palau was selling 15cm diameter *T. derasa* shells for US$5, and 20cm diameter shells for US$8; *H. hippopus* sold for US$5 for a 5cm shell and US$8 for a 15cm shell.

In Indonesia there is a substantial market for clam shells which are crushed and made into `teraso' tiles, a popular form of interior decoration. Fossil shells are often used, but it seems that live clams are also being taken for this purpose. The industry led to a marked decline in clam populations and supply, and an associated price rise in the 1980s. The Jakarta trade declined from 7,920 tonnes in 1982 to 3,677 tonnes in 1984 and only 260 tonnes in 1985. However, there are reports that it is increasing and that as much as 10-20 tonnes of crushed shell are being used every two weeks for making tiles in Jakarta alone, which could amount to 500 tonnes a year. Exploitation has been heavy in the region of Jepara on the north coast of Java, and collectors now have to go further afield, particularly to Karimunjawa, a group of islands 100 km off the coast, or even to Bangka and Belitung in southern Sumatra. Collectors form groups of 5-10 people who are financed and employed by professional middlemen in Jepara and the latter sell the shells on to the tile manufacturers in Jakarta. Shells have also been collected for this purpose elsewhere in Java and in Bali, but collecting appears to have declined in these areas (Brown and Muskanofola, 1985; Pasaribu, 1988; Firdausy and Tisdell, 1992).

3.2.3. Aquarium specimens

With the growth of the aquarium industry, and in particular the popularity of 'mini-reefs', there is now a commercial demand for live clams (Carlson, 1991). They can be costly to maintain in tanks as extra lighting is often required, but clams also play a beneficial role by removing nitrates, nitrites and ammonia from the water. Much of the supply appears to be met through international trade, but there are small domestic markets in Australia and Japan. In Australia, clams are as popular as corals and anemones for providing tank decoration. *T. crocea* and the other small species are preferred; specimens 2.5-5cm in length sell for A$10-13, and those 5-10cm in length sell for A$19 (Tisdell, 1991b). The main source of supply is the mariculture operation Reefarm. There is a small domestic market in Japan where about 600 clams/year of locally-caught clams are sold by a wholesaler in Okinawa to aquarium shops (Shang *et al.*, 1990).

3.3. International Trade

In the late 1980s and early 1990s, the international trade in wild giant clam products was dominated by meat destined for Taiwan, fished mainly by Taiwanese vessels in foreign waters (often illegally). A smaller amount went to Japan. There was also significant trade in shells and live specimens destined for the curio and aquarium trades in the USA, Europe and Japan. The following sections have made use of a number of sources of information for the trade data, as referenced. It should be noted that where the 'Significant Trade Review' (IUCN/TRAFFIC/WCMC, 1996) has been used, 'net' trade figures are given. Net imports therefore mean that exports and re-exports have been subtracted from the imports for any country; net exports mean that imports have been subtracted for each country.

3.3.1. International trade in giant clam meat

Historically, the main commercial demand has been for frozen adductor muscle, the vast majority of which was destined for luxury restaurants in Taiwan. Long-range Taiwanese fishing vessels, operating mainly out of Kaohsiung, were responsible for most of the catch. Exploitation, much of it apparently illegal, has taken place for several decades, reaching a peak in the 1970s when over 20 boats were involved. By 1986, boat numbers had dropped to 13 mainly because the large, preferred species of clams had become rare but also because of strong international pressure and improved surveillance (see below) (Dawson and Philipson, 1989). Large muscles from *T. gigas* (of about 1kg each) and *T. derasa* are preferred. The muscle is removed *in situ* (the mantle and shell are usually left behind) and frozen on board, and then landed at Kaohsiung or nearby ports (Dawson, 1986).

The size of the international market in giant clam is not known as only a very small proportion of the meat trade is reported in CITES Annual Reports (since most of the countries involved are not Parties) and generic terms for mollusc meat are used in statistics in Asia, which include adductor muscles from clams, scallops and other shellfish. Dawson (1986) estimated that about 50-100 tonnes of giant clam meat were consumed in the 1980s. Shang *et al.* (1990) suggested that there was a potential demand of about 240 tonnes a year for fresh and frozen giant clam muscle, and considered that supply did not meet demand; subsequently Shang *et al.* (1992) suggested that there was an annual demand of 300 tonnes. Tisdell and Chen (1994) believe that the market for frozen muscle has declined more recently and that the main imports into Taiwan are of canned and dried clam meat.

Trials carried out to create clam products such as smoked mantle (Sanders, 1987; Trachet, 1989; Parry, 1990; Cowan, 1991) suggested that it would be difficult for giant clam products to compete in the seafood market, despite the annual estimated demand of 300 tonnes of adductor muscle in Taiwan. The main source of dried bivalve adductor muscle in Asia is the scallop *Patinopecten yessoensis*, and giant clams are considered inferior and more expensive, but are appreciated for their size. In the late 1980s, prices were US$17-25 per kg for chilled or frozen muscle (Shang *et al.*, 1990).

Nevertheless, it seems that markets are developing for clam meat. There is interest in Hong Kong (Shang *et al.*, 1990), where Fiji exported meat in the past. CAC sent trial shipments of captive-bred clams to Singapore and Taiwan for the sashimi market in 1993 (Munro *in litt.* to S. Wells, 1994), and 3,615kg of *T. gigas* meat were exported to Singapore from the Solomon Islands in 1992 (Table 3). The MMDC in Palau provided clam meat for the sashimi market in Japan, where small (15-20cm) clams are preferred. *T. crocea* is the preferred species in Japan, but Shang *et al.* (1992) found that *T. derasa* is acceptable if the former is not available. MMDC sold 5,000 of its surplus broodstock to Okinawa for the meat trade in the early 1990s, and in 1991 was exporting 100kg/week of *T. derasa* meat for sashimi (Heslinga, 1993). The US CITES Annual Report for 1991 showed exports of 1,195kg of *T. derasa* meat from captive-bred animals (presumably from MMDC) from Palau to Japan. Shang *et al.* (1992) found some market potential for meat in Honolulu, Guam and Saipan, and there is also a potential market among Pacific island immigrant communities in New Zealand and the USA (Tisdell, 1992), and for the restaurant market in Germany (Knop, 1995c).

Principle fisheries.

Taiwan. Information is largely anecdotal concerning the areas where the Taiwanese fleet operates and the quantities taken, and it is often unclear whether meat recorded in statistics has been taken by the Taiwanese fleet, or by fishing vessels belonging to the country of origin. According to Shang *et al.* (1990), imports into Taiwan totalled about 31 tonnes of frozen meat in 1987, and 40 tonnes in 1988, from countries including Indonesia, PNG and Fiji. In Indonesia, local clam gatherers are known to be involved; for example, in 1989 clam meat was reportedly being taken illegally by Indonesians from reefs in Irian Jaya for export to Taiwan. Up to 1,000 clams were taken in three months at one site (Nash, *in litt.* to S. Wells, 1989). In PNG the fishery was closed after 84 tonnes of adductor muscle (equivalent to 738 tonnes total flesh weight) were harvested (Munro, 1993b). There was some commercial fishing by Taiwanese boats in the Solomon Islands in the 1970s and early 1980s, but the last licence (for a harvest of 1,318 clams) was issued in 1983 because of concern about the depletion of stocks (Skewes, 1990). In 1995, 1,100kg of meat bound for Taiwan, from *T. gigas* caught by local fishermen and representing 1,000-2,000 large specimens was confiscated by the Solomon Islands authorities (Anon, 1995). Taiwanese boats have also operated in Fijian waters (Lewis *et al.*, 1988) and in Philippine waters around Tawi-Tawi and the Polillo Islands (Salamanca *in litt.* to S. Wells, 1993). Lucas (1994) estimates that c. 2 million *T. gigas* and *T. derasa* were poached by foreign vessels between 1969 and 1976 in Australian waters.

Fiji. In Fiji, a locally-operated fishery was very active in the 1980s, prior to the imposition of a 10-year moratorium on harvesting (Ram, 1994). Operators catered for both the local market (see above) and the export market, and gathered clams on reefs with permission of the local owners. *T. derasa* was the only species taken, and annual exports varied considerably (Table 1). Lewis *et al.* (1988) and Tacconi and Tisdell (1992b) give similar but slightly different figures (although apparently both sets came from the Fisheries Division), but the highest annual exports were 20-30 tonnes. Export destinations included Taiwan, New Zealand (mantle only), Hong Kong, and other South-east Asian countries (not specified) via Australia. Sant (1996) reports that quantities of clam meat (totalling 17 tonnes in a nine-month period in 1994) are still being exported from Fiji as exemptions from the export ban, giving rise to concern as to the efficacy of the ban.

Philippines. The Philippines also has an active fishery, supplying meat to Japan (no other places), presumably because of the decline in Japanese supplies (see 3.2.1). Table 2 shows Philippine exports of clam meat to Japan. CITES statistics indicate exports of 29 tonnes in 1992, but the Philippines Bureau of Fisheries and Aquatic Resources (BFAR) reported just over 39 tonnes in 1992, and over 66 tonnes in 1993, from Palawan waters and representing 6.61 million clams (Philippines CITES Management Authority *in litt.* to CITES Secretariat, 1995). Virtually all of the meat for this trade is *T. crocea.* In the 1980s, much of it was harvested in the Polillo Islands (Juinio *et al.*, 1987).

Table 2. **Clam meat exports from Philippines to Japan (tonnes). Source: CITES Annual Reports; Wood and Wells (1988)**

	T. crocea	*T. squamosa*
1984	1.0	
1986*	12.0	5
1987	11.9	
1988	1.5	
1989	6.1	
1990	**	
1991+	41.2	
1992	29.0	

* 2,068 boxes and 420 pieces also exported
\+ 1,000 pieces also exported
** no report

Maldives. In the Maldives (where there is no traditional use of clams), a commercial fishery existed for one year in 1990, based on the export of adductor muscles of *T. squamosa* and very occasionally *T. maxima* to Taiwan. The shells were accumulated in the hope of finding a buyer (40-50 thousand were stock-piled). A survey found that *T. squamosa* populations had been substantially reduced and in many cases eliminated on fished reefs (Barker, 1991; Barker and Shakeel, 1991; Shakeel, 1994).

Pacific. Small, and mainly insignificant, amounts of meat are traded between some of the Pacific countries (Table 3) (see IUCN/TRAFFIC/WCMC, 1996). The 1991 CITES report for New Zealand recorded illegal consignments (9 cans, 22 bags, 6 cartons, and 1 box) of giant clam meat from Tonga, Hong Kong, Cook Islands, Australia, Fiji, Nauru, Tokelau, and Western Samoa. These are thought to have been destined for Pacific islanders living in New Zealand (Tisdell and Wittenberg, 1990). Although exports of wild caught clams from Palau are illegal, wild-caught meat has been exported from this territory to Taiwan and Guam according to Nichols (1991).

Table 3. Other exporters of clam meat (all species). Source: CITES Annual Reports

	1988	1989	1990	1991	1992
Australia			30 kg	6 cans	25 kg
Cook Islands			4 bags	1 bag 3 pcs	
Fiji			2 cans	1 box	
FSM				5 kg	
Hong Kong				5 pcs 2 bags	
Kiribati	45kg			685 kg	
Nauru				1 bag	
Palau			500 kg	1,320 kg 100 pcs	
Solomons					3,615 kg
Tokelau				1 bag	
Tonga			2 bags 11 kg	5 bags 10 pcs	3,915kg
Western Samoa				1 pcs 1 bag	

3.3.2. International trade in giant clam shells

Giant clam shells are used for a variety of decorative and practical purposes. *H. hippopus* and *T. squamosa* are particularly in demand as their size makes them suitable for bowls, ash trays and soap dishes, and *T. squamosa* is attractively coloured and has a fluted appearance. *H. porcellanus* is also popular because of its translucent quality (Munro, 1989). *T. gigas* has comprised a very small proportion of the trade in recent years. Table 4 shows exports by species from the Philippines in 1991 and 1992. *T. derasa* does not feature in statistics for shell exports and imports at all (possibly due to confusion with *T. gigas*, although this is not likely as *T. derasa* has a very heavy and rather unattractive shell). In the mid-1980s, large clams (60cm) were selling in the Philippines for US$150/pair and small clams for US$0.6/kg (Munro, 1986). In the early 1990s, a single valve of a medium-size shell was selling for US$40 retail price (Mingoa-Licuan *in litt.* to S. Wells, 1994).

Almost none of the shells and carvings recorded in CITES trade are reported as being from captive-bred stock, suggesting that they were wild-collected. Initially, it appeared that mariculture had little potential for supplying the shell market. Captive-bred shells were thought to be too large for bowls and too small for interior design purposes. In reality, shells of all sizes are produced because of natural mortality throughout the process, and they have provided an important source of income for some operations. MMDC cultured

Hippopus hippopus for the shell market alone, reportedly producing about 25,000 clams a year for the trade (Gervis, 1993).

Principal exporters

Philippines. This country has been the main exporter of giant clam shells, probably accounting for 90% of the trade. Exports have fluctuated over the last 15 years. BFAR recorded exports of 895,000 pairs of shells from Zamboanga in 1979. Exports subsequently declined and from 1982 to 1985 averaged about 90,000 pairs (Juinio *et al.*, 1987). In the early 1980s, much of the harvesting for shells was carried out in waters around the Sulu Archipelago and southern Palawan. Net exports of clams from the Philippines (Table 4) increased to a peak of nearly 1.2 million shells, over 460,000 carvings and over 1,186 tonnes of shells in 1991 (equivalent to over 825,000 pairs of shells, and thus similar to figures for 1979). There have been some suggestions that these large volumes may be partially accounted for by shells harvested outside Philippine waters, for example in Indonesia and Malaysia (see below). Exports in 1992, however, dropped significantly to just over 374,000 shells and nearly 70,000 carvings (equivalent to over 221,706 pairs of shells). This decrease was probably related to the clamp-down in illegal exports following the issuance of CITES Notification No. 663 (16 January 1992) to the Parties which stated that export permits from the Philippines should not be accepted for clams except for *T. crocea*, in accordance with Philippine legislation. More recently, in 1996, export of all tridacnids from the Philippines was banned (see Annex 3).

Table 4. Net exports of giant clam shells (all species) from the Philippines, 1985-1992. Source: IUCN/TRAFFIC/WCMC (1996)

	shells (no.)	shells (kg)	carvings (no.)
1985	68,882	21,039	196
1986	685,103	71,769	76,616
1987	672,979	225,260	471,519
1988	671,507	117,138	301,174
1989	504,599	126,951	320,725
1990	1,129,471	255,691	428,495
1991	1,190,207	1,186,353	460,118
1992	374,048	39,713	69,364

NB: In several years, exports of `skins' of giant clams are recorded. The only significantly large quantities were in 1989 (222,557 skins) and 1990 (228,742 skins). In several years, there were small additional quantities of carvings recorded as kg or sets.

Until 1992, exports from the Philippines were dominated by *H. hippopus*, *T. squamosa*, and *H. porcellanus*. In 1991, *H. hippopus* comprised 53% of shell exports and 94% of carvings (Table 5). In 1992, the species composition of Philippine shell exports changed, and *T. crocea*, the only species for which export permits could be issued, dominated, making up nearly 55% of exports. However, this species has a small and not particularly attractive shell, and it is possible that other species are being exported wrongly labelled, particularly since illegal exports of banned species were in any case continuing (see below).

Table 5. Exports of giant clams from the Philippines (1991 and 1992) by species. Source: CITES Annual Reports from the Philippines

	shells (no.) 1991	shells (kg) 1991	carv. (no.) 1991	shell (no.) 1992	carv. (no.) 1992
H.hippopus	537,617	47,658	267,444	12,068	652
T. squamosa	304,696	13,671	37,942	3,460	0
H. porcellanus	131,676	13,484	16,237	33,408	0
T. crocea	17,415	0	3,497	59,099	1,820
T. gigas	6,559	15,231	144	113	0
T. maxima	5,969	181	140	0	0

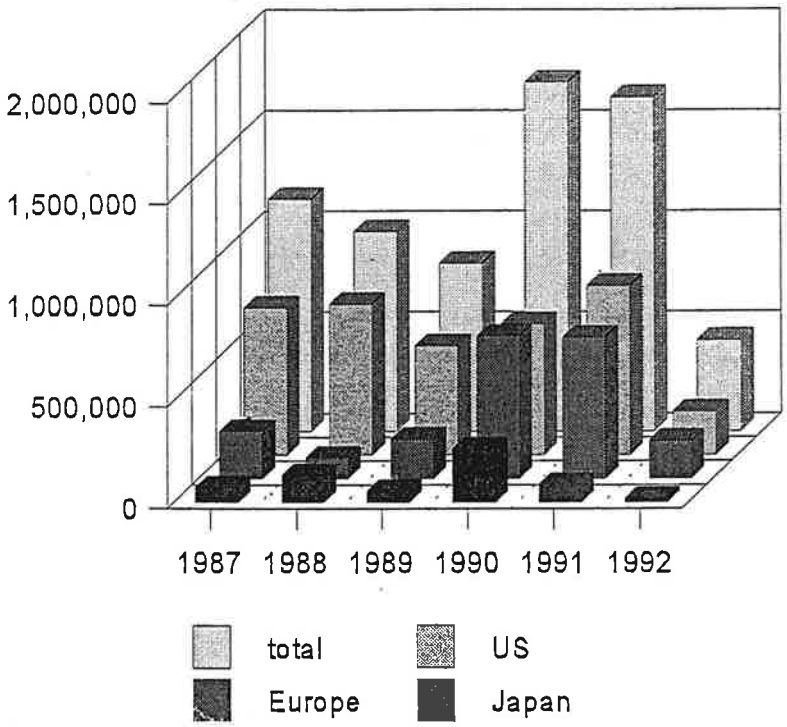
Indonesia. This country used to export giant clam shells (e.g. 4,380 shells, 19 carvings and 100kg of shells in 1986, Wood and Wells, 1988), but since the 1987 export ban (see Annex 3), almost no exports have been recorded in CITES reports. However, Tisdell (1992) suggested that clam shells were exported from Indonesia into the Philippines in 'considerable quantities'. If collectors are visiting Kalimantan as well as Sabah on Borneo, Indonesia could be a continuing source. Further information is required on the exploitation of shells in Indonesian waters and, if shells continue to be exported from the Philippines, the sources should be investigated (in addition to further efforts to enforce existing legislation - see below).

Malaysia. Philippine shell collectors based in the Tawi-Tawi islands in the Sulu Archipelago have reported that they go as far as Sabah in Malaysian waters and have mentioned stockpiles of shells on remote islands near Borneo (Salamanca *in litt.* to S. Wells, 1993). Wood (*in litt.* to S. Wells, 1994) reported seeing large piles of tridacnid shells, probably of *T. gigas*, in Semporna on the east coast of Sabah.

Importers

USA. This country is the main importer of giant clam shells (Fig. 1).

Figure 1. Global Net Imports of Giant Clam Shells and Carvings (numbers)



Shells are used both for home and aquarium decoration and demand was said to exceed supply in the 1980s (Shang *et al.*, 1990). CITES Annual Report data record the net import into the USA of some 2.5 million shells, 1.2 million carvings and an additional 279 tonnes of carvings and shells from 1987-92 (Table 6).

Table 6 **US net imports of shells and carvings, 1987-1992. Source: IUCN/TRAFFIC/WCMC (1996)**

	shells	carvings	kg shells/carvings
1987	360,258	364,618	82,182
1988	498,884	244,795	78,273
1989	306,309	230,660	32,185
1990	474,747	169,068	56,673
1991	664,898	167,048	26,754
1992	152,163	61,370	3,103
Total	2,457,259	1,237,559	279,170

US imports accounted for 52% of all shells, 60% of all carvings and 29% by weight of all shells and carvings reported by CITES Parties over this period (IUCN/TRAFFIC/WCMC, 1996). The Philippine CITES Annual Report for 1991 indicates that permits were issued for exports of 500,000 shells, 47,000 carvings and 13 tonnes of shell to the US - nearly ten times more shells than to any other country. 57% of permits issued for exports from the Philippines in 1991 were for the US (Table 7). The US annual CITES report for 1991 gives a different breakdown (just over 275,000 shells, 167,000 carvings, 1.3 tonnes carvings and 22 tonnes of shells) for imports from the Philippines, but a similar overall amount. Some of these discrepancies can be accounted for by CITES permits that were issued but not filled. The only other sources of supply were 10 shells from Taiwan and 25 from Fiji. Annual net imports of giant clams for the US between 1987 and 1992 (Table 6) show a similar pattern to that for exports from the Philippines (Table 5), with a marked reduction of imports in 1992.

Table 7. **Exports of giant clams from the Philippines (1991) by country of destination (30,000 shells or more only).**
Source: CITES Annual Reports from the Philippines

	shells (no.)	shells (kg)	carvings (no.)	carvings (kg)
USA	575,012	13,547	47,269	1,138
UK	85,320	10,655	107,321	2,979
Germany	55,916	8,638	37,688	0
Greece	55,168	0	1,142	0
Spain	50,812	20,644	12,971	0
France	43,100	3,304	34,101	1,325
Netherlands	41,299	2,448	27,800	0
Japan	31,950	3,746	50,244	0
Belgium	30,176	16,537	1,495	719
other	35,179	10,706	5,373	0
Total	1,003,932	90,225	325,404	6,161

Japan. Appears in the CITES Annual Report data as the country importing the second largest quantity of giant clam shells and carvings, imports having reached a peak in 1991. Over 30,000 shells and 50,000 carvings in 1991 were exported to Japan from the Philippines (Table 7). Shells are used as serving dishes in sushi bars, for vases in flower shops, as decoration, ash trays (popular in hotels and restaurants) and as gifts. A 90cm shell sells for $187.50, a 20cm one for $12.0 (Shang *et al.*, 1990). There is also reported to be a market for clam shells in Japan to make tokens for the game 'go'.

Europe. The UK, Germany, Greece, Spain, France, the Netherlands, and Belgium are all significant importers of giant clams (IUCN/TRAFFIC/WCMC, 1996), and since 1990 annual imports into the European Union have been similar to those into the US (Fig. 1). Over the period 1987-1992, these seven countries between them accounted for a net import of 1,596,906 shells, 519,814 carvings and 472,154kg of shells and carvings, or 34%, 25%, and 49% respectively of world net imports. Annual figures show high imports in 1990 and 1991 and a decrease in 1992 (Table 8). The UK Department of the Environment received applications for the import of over 80,000 shells in 1991 but according to their statistics, these were not all used (Morgan *in litt.* to S. Wells, 1994). In the early 1990s, German imports of shells and carvings were averaging 43,805 a year, mainly from the Philippines (Bauer *in litt.* to S. Wells, 1994).

Table 8. **Net imports into Europe of giant clam shells and carvings (main importers only: Spain, UK, Netherlands, Germany, France, Italy, Greece, Belgium).**
Source: IUCN/TRAFFIC/WCMC (1996)

	shells (no.)	carvings (no.)	shells/carvings kg
1987	154,321	80,448	97,003
1988	91,484	11,883	38,865
1989	141,004	55,360	35,843
1990	569,353	130,428	131,405
1991	456,440	238,153	147,706
1992	184,304	5,542	31,514
Total	1,596,906	519,814	472,154

Australia. CITES Annual Reports for Australia only record small quantities of clam shell imports (a total of eight shells imported from 1987-92 for scientific and personal use). In contrast, the Philippine CITES Annual Reports show that large numbers of export permits were issued for this country up until 1991 (Table 9). Of the 23,951 permits issued in 1990, nearly 95% (as well as the 5.4 tonnes of shell) were for *H. hippopus*, with the remainder made up by *H. porcellanus*, *T. crocea* and *T. squamosa*. In 1991, the Philippines issued permits for only 4,996 shells and 6.5 tonnes of clam shells (mainly *T. squamosa* and *H. hippopus*) to Australia. Under Australian legislation (Annex 3), these imports were illegal.

Table 9. Philippine exports of giant clams to Australia, 1985-1991. Source: CITES Annual Reports from the Philippines

	shells (no.)	shell (kg)	carvings (no.)	carvings (kg)	sets
1985	0	0	6	0	0
1986	4,680	3,606	8	0	90
1987	40,162	310	0	0	0
1988	0	0	0	0	0
1989	5,105	3,030	1,459	897	0
1990	23,951	5,444	1,660	1,030	0
1991	4,996	6,559	0	0	0
1992	17	0	0	0	0

Several studies of the market for clam shells in Australia have been carried out (Tisdell and Wittenberg, 1989; Shang *et al.*, 1990; Tisdell *et al.*, 1990). A survey of wholesalers and retailers in southern Queensland in the late 1980s suggested a potential market of 100,000-200,000 clam shells a year, with 60-70% of the sales going to domestic tourists. Greatest demand is for small shells (15-20cm), with large shells being sold for gardens and interior design. A shortage of large shells in the early 1990s led to a price increase to A$62 for 90-120cm shells, with small shells retailing at about A$3 each. However, these studies do not report on the source of shells that were on sale.

3.3.3. International trade in live giant clams

It is not always clear from the statistics available for international trade in live clams whether specimens are destined for the aquarium trade or for mariculture operations, but it would appear that the aquarium trade is now the main market for both wild-collected and mariculture clams. The vast majority of cultured giant clams are sold to the aquarium trade in the USA and Europe, and smaller quantities are sold as biological specimens for scientific demonstration and research, or are exported as seedstock for mariculture operations. The USA is probably the main importer of clams (including farmed specimens) for the aquarium trade, as it is of marine fish and corals for the same purpose. CITES data indicate a total of 1,245,960 live tridacnids imported by the USA over the period 1987-1992, of which most were *H. hippopus* (761,002) and *H. porcellanus* (421,115) (IUCN/TRAFFIC/WCMC, 1996), which are in fact not the preferred aquarium species. *T. maxima* is preferred by aquarists as it is small and brightly coloured.

Shang *et al.* (1990) estimated a potential market of 5,000-50,000 aquarium specimens of giant clams a year in this country, and revised this to 33,400 clams a year in their 1992 report (Shang *et al.*, 1992). Gervis (1993) considered the market could be higher, with some 300,000-400,000 aquarists in the USA alone. The growing popularity of giant clams among aquarists is indicated by a recent publication on giant clams specifically as aquarist readership (Knop, 1995c). Gervis *et al.* (1995), however, suggest that the US market for aquarium species may be becoming saturated.

Wild-caught clams

The Philippines has been a major supplier of live specimens, but quantities fluctuate greatly (Table 10). CITES Reports show that 58,640 were exported from the Philippines between 1987 and 1992. In 1988, over 52,000 live specimens were exported of which 99% went to the UK (but were recorded only in the UK Annual Report, not that for the Philippines). In 1991, most of the 5,000+ specimens exported went to Germany, while in 1993, Germany imported 8,630 live specimens (Bauer *in. litt.* to S. Wells, 1994). One aquarium shop in Japan reportedly imports clams from the Philippines, and potentially could sell about 20-30 clams/month (Shang *et al.*, 1990). Munro (*in litt.* to S. Wells, 1994) reported that there was an active fishery in Palawan for live *T. crocea* for the aquarium trade, which caused reef damage, as coral heads were smashed to extract the clams; *T. crocea* is particularly popular for its iridescent blue colouring.

Table 10. Net exports of live specimens of captive-bred and wild-caught giant clams, by country of origin (net trade figures). Source: CITES Annual Reports

	1988	1989	1990	1991	1992
Philippines	52,275	685	0	5,042	206
Australia	10	0	19,700	19,211	1,157
Palau	0	0	31,907	6,034	0
Marshall Is	0	0	341	4,003	0
Indonesia	54	0	32	26	1
Sri Lanka	46	39	0	4	0
`Trust Territory'	0	0	48	0	60
Thailand	25	0	0	0	0
Tonga	0	0	0	3	0

Other exporters of wild-caught live clams have included Palau (illegal), the Marshall Islands, Tonga, Indonesia (illegal) and Sri Lanka. According to CITES statistics, these tend to be in small quantities (less than 100 a year), although the Marshall Islands exported over 3,000 in 1991. Aquarium specimens were being exported from Tonga (until banned by a Cabinet Decision on 22.12.93), in quantities thought to be significantly higher than those reported in Annual Reports (Table 10); about 2,000 specimens were exported in 1993 (Bell *et al.*, 1994). Exports from Indonesia are also thought to be much higher than recorded in Annual Reports; a major Indonesian marine resources company was reported to be exporting over 100,000 live *T. crocea* to the international market (Lucas, *in litt.* to S. Wells, 1994).

Farmed clams

Several shipments of live clams of five species were exported from the MMDC in Palau to the USA specifically for the aquarium trade (Shang *et al.*, 1990; Heslinga, 1993). CITES Annual Reports indicate that in 1990, the MMDC exported 6,000 live clams to the Philippines, 23,290

to Japan, over 2,000 to the USA, and 239 to Canada. In 1991, mariculture operations in Palau, Australia and the Marshall Islands exported over 25,000 live captive-bred specimens of several species to North America and Europe. The CAC in the Solomon Islands exported large numbers of *T. gigas* in 1993 to the USA, a retailer having ordered 26,000 specimens a year (Munro, pers comm. to S. Wells, 1994). Around 4,924 clams of different species were exported for the live trade in 1993 from CAC, and 2,155 in the early part of 1994 and village-based trials are also aimed at producing aquarium specimens. It had been hoped that 25,000 could be exported a year, but this has been hindered by alterations to flight schedules and packaging problems.

Between 1987 and 1992, a total of 203,078 captive-bred live clams were exported from Australia, mainly *H. hippopus* and *T. squamosa*, of which 58% were for commercial purposes and 42% for scientific purposes. Reefarm (PTY) Ltd. in Cairns, Australia is supplying the German market and other overseas markets (Bauer *in litt.* to S. Wells, 1994; Tisdell *et al.*, 1994); Praslin Ocean Farm (PTY) Ltd. in the Seychelles is supplying *T. maxima* to the trade in Europe, and plans to start exporting *T. crocea*.

The aquarium trade is one of the best outlets for farmed clams, with prices ranging from $1.00 for a 6cm *T. derasa* to $18 for a 16cm *T. crocea* (Shang *et al.*, 1990); Shang *et al.* (1992) give a retail price of US$10 for a 5-10cm specimen. One problem was that the mariculture industry could not produce the high proportions of clams with highly coloured mantles found in the wild, which lowered the value of cultured specimens, but it now seems that colour can be manipulated through selective breeding (see section 4.2).

3.4. Total numbers of clams involved in trade

Using data from Heslinga *et al.* (1984) which estimated meat yields (adductor muscle and mantle) from *T. derasa, H. hippopus*, and *T. gigas*, Dawson (1986) calculated that the 50-100 tonnes of clam meat consumed a year in the 1980s, represented 300,000-450,000 clams. Munro (1993b) used data on size distributions of unexploited stocks on the Great Barrier Reef (Pearson and Munro, 1991) and, assuming that most of the harvest for Taiwan consisted of *T. derasa* and *T. gigas*, estimated that 100 tonnes represented about 100,000 clams. If 295 tonnes were being consumed annually at the beginning of the 1990s, the Taiwanese meat trade could have represented 300,000-900,000 clams taken annually. Juinio *et al.* (1987) suggested that 50-60 *T. crocea* provide about 1kg of meat and that the 1991 exports of 41 tonnes from the Philippines to Japan represented some 250,000 clams; however, IUCN/TRAFFIC/WCMC (1996) cites a Philippines CITES Authority figure of 100 *T. crocea* yielding 1kg frozen meat.

Global net imports of giant clam shells over the period 1987-1992 amounted to 4.7 million shells, 2.1 million carvings and 955 tonnes of shells and carvings. If each carving is a single clam valve (carvings are thought to be the shells that are filed and polished for sale as bowls etc.), this trade represented a take of 3.4 million clams over this six-year period. However, annual quantities taken have fluctuated and there is some evidence of a downward trend following a peak in 1991 when the shell trade represented a minimum of some 800,000 clams (Table 11), and possibly as many as a million if the quantities recorded by weight are taken into consideration. The numbers of aquarium specimens in trade each year are highly variable, but wild caught specimens for this purpose were relatively low in the early 1990s: for example, about 5,000 specimens from the Philippines in 1991.

Table 11. Total net imports of giant clam shells and carvings (1987-1992) and extrapolation to number of clams. Source:IUCN/TRAFFIC/WCMC (1996)

	shells (no.)	carvings (no.)	est. no. clams*	kg shells/carv.
1987	673,339	471,881	572,610	225,260
1988	672,847	310,765	491,806	117,138
1989	505,147	320,735	412,941	126,951
1990	1,296,842	428,510	862,676	256,075
1991	1,191,801	460,141	825,971	190,256
1992	376,085	69,368	222,726	39,713

* = 'shells' + 'carvings', divided by 2

Using estimates for the amount of meat per clam, the estimated subsistence catch of 197 tonnes of meat a year would represent about 200,000-600,000 clams, considerably fewer than the numbers taken for international trade. As mentioned earlier, the size of domestic markets is virtually unknown.

4. MARICULTURE

As with other valuable marine food species, mariculture is a potential long-term solution to the continued supply of clams. Although a relatively recent development compared with mariculture of other marine molluscs, clam mariculture is of particular interest for several reasons. Since the late 1980s, it has been technically feasible to spawn mature giant clams and raise larvae and juveniles to maturity (Heslinga and Fitt, 1987). Giant clams are autotrophic (requiring no artificial feeding); breeding and rearing techniques are relatively simple; the ocean growout phase is technically simple, requires little capital investment, and can involve local people; and giant clams are well adapted to the sunlit waters of coral reef areas otherwise low in nutrients. Furthermore, the period and timing of harvesting is flexible as clams can be stored *in situ*. Clams can also be stocked, and occur naturally, at high densities. Clam mariculture does not require the continued capture of broodstock or the taking of seed from the wild, and is potentially less damaging than many other forms of mariculture.

In Pacific countries, with their limited land and freshwater resources, clam mariculture is seen as a way of: diversifying narrowly-based economies; providing food and employment for small-scale farmers and fishermen; earning foreign exchange; and providing clams to restock depleted coral reefs and increase populations of the rarest species.

Major clam mariculture programmes were undertaken for more than 20 years through the MMDC in Palau, and more recently through the CAC of the ICLARM in the Solomon Islands. In addition, two regional programmes were carried out sponsored mainly by the ACIAR from 1984 to 1992. The first involved many countries including Cook Islands, Fiji, Philippines, Australia (JCU, Australian Institute of Marine Sciences, Queensland Dept of Primary Industries), PNG, Tonga, Tuvalu, and Kiribati. It covered research and technical aspects of giant clam farming, aimed at restocking depleted reefs (Copland and Lucas, 1988) and resulted in over 200 publications. The second regional programme, run by the University of Queensland in collaboration with several South Pacific institutions, focused on the economics of giant clam mariculture and aimed to provide guidance on market prospects, trading arrangements and the potential role of giant clam mariculture in the development of the South Pacific. The findings are summarised in Tisdell (1992) and Tisdell *et al.*, (1994).

There have also been a number of US government funded projects, focusing particularly on US-affiliated territories that lie within the distribution range of clams. For example, the CTSA, based in Hawaii, looked at markets, marketing strategies and production economics for clams (Shang *et al.*, 1990, 1992; Leung *et al.*, 1994), sponsored a workshop on CITES and clam mariculture (Killelea-Almonte, 1992), funded hatchery development in American Samoa in collaboration with the Pacific Aquaculture Association (Bell, 1993b), and is providing clam aquaculture extension and training support for the US-affiliated Pacific islands. The Asian Development Bank and Japanese International Co-operation have also provided funding for clam mariculture work.

At least 22 countries and Territories now have one or more small-scale hatcheries or grow-out facilities; feasibility studies have been carried out in several others (Annex 4). The majority of the hatcheries are in the Pacific (with one in Japan). MMDC has now closed, although it was producing up to one million juvenile clams a year of seven species, was essentially a self-sustaining commercial operation, and provided large numbers of seed clams for grow-out to other states in Palau, the FSM, and the Marshalls (as well as aquarium specimens, souvenirs, meat for local restaurants, tourist visits and training courses for giant clam farmers). CAC and

Reefarm are now the main operations. CAC provides seed clams from six species for grow-out and sale at other small farms in the Solomons (it also encourages villages to keep a proportion of the fastest growing individuals to restock nearby reefs) and has also provided considerable technical assistance to other countries. Its focus is to develop commercially viable (but not-for-profit), village-based farming systems. Reefarm Pty, in Australia, is now having considerable success and is the longest surviving commercial operation, also producing pearl oyster seed and operating as a tourist attraction. In American Samoa, commercial farming of the fastest growing species is the aim. Several operations in the Pacific have had success supplying small specimens for the meat trade (sashimi and sushi) in Japan and for the aquarium industry. The smaller hatcheries and 'grow-out' facilities being established in many places, such as Japan, the Philippines, the Cook Islands, FSM, and Fiji, tend to be oriented more towards restocking of depleted reefs. Rather less active interest has been taken in south-east Asia and the Indian Ocean, although preliminary work is underway in Indonesia, Malaysia and the Seychelles.

4.1. Mariculture methods

The recommended methods are described in a number of manuals, videos and publications (e.g. Braley, 1992; Calumpong, 1992, 1993; Lucas, 1994). Most of the research has been carried out at JCU in Australia (project now terminated) where both intensive and extensive methods were developed, the latter through collaborative work in the Philippines, Fiji, Tonga and the Cook Islands; and at MMDC in Palau and CAC in the Solomon Islands, where relatively low-technology 'extensive' methods are used (at CAC based on methods developed by JCU). Hatcheries initially targeted the two largest, fastest growing species *T. gigas* and *T. derasa*, but *H. hippopus*, *T. squamosa*, *T. crocea* and *T. maxima* are increasingly produced. In Japan, hatchery production and research has been focused on *T. crocea* the main species that is consumed (Murakoshi, 1987). In Fiji and Tonga, *T. tevoroa* are being reared through early stages.

Although hatchery protocols and techniques vary, there are four basic phases to giant clam culture: hatchery, land-based nursery, ocean nursery and grow-out. At the hatchery, brood stock are induced to spawn either by introducing macerated gonad into the tank, injecting them in the gonad with the hormone serotonin, or exposing them to high temperatures. Eggs hatch within one day. The clam larvae are reared for one week in tanks, using static or flow-through techniques. They are settled outdoors in nursery tanks where the juveniles are inoculated with zooxanthellae. Freeze-dried algae or ammonium sulphate may be used as food.

In the land-based nursery tanks, the juveniles are provided with free-flowing sea water and aeration, and allowed to grow to 3cm (8-10 months). At CAC, 4 month old spat (0.4-0.6cm) are stocked in floating nurseries and grown to 3.5cm (5-8 months) at which stage they are supplied to village farms. Fertiliser is added to the tanks. (The Japanese hatchery for the sashimi market is entirely land-based in tanks).

Clams may be transferred to exclosures on the seabed on the reef at the age of about 1 year (*c.*3cm); the exclosures are removed when the clams reach about 20cm. Clams are transferred to the sea in mesh cages, which protect them from predators. Cages may be placed directly on the seabed, on trestles, or floating. The culture site may be intertidal (good for *T. gigas* and *H. hippopus*) or subtidal (good for *T. derasa*). Intertidal sites are easier to maintain and more accessible, but are more at risk from cyclone or typhoon damage and poachers. They should

not be sited directly on a reef where there are many predators and space is limited by coral. They also need to be sited away from freshwater input or high siltation; a flat sand or rubble bottom is best, with minimal water currents and wave action. The length of time in an ocean-based nursery depends on species and conditions; generally clams are kept there until they reach at least 10cm in size or 2-3 years. Clams can be harvested at the age of two years or more for aquarium specimens or sashimi. In the Marshalls, floating platforms have been used (Heyman and Skinner, 1993). Floating ocean nurseries also show good potential (Munro *et. al.*, 1994). The grow-out period is about 5-6 years for good, healthy 45cm *T. gigas* harvestable for their adductor muscles, if placed in moderately strong water currents on reef slopes (the optimum environment), but up to 9-10 years for clams placed on reef flats with poorer water circulation.

Clam mariculture carries a number of risks. Losses from typhoons and storms, freshwater run-off, diseases and predators, and poaching during translocation can be high, and fouling algae can be a problem. There have been mass mortalities of farmed clams in the Solomons, the Philippines, Palau and Australia (Lucas, 1994; Estacion, 1996). Norton and Jones (1992) and Estacion (1996) provide information on diseases that affect clams. An infectious disease was reported to cause high mortality in aquarium specimens in Germany (Knop, 1995a). Serious pests, particularly at the juvenile stage, include gastropods in the families Cymatiidae (Ranellidae) (Govan 1995), and Pyramellidae. The gastropod *Cymatium muricinum* is one of the most common; juveniles embed themselves in the tissues at the base of the clam, on which they feed. Pyramellids are a problem if the clams are placed in poorly maintained or overcrowded raceways. Other predators include flatworms (Stylochidae), crabs, fish, and octopus (Copland and Lucas, 1988; Eldredge, 1993). Methods for reducing predation are described in Govan *et. al.*, (1994) and Govan (1995).

Unlike many forms of mariculture, however, giant clam farming need not be environmentally damaging. Pollution is not a problem as clams do not create large quantities of organic waste, and the increased density of clams in an area may lead to higher levels of recruitment to wild populations. However, the best grow-out area on a reef is generally the slope, which is often the more vulnerable part with dense coral growth (in practice, most grow-out is done on the reef flat, or sand and rubble). Damage can be minimised by careful siting and by taking great care during planting out. A further concern is that the promotion of a market for clam products may encourage collection from the wild, particularly if people think that stocks can easily be replaced by farmed specimens.

4.2. Commercial viability of mariculture

Rapid changes in technology have meant that costs of production have become cheaper and the economics of giant clam farming have therefore been changing quickly. The initial emphasis was to produce meat from the two largest species for subsistence use, local markets and the export trade. In fact, it has not proved commercially viable to grow clams for subsistence purposes. Work in Tonga, Fiji and Western Samoa has shown that the contribution of wild-caught clams to the local diet is very small (Vuki *et al.*, 1991; Tacconi and Tisdell, 1992b), and that they are more often sold than eaten because they are a good source of cash and because other fish products provide a cheaper source of protein (Tacconi and Tisdell, 1992b). Farmed giant clams are therefore usually seen as a source of income.

Initially it was feared that commercial viability would be difficult to achieve as the seafood market is difficult to penetrate, only a small part (the adductor muscle) of meat from any clam

has a high value, and the prices of shells did not seem high enough to make their export feasible (Hambrey and Gervis, 1994). Successful clam mariculture takes time and commitment, requires well-trained personnel, large numbers of broodstock and a site with reliable pumping of sea water and other appropriate environmental conditions. If clam farming is to be profitable to local growers, the cost of clam seed must be kept low and, this involves subsidies. In general, the returns are unlikely to be as high as for seaweed farming which is now a widespread village-based activity in many countries and which can lead quickly to a high income as there are no seed production costs, cuttings being taken from existing natural seaweed stocks, growth is fast and there are established markets (Tisdell, 1991a; in press). However, a pilot project on integrated mariculture of clams and seaweed has been initiated at Silliman University Marine Laboratory (Calumpong, *in litt.* to S. Wells, 1993). Others consider that returns for village farmers can be greater than for seaweed farming. In the Solomon Islands it has been estimated that returns could be ten times higher than for copra production.

In fact, several hatcheries appear to be having increasing commercial success, particularly in supplying the sashimi market and the aquarium industry, as for these the grow-out phase may be as short as six months, giving a lower risk of predation and greater incentive for village farmers. There is good evidence that trade in farmed clams will continue to expand for some time, particularly in islands with a well-developed tourist industry or with good air connections to high-value markets. Gervis (1993) suggested that the marketing strategy should be: promotion of the export of clams for the aquarium trade; refinement of transportation methods for clams; co-operation between mariculture operations in testing new markets; emphasis of the conservation aspects of farmed clams in marketing and advertising (clams should be able to command an additional premium by being marketed as pollution-free, locally produced products); and development of the Japanese and Southeast Asian tourist markets in the Pacific. Several hatcheries are increasingly getting revenue through tourism e.g. Reefarm. Leung *et al.*, (1994) published an economic analysis of giant clam mariculture systems and concluded that clam mariculture can be profitable if all products including shells are sold. If only the meat is sold, prices must be higher and production costs lower. Hart and Lasi (1996) report that at CAC, *T. gigas, T. squamosa* and *T. derasa* are suitable for culture for the aquarium trade, but *T. crocea* and *T. maxima* are most sought after for this trade. Studies are under way with these two latter species.

The Association of Farmed Aquarium Clam Exporters (AFACE) was formed in 1994, comprising representatives of MMDC, Reefarm, Praslin Ocean Farms, CAC, and CTSA. This will help to develop an agreed standardised grading and sizing system, minimum prices, etc. Clams can now be bred specifically for bright mantle colours; an additional advantage is that they can be harvested at a uniform size.

4.3. Conservation benefits of clam mariculture

Although some hatcheries have been established for over a decade, early technical problems have meant that commercial viability has only recently been achieved. It is, therefore, too early to judge conclusively the success of these operations in terms of conservation and whether mariculture will lead to reduced exploitation of wild stocks.

Captive-bred clams are not yet being used to supply the market for adductor muscle in Taiwan nor the international shell trade, although MMDC produced them until it closed. The aquarium industry is a new market for clams and, if mariculture operations can keep pace with

this (although the market is reportedly showing signs of saturation), it may prevent increased pressure on wild stocks. Restocking programmes on reefs (see section 6.2) have not been underway for long enough, nor sufficiently well-monitored to judge their success, but large numbers of clams have been released and the outlook is considered positive. The potential negative impacts of introductions, another outcome of mariculture operations, are discussed in section 6.2.2.

Giant clam mariculture has undoubtedly played a major role in increasing public awareness of the need for sustainable management of giant clams and coral reefs. It is also being promoted as an alternative livelihood in coastal communities which, if successful, could help take pressure off other fisheries resources. In many countries, clam farming is being carried out with the participation of local fishing villages, usually at the grow-out phase. In the Solomon Islands, CAC supplies 2.0-2.9cm clams to 14 villages who grow them in cages for six months or more before selling them back to CAC (minus costs) for sale to the aquarium trade (Hart and Lasi, 1996). In American Samoa, three villages are involved (Bell, 1993b). In Fiji, there have been trial placements from the Makogai hatchery with selected villages and resort owners (Ledua, 1993). In the FSM, large numbers of villages have been involved, particularly in Kosrae, and the Philippines has also experimented with farming techniques at the village level (Annex 4).

The success of these community projects depends on careful supervision, usually by professionals from commercial or government hatcheries, to ensure that predation is controlled through the weekly removal of snails. Where there is inadequate follow-up and villagers have not checked clams carefully enough, survival rates have been less than 20% and the grow-out times have been too long to provide sufficient incentives. High mortalities have led to villagers losing interest and abandoning projects in several instances. In the Solomon Islands, CAC staff visit village sites every three months, but consider that greater long-term involvement may be necessary if village farms are to meet their full potential. Participants and the sites must also be very carefully selected, to ensure that the former have commitment and the latter are ecologically suitable. Participants must be prepared for a constant, although low level, labour input for several years, until clams reach marketable size (Gervis, 1993). CAC, and previously MMDC, have held training courses and workshops for village-based participants both at the main hatcheries and at village nursery sites.

5. CONVENTION ON INTERNATIONAL TRADE IN ENDANGERED SPECIES OF WILD FAUNA AND FLORA (CITES)

The perception of many of those involved in giant clam mariculture has been that CITES prohibits international trade in endangered species, that giant clams have incorrectly been classified as endangered species and that thus the Convention is a major impediment to giant clam mariculture. Thus, Tisdell (1989) incorrectly states that 'signatories to this Convention should prohibit the export or import' of giant clams; Shang *et al.* (1990) suggested that reduced supplies of giant clam were due to CITES; Heyman and Skinner (1993) incorrectly state that 'signing nations have agreed to neither buy nor sell wild-caught clams'; Stanton (1994) implies that international trade in clams is prohibited; Lucas (1994) refers to an 'IUCN ban on international trading in tridacnid products'; and Tisdell *et al.* (1994) state that giant clams are 'listed as endangered species under CITES'. There has also been confusion due to the fact that national legislation in a number of countries requires stricter controls on clam exports and imports than is required under CITES.

5.1. CITES requirements in relation to clams

All giant clams (family Tridacnidae) are listed in Appendix II of CITES. CITES Appendix II includes species that are **not necessarily currently threatened with extinction but that may become so unless trade is regulated** (see Wijnstekers, 1995). International trade is permitted in CITES Appendix II listed species provided appropriate export permits are issued. *T. gigas* and *T. derasa* were listed in 1983, and the remaining members of the Tridacnidae family were listed in 1985 on the `look-alike' principle (i.e. species are listed which may not be at risk but which can only be distinguished with difficulty from species threatened by international trade). Species are listed in or removed from CITES Appendices at the biennial meetings of the Parties or, in rarer cases, by postal procedures with a two-thirds majority vote of all member states (see Rosser and Haywood, 1996).

All living or dead clams, including all readily recognisable parts and derivatives, are subject to the Treaty's provisions for Appendix II species. Among these is the requirement that an export permit or re-export certificate from the exporting or re-exporting country be issued for each shipment. These permits may be issued so long as the Scientific Authority of the exporting country has advised that such export or re-export will not be detrimental to the survival of the species. Permits are also required for the export of souvenirs by tourists, if purchased in a country of origin which requires an export permit, and if imported into the country of residence. CITES regulations also apply to scientific specimens (if preserved or dried), unless the scientists or scientific organisations have been registered for non-commercial exchange of specimens by the CITES Management Authority of the country in which they are situated.

Countries that are not party to CITES but trade with CITES Parties, are required to have a `competent authority' to issue documentation comparable to CITES permits. These permits may or may not be accepted in lieu of CITES permits by party States. Parties are advised only to accept documentation from authorities that are the equivalent of a Scientific Authority and are registered with the CITES Secretariat.

5.2. CITES implementation and national legislation

The effectiveness of CITES is dependent to a large extent on whether countries involved in the trade are Party to the Treaty and, if they are not a Party, on whether they trade with Parties. Table 12 lists the 28 CITES Parties within the distribution range of giant clams and, as indicated, rather few of these are involved in international trade in clams and their products. Conversely, several of the countries involved in the trade (including both wild and cultivated stocks) are not CITES Parties, such as Taiwan and the Solomon Islands. Unlike other US-affiliated territories, Palau and the Republic of the Marshall Islands are not covered by the US ratification of CITES.

Table 12. CITES Parties within the distribution range of giant clams (with year of entry into force) as of November 1997. Source: CITES World Wide Web Site, 1997

* = Parties known to be involved in international trade (others may be involved e.g. countries such as Kenya may export clam shells with other ornamental shells)
+ = Parties that have import/export bans

*	Australia	1976
+	China	1981
	Comoros	1995
	Egypt	1978
*+	Fiji	1997
	France	
	French Polynesia	1978
	New Caledonia	1978
	Reunion	1978
	Wallis and Futuna	1978
+	India	1976
*+	Indonesia	1979
*	Japan	1980
	Kenya	1979
	Madagascar	1975
	Malaysia	1978
	Myanmar	1997
	Mauritius	1975
+	Papua New Guinea	1976
*+	Philippines	1981
	Saudi Arabia	1996
	Seychelles	1977
*+	Singapore	1987
	Somalia	1986
	South Africa	1975
*	Sri Lanka	1979
	Tanzania	1980
	Thailand	1983
	UK	
	Pitcairn Is	1976
	USA	
	American Samoa	1975
*+	Guam	1975
	FSM	
	Northern Mariana Is	1975
	Vanuatu	1989
	Vietnam	1994

New Caledonia, French Polynesia and Wallis and Futuna are covered by the French regulations for CITES.
Guam, American Samoa, the Northern Mariana Islands and FSM are covered by the US ratification of CITES. Palau was covered by this until 1994, but is no longer a CITES Party.

Several CITES Parties (or territories covered by ratifications of other countries) enforce stricter legislation than is required by the Convention, such as Indonesia, Palau, PNG Fiji and the Philippines which prohibit the export of wild clams (Annex 3). In such cases, CITES

export permits should not be issued, but there is evidence of illegal trade, as discussed above. Import permits as well as export permits are required for the importation of Appendix II listed species into countries within the European Community, and Australia has very specific requirements for the import and export of Appendix II specimens. At least 22 countries and territories have national legislation that specifically relates to giant clams (Annex 3). In several countries (e.g. Indonesia, Philippines, Singapore), clams are fully protected (collection, sale and export of wild specimens prohibited); in others (e.g., PNG, Fiji, Palau) export of wild-caught specimens is prohibited. Much of this legislation is poorly enforced Giant clams may be covered under general legislation for fishery products in other countries, but this has not been reviewed in detail.

It seems too early to say whether CITES is having any impact on trade in giant clams as shells or aquarium specimens. As so little clam meat is recorded in CITES Annual Reports, it has to be concluded that the Convention is currently playing little, if any, role in regulating trade in this product. On a more positive note, the CITES Annual Reports are providing a useful source of data for the analysis of past trade of some products and for the identification of possible areas of illegal trade. The CITES Secretariat can assist in the enforcement of national legislation by issuing `Notifications to the Parties', urging them to comply with national export bans or other domestic legislation. The following cases provide examples of some of the issues involved.

Australia. Since 1 May 1984, Australia has only permitted private or commercial imports of Appendix II listed species when they are bred in captivity, taken under an approved management programme, or declared as `controlled specimens' (Annex 3). The requirements for approved management programmes are prescribed by law; those for 'controlled specimens' are less stringent but certain prescribed management-related factors are nevertheless considered before approval is granted. The CITES Annual Reports for Australia show very few imports of clams and none from the Philippines. However, the CITES Annual Reports for the Philippines show that large numbers of giant clam shells have been exported to Australia since 1985 (Table 9), even though the Philippines does not have a management programme recognised by the Australian Government and is not exporting captive-bred clams for this purpose. This suggests that large-scale illegal importation of giant clams into Australia was taking place at least until 1991. In October 1991, the Wildlife Protection Authority in Australia sent a notification to Australian importers and exporters explaining the regulations in relation to CITES, and pointing out that import of clams is prohibited. No exports to Australia were recorded in the Philippine 1992 CITES Annual Report, but giant clams are freely available in souvenir shops along the Great Barrier Reef (Lucas, 1994). Sant (1996) also reports the presence of wild stocks on the Australian aquarium specimen market and ponders the potential for laundering wild stocks with captive-bred specimens.

Philippines. Enforcement of the Philippine legislation (see Annex 3) has been a major problem, partly because its interpretation has varied. Numerous export permits for prohibited species were issued after institution of the 1990 ban, and the statistics indicate a large trade in 1991 and 1992, as described above. Some Government personnel apparently interpreted the ban on export of shelled molluscs to exclude 'pre-ban stock' and so continued to issue export permits until 1992. According to the Philippine Department of Agriculture, over one million pairs of giant clam shells (of species other than *T. crocea*) inventoried in 1986 were held by traders as of 31 January 1992.

In 1989, the Marine Conservation Society of the UK attempted to alert importers and retailers of the illegality of clam imports from the Philippines, and in 1991 a booklet outlining the requirements of CITES was circulated within the UK (Wells and Wood, 1991). In 1991, UK imports of clam shells from the Philippines were among the highest, after the USA; imports in 1992 were also high (IUCN/TRAFFIC/WCMC, 1996). Poor enforcement of existing legislation in the USA has also contributed to the ongoing trade from the Philippines. Since the 1990 Philippine export ban, imports of clams into the USA have been illegal, regardless of CITES regulations, as the U.S. Lacey Act prohibits imports of wildlife, including invertebrates, obtained illegally in the country of origin.

CITES 'Notifications' were used to try and improve enforcement of and clarify the meaning of the Philippine legislation. In January 1992, CITES Notification No. 663 was sent to the Parties, urging them to refuse permits from the Philippines for prohibited species (i.e., all species except for *T. crocea*, which was exempted in 1991 legislation). A second CITES Notification in June 1992 (No. 676) urged Parties not to recognise pre-ban stockpiles of giant clams, the Philippine government having announced that these were to be exempt from the ban. The apparent decline in exports in 1992 may indicate that these Notifications were of some benefit, although large quantities of *T. squamosa* and *H. hippopus* were seen packed for export at one dealer's premises near Cebu in December 1993 (Wells, pers. obs.). Germany imported several species in 1993, but only *T. crocea* was being imported from the Philippines (Bauer *in litt.* to S. Wells, 1994). The Haribon Foundation, in the course of a survey of the shell trade in the southern Philippines in 1993, found stockpiles of shells in Tawi-Tawi and the Polillo Islands, which were awaiting further changes in legislation according to the dealers (Salamanca *in litt.* to S. Wells, 1993). In June 1996, a third CITES Notification (No.915) was sent to the Parties informing them of the suspension of the exemption of *T. crocea* from the export ban.

Given the considerable delay in the production of CITES Annual Reports, it will be some time before one can judge whether the CITES Notifications concerning the Philippine legislation have had any impact. The situation appears to be similar to that documented for the illegal coral trade in the Philippines. Export businesses in the Philippines deal in corals, shells and shellcraft and are consequently a significant source of local employment and foreign exchange. They thus have great economic and political influence, especially at the local level, and it seems that government personnel are often put under pressure to provide permits and overlook illegal activities (Mulliken and Nash, 1993). According to Salamanca (*in litt.* to S. Wells, 1993), exporters also have mechanisms for avoiding permitting regulations; for example, some reportedly send clams to Hong Kong where they are repackaged for shipment elsewhere.

Indonesia. Enforcement of the harvesting ban in Indonesia has been poor. In 1989, clam meat was apparently being taken illegally from reefs in Irian Jaya for export to Taiwan (Nash, *in litt.* to S. Wells, 1989) but it is not known whether this illegal trade is continuing.

Palau. Palau has a ban on clam exports, but meat from wild stocks has reportedly been illegally exported to Taiwan and Guam: about 2 tonnes in 1990 and just under a tonne in the first half of 1991 (Nichols, 1991). In 1991, the CITES Annual Report for the USA recorded the export of 137 live wild specimens from Palau to Germany and Canada.

Taiwan. A major part of the trade in giant clam products, the meat trade, is not covered directly by CITES as it is imported directly into Taiwan, which is not recognised as an

independent state by the United Nations. Taiwan is included in the CITES ratification for China, but acts independently. Many Taiwanese clam fishing operations were apparently carried out by vessels exploiting the territorial waters of foreign countries without licences. This was a problem in Australia in the early 1980s when Taiwanese vessels were excluded from the Great Barrier Reef by the early 1980s through aerial surveillance, reporting by recreational and commercial boat operators, and stiff penalties including forfeiture of the vessel, catch and gear and forced repatriation of the crew. Concerned about its image, and in response to threats from Australia, the authorities in Taiwan increased inspection of boats before and after trips, rejected requests by vessels for permits for clam fishing, and suspended licences if boats were found to have been involved in illegal practices (Dawson, 1986).

Many Taiwanese boats subsequently moved to areas with fewer resources for effective enforcement and where territorial waters are very difficult to patrol, such as the outer Fiji islands, PNG, Solomons, Palau, southern Philippines and FSM (Lewis *et al.*, 1988; Dawson and Philipson, 1989; Munro 1993b; Salamanca, *in litt.* to S. Wells, 1993). There have been at least three illegal fishing incidents in the Solomons since 1983, when the last licence was issued, with the last apprehension in 1987 (Skewes, 1990). In 1994, the Solomon Islands government made a verbal statement that licences should not be issued for the export of clams and their products unless cultured (Gervis and Bell, *in litt.* to S. Wells, 1994).

5.3. CITES and mariculture

If implemented appropriately, CITES regulations should not impede international trade in farmed giant clams. However, problems have arisen in three areas: 1) interpretation of the criteria for eligibility as a captive-breeding operation and delays in recognition as such operations; 2) obtaining appropriate permits, particularly in non-Party States; and 3) distinguishing farmed from wild-caught specimens. These problems are not unique to giant clams and have been investigated in connection with other CITES-listed species, and solutions are now largely in reach.

5.3.1. Criteria for captive-bred specimens

Specimens of captive-bred Appendix II species that meet the necessary CITES criteria are eligible for a captive-bred certificate, which may be used for multiple shipments if so stated by the Management Authority on the certificate. As interpreted for giant clams, these criteria are as follows:

- captive-bred specimens must be the offspring, produced in a controlled environment, of individuals that reproduced in a controlled environment.

- a controlled environment is one that humans intensively manipulate in order to produce the species in question, and must have boundaries that prevent animals, eggs or gametes of the species from entering or leaving.

- the parental breeding stock must be established in a manner that is not detrimental to the survival of the species in the wild, and must be managed in a manner designed to maintain it indefinitely without additions from the wild. It will be considered to be managed in that manner only if it has been demonstrated to be capable of reliably producing second-generation offspring in a controlled environment, i.e., that the life cycle is closed and no longer dependent on natural stocks.

There has been some confusion over the definition of a `second-generation offspring', what it means in terms of a closed life cycle in the context of giant clams, and whether offspring of broodstock meet this criterion. Giant clam hatcheries generally have a small number of broodstock clams, probably originating from the wild, but able to spawn on a regular basis over a long time period, so that additional clams do not need to be taken from the wild (except for genetic improvement as discussed below). Problems arise if there is insistence that the second generation individuals must be produced by the F2 generation. The generation time for giant clams can take 5-10 years (*T. gigas* takes at least seven years before it matures as a female) and there is therefore a very long time-lag. The MMDC had reached this stage before it closed down; in 1984 it produced F2 *T. derasa* using F1 broodstock produced in 1979, and subsequently it produced F3 cohorts (Heslinga, 1993). The Marine Science Center, University of the Philippines has also produced individuals from F2 generation of *Hippopus hippopus* and *T. maxima* (Mingoa-Licuanan, *in litt.* to S. Wells, 1994). Australia, however, in approving clam breeding operations (such as Reefarm and CAC) has not required operations to have produced F2 offspring, but only to demonstrate that they are capable of doing so given time. For clams, it may in fact be preferable to use broodstock only once and then return them to the reef; the use of different broodstock will help to increase genetic diversity in farmed stock.

5.3.2. Permitting arrangements

In the recent past, several giant clam mariculture operations have reported problems in marketing their products because of difficulties in obtaining CITES permits and delays in inspection, which have caused lost orders. The MMDC in Palau ran into such problems; an estimated US$20,000-30,000 was reportedly lost by the company in early 1992 due to the loss of a major account in Japan because of problems during the inspection of a shipment. All shipments had to be exported via Guam which was the nearest designated port for export of CITES specimens (i.e. it has the nearest USFWS inspection agent). Inspection cost US$200 per shipment, often up to 13% of its value, and applications for permit renewals had to be made to USFWS every six months (Killelea-Almonte, 1992). Efforts were launched to provide Palau with its own USFWS wildlife inspector who could certify exports (Nichols,1991)[1].

Countries that are not party to CITES may have problems if they are unable to produce the necessary documentation required by importing Party countries. This is particularly the case in small Pacific island States lacking expertise in this field. This apparently deterred the Wau Island Clam Hatchery and Farm in the Marshall Islands from exporting to the USA, although an order for aquarium specimens had been received (Killelea-Almonte, 1992). CAC in the Solomon Islands also experienced difficulties in the past, as shipments went via Australia (Bell *in litt.* to S. Wells, 1993). These were resolved when the operation received formal approval that it met the requirements of the Australian Wildlife Protection Act (see Annex 3). The Marine Science Institute in the Philippines is still experiencing such problems, as its hatchery is not recognised by the Bureau of Fisheries and Aquatic Resources, which issues export permits (Gomez pers. comm. to S. Wells, 1996).

[1]It should be mentioned that the US sanitary regulations also impose strict requirements on certain imports. Clams are classified as filter feeders by the US Food and Drug Administration (FDA) and cannot be imported into the USA and its territories for human consumption from countries that do not have a recognised shellfish sanitation programme. Australia has such a programme, but neither Palau nor FSM does, which means that cultured clams cannot be imported from these territories into the USA for food purposes (Crawford, 1992).

In the US-affiliated territories, many of these problems are being overcome through training courses and extension work, and information on CITES has been provided to many of the hatcheries. A workshop was held in Honolulu in 1992 for those involved in giant clam farming in the US-affiliated territories to discuss some of these issues with the US Fish and Wildlife Service (Killelea-Almonte, 1992), and similar initiatives have been taken since.

5.3.3. Marking captive-bred specimens

Little, if any, attention has been paid to the question of how captive-bred giant clam products could be marked so that they can be distinguished from products produced from wild stock, a requirement under CITES to discourage illegal trade. For example, Japan refused to clear for import a consignment of clam shells from the Wau Island Clam Hatchery in the Marshall Islands in 1989, due to the difficulty of separating farmed from wild-caught products.

This problem has been studied in some depth for other CITES-listed species, following a recommendation made at the Seventh Meeting of the Conference of the Parties in Lausanne, 1989, that uniform marking systems be developed for CITES species. The marking system must be simple, easy to implement, secure and relatively cost-effective. A variety of methods are available, including clipping, branding, tattooing, banding and tagging, bone and shell marking, radiotelemetry, radioisotopes and microchip implants. Many of these methods, as well as coded non-reusable tags and indelible dyes and stamps (for non-edible products), can also be used for parts and derivatives.

An important additional tactic is clear, correct identification of the product; for example, meat can be packaged in sealed containers with appropriately numbered labels issued by the relevant authority of the exporting country. In Australia, product cards were produced for crocodile product souvenir items and issued by the CITES Management Authority to licensed manufacturers who were required to submit regular returns linking the number of cards to the number of articles sold; a revised permitting system is now in place. In Germany, species protection tags have been developed for articles made from reptile skins.

Whether any of these methods would be appropriate for captive-bred giant clam products requires further consideration. Batches of cultured clams have a uniformity not evident in wild collected specimens, so that a shipment of number of individuals from the same size class would be distinguishable as farmed through their appearance. This however, would not work for all shipments. Cultured *T. maxima* and *T. crocea* have scutes that extend to near the base of the shell, unlike wild specimens, but whether this is a sufficient distinguishing characteristic needs further study.

6. STRATEGIES FOR GIANT CLAM CONSERVATION

6.1. Management of remaining wild stock

Management of the remaining wild populations of giant clams in their natural habitat must be considered one of the highest priorities at present, particularly for those species most severely under threat. There are a number of different approaches to this, their suitability depending on the situation, and often a combination of techniques is required.

6.1.1. Community-based management

Access to giant clam stocks in many Pacific countries, is controlled by traditional reef tenure systems which have evolved over many years, and clams are subject to traditional fishing rights along with other fishery resources (Tisdell, 1992; Hviding, 1993). There are many different systems, but they commonly involve the exclusion of outsiders from fishing in the `owned' area, or the restriction of the use of stocks of a specific reef or lagoon to one family group. One common method of control is for a *tabu* to be applied to an area by a tribal chief, prohibiting certain activities within the area (e.g. harvesting of certain species). The area over which a community's rights extend commonly stretches from the shore (or even inland in some cases) out to the edge of the reef, the 'horizon', or some other natural boundary. Traditional rights are widely respected in most Pacific countries and in some, such as PNG, Vanuatu and Fiji, have been formalised in the Constitution or in modern legislation (Vuki *et al.*, 1991; Fairbairn, 1992b).

Traditional use and ownership of nearshore resources are therefore vital considerations in the Pacific as they may restrict government authority to enforce legislation or establish protected areas. On the other hand, many traditional regulations complement and augment current management efforts. For example, in the Cook Islands, a traditional form of control called a *raui* has been placed on giant clams in Aitutaki, which means that they may not be harvested for a certain period; this will probably remain in force until populations have recovered (Anon., in press). In Western Samoa in 1988, a village council on Savai'i, concerned at depletion of clam stocks, prohibited commercial exploitation and declared that for three years clams could only be taken for subsistence purposes (Tacconi and Tisdell, 1992b).

Community-based management is important even where it is not a tradition. The support of local people and their involvement at all stages in the design and management of protected areas is now recognised as essential for successful management of nearshore resources. Village-run clam grow-out facilities that have been set up in the Solomon Islands (see above) suggest that giant clams can provide an incentive for the establishment of community-owned and managed marine protected areas and raise public awareness of the need to conserve and sustainably manage marine resources in general (Gervis, 1993; Govan, 1993; Hviding, 1993). In the FSM, a major village-based clam re-introduction programme was supported in Yap by the MMDC. From 1984, over 12,000 *T. derasa* were sent to Yap from Palau for rearing in community-managed sites. Initially there was a high (60-70%) survival rate, attributed in part to a strict reef tenure system which minimised poaching (Nichols, 1991); unfortunately in 1992, a storm surge killed most of this population (Smith *in litt.* to S. Wells, 1994). A similar approach has been adopted in the Philippines where captive-bred clams are being introduced to community-managed reserves (Calumpong and Cadiz, 1993).

6.1.2. Creation of artificial clump populations

As explained earlier, clams release a chemical with their gametes and this induces gamete release if detected by another clam. A clumped distribution, or a critical mass of individuals, is therefore thought to be essential for successful reproduction, although the minimum stock density for successful spawning is not yet known (Braley, 1984 and in press a; Adams *et al.*, 1988).

In several Pacific countries, such as the Solomons, Fiji, PNG and Western Samoa, clams have traditionally been collected and placed in sheltered, protected areas (or clam gardens) close to the village (Vuki *et al.*, 1991; Fairbairn, 1992b). In some cases clam gardens may be established for conservation purposes (Govan *et al.*, 1988), but in many cases it may simply be a means of providing emergency food stocks. In either case, such a practise may inadvertently have had, and may still have, a beneficial effect by encouraging spawning and fertilisation.

The custom of aggregating clams in order to protect them is being resuscitated in Tonga where a Giant Clam Circle project was initiated in 1986. The main aim was to increase public awareness of threats to giant clams, but also to attempt to revitalise dwindling natural stocks. *T. derasa* and *T. squamosa* were collected from a wide area and arranged in circles consisting of nine clams, two metres apart, in Vava'u, and the area was designated the Falevai Community Giant Clam Sanctuary, under the management of the local community. In 1990, with support from FAO, three more sanctuaries were created to protect clam circles, one within an existing marine protected area, Pagaimotu Marine Reserve. The circles are generally marked with a buoy and in some cases have underwater trails and serve as a visitor attraction. Surveys in 1988, 1989 and 1990, indicated that clams had increased in number in the Falevai circles, and there are now over 300 clams in the area (although it is not known if this is due to increased recruitment). Sanctuaries have also been set up by private individuals or the government but are said not to have been as successful as those run by local communities (Fairbairn, 1992a; Chesher, 1993). Similar programmes have been recommended for Niue (Bell and Gervis, 1994).

One problem with this approach is that it will take a long time before benefits can be realised naturally. Given the low recruitment rates of clams, circles could take five years before they prove their value (Braley, in press a). Munro (1993a) suggests that it may be better to aggregate clams randomly or distribute them systematically within a circular patch of reef, rather than in an actual circle, if they are to be put in an area of relatively strong current (where they are likely to thrive best). In a circle, a proportion of the unfertilised eggs is likely to be swept away from the aggregation.

An additional problem is the likelihood of poaching from clam aggregations, particularly if they have been placed in accessible areas, which may be necessary if the owners are to check them regularly. There have been concerns over one of the giant clam circles in Tonga as it involved the removal of clams from their natural habitat to highly accessible sites in the harbour, and a number of the clams were stolen in the course of the project (Langi and 'Aloua, 1988). However, one argument for clam circles is that they will be clearly identified as belonging to someone, and this could deter poaching. A further problem is that aggregations may increase predation, for example by rays, which are a major predator in the Solomons.

6.1.3. Protected Areas

Protected areas (whether through traditional tenure systems, as community-managed enterprises, or as part of government-led marine protected area programmes) containing populations of giant clams should be established for all regions where clams are depleted, if only to conserve the remaining genetic stock (Braley, in press a; Sims and Howard, 1988). This is the safest and cheapest way to enhance local stocks and is an essential adjunct to re-stocking programmes. Sanctuaries have been established specifically for clams in Tonga (see above), and in Kosrae (FSM) a sanctuary has been set up adjacent to the National Aquaculture Center (Smith, 1992a). The Marine Resources Division of Pohnpei State (FSM) was planning to establish several clam sanctuaries using *H. hippopus* from the hatchery in 1992 (Killelea-Almonte, 1992). Community-owned sanctuaries are being established in Yap, to be managed with the support of the Marine Resources Division (Lindsay, 1994). In Japan, a 275 ha sanctuary was established in 1974 for *T. crocea* at Kabira on Ishigaki Island, but there was little increase in stock density between then and 1981 when a survey was carried out (Murakoshi, 1987).

Many marine protected areas already exist within the distribution range of giant clams, established for the protection of other marine resources or for the regulation of tourism. Where these are well enforced, they will contribute to maintenance of wild populations. In Malaysia, for example, enforcement of marine protected areas legislation is relatively strong, to the extent that in July 1996, a Singaporean was sentenced to one day's imprisonment and fined the equivalent of US$2000 for removing one specimen of *T. squamosa* from Pulau Redang Marine Park (*TRAFFIC Bulletin,* 16(3):115).

However, the global marine protected area system is still by no means comprehensive or fully representative of features of marine biodiversity. IUCN's World Commission on Protected Areas is currently addressing this problem, and regional working groups have been set up to assess the effectiveness of existing marine protected areas networks in conserving marine biodiversity and to make recommendations for improvement. In the Pacific, the initiative for this is being led through the SPREP's South Pacific Biodiversity Conservation Programme and its Integrated Coastal Zone Management initiatives.

Although there is little genetic differentiation among clam populations on highly connected reef systems such as the Great Barrier Reef, there are significant regional differences for *T. gigas*, *T. derasa* and *T. maxima*, and three main groups can be identified (Benzie, 1993a and b):

i. Great Barrier Reef, Solomon Islands and Philippines
ii. Western Pacific: i.e. Fiji and Tonga
iii. Eastern Pacific: Cook Islands, Kiribati and Marshalls

The presence of these genetically distinct groups indicates that reserves for giant clams should be established in each region if appropriate protected areas do not already exist.
Marine protected areas may not markedly increase recruitment rates in surrounding areas, unless artificial clumps are established. This is because natural recruitment rates to protected stocks, such as those on the Great Barrier Reef, are extremely low. In the Philippines, clam population densities have been found to be low in a number of fairly long-established community-managed marine reserves, for reasons that are not yet clear but are probably related to poor enforcement; in some areas species have actually declined (Calumpong and Cadiz, 1993).

6.1.4. Regulation of harvesting

Mechanisms to regulate harvesting include total bans on harvesting, bans on harvesting for commercial sale, or bans on export (Annex 3). Few countries have implemented other forms of harvesting regulation, although Fiji has guidelines that are reported to be followed and to be of value. Data on growth and mortality rates are accumulating rapidly through the mariculture programmes and could be used to estimate potential yields and thus assess appropriate harvests. It should, therefore, become possible to implement the types of restrictions used in other fisheries, such as size limits, seasonal harvesting closures and annual quotas (Munro, 1993b), if an education programme is carried out to explain the purpose of such regulations and if appropriate enforcement mechanisms can be implemented.

Minimum sizes could be stipulated for the exploitation of adductor muscles, with their corresponding shell lengths and body weights. Undersized clams could be accumulated in traditional, individually owned clam gardens until they reach the minimum harvestable size. In order to enforce this it may be necessary to restrict clam sales to whole clams with their shells intact so that measurements can be made and size limits for different species enforced (Munro, 1993b). The only known example of the use of size limits is in Japan, where there is a minimum legal catch size for *T. crocea* (Annex 3). The data on which these regulations are based are not available in the literature. Enforcement however is poor and there is no evidence that these measures have been particularly successful. Size limits (260 mm for *T. derasa*, 180 mm for *T. squamosa*, 155 mm for *T. maxima*) were recommended in Tonga (McKoy, 1980; Tisdell, 1992; Bell *et al.*, 1994) but perhaps because of the potential difficulty of enforcement, particularly for meat, an export ban has been imposed (Annex 3). Minimum size limits of 25cm for *T. squamosa* and 18cm for *T. maxima* have been recommended for Niue (Bell and Gervis, 1994).

Japan also has a closed season for the harvest of *T. crocea*, but whether this relates to the spawning season of this species in this area is not known. Rotational closures of fishing areas for clams has been suggested for the Cook Islands (Anon., in press). In the central Pacific there is no evidence of seasonality in reproduction in most species, but on the Great Barrier Reef spawning of *T. gigas*, *T. crocea* and *H. hippopus* is restricted to a short summer season (Munro, 1993b). There is some seasonality in the Solomons, and spawning can be most easily induced in April and December, but it can happen year round. This is an area in which further research is required.

Annual quotas could be determined for different areas on the basis of stock assessments which are starting to become available, and could be combined with a size restriction. This approach would be most easily enforced by imposing a single short harvesting season each year in which a certain number of clams could be taken (Munro *et al.*, 1994), although this might prove difficult to enforce in places where subsistence harvesting is important.

6.2. Restocking and re-introductions

Translocations can be for the purposes of introductions (attempts to establish a species in an area outside its original range) or re-introductions (attempts to re-establish a species into an area where it once occurred). Translocations of cultivated clams have been carried out in numerous countries (Annex 4), but the literature does not always clearly indicate if attempts have also been made to restock or re-inforce (i.e. augment populations) on depleted reefs. Eldredge (1993) has compiled an inventory of introductions and re-introductions, and a central database of international translocations is to be maintained at ICLARM (Munro, 1993b).

The MMDC was very active in introducing and re-introducing cultivated stock, and the research mariculture facility at JCU in Australia also sent many consignments abroad. Often these were re-introductions or restocking of areas where the original populations had been depleted. In many other cases, however, species have been introduced to islands outside their known historical range. Thus, *T. gigas* has been introduced to American Samoa, the Cook Islands, Tonga and Western Samoa; *T. derasa* has been introduced to American Samoa, the Cook Islands, FSM, the Marshall Islands and Western Samoa, and *H. hippopus* has been introduced to the Cook Islands. In the most extreme cases, species have been introduced to Hawaii and even the Caribbean, although there is no evidence at present that populations have become established in the wild. CAC in the Solomon Islands and other smaller hatcheries have tended only to carry out translocations within a country, although CAC has also shipped stock to the Philippines and Western Samoa (where populations have a similar genetic structure to the Solomon Islands). In the Philippines, over 20,000 clams of all species have been re-introduced to over 20 sites, but there has tended to be a poor survival rate (Calumpong and Solis-Duran, 1994). Where re-introductions are made, it is important to have some form of good monitoring and protection, for example through a well managed sanctuary or protected area. These precautions would be in line with the recommendations made by IUCN for re-introductions (IUCN, 1995).

6.2.1. Strategies for re-establishment of stocks

Restocking can take place in two ways: hatchery-reared clams can be re-introduced onto reefs within the same country - the clams may have originated within the country or come from one of the large hatcheries; or hatchery-reared clams are introduced to the reefs direct from overseas hatcheries (Munro, 1993a). There are several examples of the former: in May 1992, 5,500 five to six year old *T. gigas* were transferred to various sites on the Great Barrier Reef in Australia from the mariculture programme set up by James Cook University (Braley, 1993). The MMDC donated large numbers of broodstock to each of the 16 states in Palau; CAC has distributed many clams within the Solomon Islands to village farms and the CAC field station at Nusa Tupe, and in Japan large numbers of locally reared *T. crocea* are being released on local reefs. Similarly, there are many examples of the latter approach, such as the programme in the FSM which used clams from the MMDC hatchery in Palau. The FSM programme has had some success in restocking *T. derasa* on local reefs, with some 8% survival. However, whether this has been worth the US$500,000 investment, which was the cost of the programme, is open to question (Lindsay, 1995).

Bell (1993a) compared the benefits of setting up a hatchery with imported juveniles in the context of a proposal to reseed reefs in Niue with native *T. maxima* and *T. squamosa*. Juveniles are now available from a number of hatcheries, particularly the CAC (mainly for Solomon Is. growers) and those in the Marshall Islands; hatcheries in Fiji and Tonga are now also producing juveniles successfully. A few centralised hatcheries supplying clam seed will be the most economic in terms of demand on wild stock, as they are more likely to establish closed breeding cycles. The establishment of a new hatchery is expensive, takes time and requires technical expertise. The first method also requires the construction of a land-based facility for quarantine purposes and, if larvae are being received, a more sophisticated facility; the low survival rates of juveniles also means that exclosures or ocean nurseries are required initially.

Simple broadcast spawning of spat or juveniles onto reefs will be unsuccessful unless the costs of farming giant clams can be reduced to such an extent that large numbers can be produced at

minimal unit cost. Unprotected clam spat and juveniles suffer very high mortalities on coral reefs. Some of the Philippine restocking efforts have experienced high mortalities; 35% have been lost to typhoons and bad weather, 29% to predation, 5% to poaching, 12% to transport and handling and 1% to siltation. Survival has been found to be greater if juveniles are firmly attached to the substrate or are protected in cages (Calumpong and Solis Duran, 1994) and in most cases exclosures are used in the grow-out stage (see above). Storms have been a major cause of clam mortalities in W. Samoa, Fiji and Australia (Lucas, 1994).

6.2.2. Risks associated with translocations

As with other molluscs that have been cultured and introduced to areas outside their natural range (such as mussels and oysters in Europe and the USA), there is a high risk of transfer of disease and parasites or pests (Pernetta, 1987; Munro, 1990), and many of the problems that can arise at the hatchery (see above) itself also apply. Although juveniles are easier to transport than adults, they have the greater risk of disease and predator transfer than larvae and spat of 14-28 days. Larvae can survive for up to 40 hours at a density of 30,000/litre of oxygenated water; CAC therefor provides them at no cost beyond packaging and freight (Bell, 1993a). Juveniles can be transported fairly safely wrapped in moist cloth in styrofoam boxes (2-5 hours), or if longer, in plastic bags which are oxygenated - clams up to 20cm in length have 95% survival rates over 30 hours, if in sufficient well-oxygenated water. A subsequent cause of loss is poaching, and the general difficulties associated with trying to maintain grow-out facilities in remote places with inadequate communications with the hatchery from which the spat originated.

An additional major concern is that local genetic diversity may become compromised through the introduction of different genetic stock. Mass-producing animals from a few adults, as happens at present, decreases genetic diversity and creates major shifts in gene frequency of cultured populations relative to those of the wild. Hatchery reared clams in the Solomons and Australia have been found to have lower average levels of genetic diversity, suggesting that as many individuals as possible should be used to produce the parent generation (Benzie, 1993a; 1994).

This problem, and the re-establishment of clam stocks in the Pacific in a genetically sound way, was discussed at a workshop held in June 1992, sponsored by ICLARM, ACIAR and a number of other agencies. As a result of this, guidelines on translocations and on sound genetic practices for the cultivation of giant clams were produced (Munro, 1993b). These require that: standardised quarantine procedures are adhered to and that stocks are taken only from populations with which an area already has genetic exchange; and that techniques are used in mariculture that ensure the production of genetically diverse stock (for example, progeny should be produced from many different matings, and there should be several introductions over time with stock derived from different parents).

A consortium has been established, consisting of representatives of various institutions involved in clam mariculture and translocations, to seek funding for the re-establishment of giant clams in the Pacific in a manner that conforms to genetic principles (Munro, 1993b).

6.2.3. Quarantine procedures

The South Pacific Commission recommends a quarantine protocol for international translocation of clams described in Munro *et al.* (1985) and elaborated in Benzie (1993b) (see also Pernetta (1987), Braley (1992), Norton and Jones (1992), and Norton *et al.* (1994)). This requires that before export, spat should be reared in 1 micron filtered water, and that juvenile clams are manually scrubbed and washed in chlorinated fresh water and then held for a one month quarantine period in land-based raceways in 1 micron filtered, UV sterilised sea water. On arrival at the destination, before introduction to a new locality, they should be held in a similar fashion for a six-month quarantine period. Waste water from this operation should be disposed of via a septic tank or ground sump and should not be discharged into the sea. Transfers should be restricted to species within their original distribution, and should be made with spat or clams that are as young as possible. Stock should be destroyed by recipients if parasites or disease appear.

The CAC in the Solomon Islands has an additional policy of not exporting a clam species to countries in which there are still good populations, unless it has become, or there is a high chance of its becoming, extinct.

7. RECOMMENDATIONS

7.1. Improvement of trade controls

- Commercial exploitation of wild stocks of giant clams should be strongly discouraged unless there is good evidence that a population is stable and can withstand the proposed level of harvest. In addition, major improvements are required in the enforcement of legislation regulating giant clam exploitation and trade. Priority areas include:
  - halting illegal exports of giant clam shells and other products from the Philippines. This trade should be closely monitored and if it continues, the sources of supply should be investigated;
  - fully enforcing the Lacey Act and other US legislation in respect of giant clams; it may be necessary for the US Fish and Wildlife Service to issue a directive to law enforcement officers, explaining the regulations;
  - encouraging European countries, Japan, Australia and other CITES Parties to heed the Notifications issued by the CITES Secretariat in respect of giant clam exports from the Philippines.
  - Distribution of booklets of the type produced by the UK Marine Conservation Society (Wells and Wood, 1991) on marine curio trade legislation could also be of value.
- The status of clam stocks and the extent to which they are being harvested for international trade should be investigated in Indonesia.
- The sources of giant clam adductor muscle in Taiwan should be reviewed to determine whether these are legal.
- Further consideration should be given to improving requirements for standardised measures and units for recording imports and exports of giant clam products in CITES Annual Reports. CITES Notification to the Parties No. 788, 10 March 1994 (Guidelines for Preparation and Submission of CITES Annual Reports) requires that meat is listed as kg, shells by number (or, if that is not possible, by kg), carvings by kg and live animals by number, or alternatively by kg. However, the variability in weight of clams means that if weight is used for any product it is not possible to estimate numbers, and interpretation of CITES statistics will continue to be problematical. It is recommended that clam products are recorded by number wherever possible.

7.2. Facilitation of trade in mariculture specimens

Given the problems encountered by several clam mariculture operations in obtaining CITES permits (despite efforts on the part of the CITES Secretariat to provide appropriate information through Notifications to the Parties), other methods of facilitating legitimate trade in cultured specimens would help to take pressure off wild populations. These might include:

- Preparation of a directory of 'recognised' clam mariculture operations, such as that produced for crocodile farms (Luxmoore and Groombridge, 1989);
- Further workshops of the type held by the US Fish and Wildlife Service for mariculture operations in the US-affiliated territories, to acquaint potential clam exporters with CITES requirements. Consideration should be given to the production of a guide for non-party states on compliance with CITES export provisions.
- Development of a method to mark products from farmed giant clams.

7.3. Establishment of community-based clam conservation initiatives and marine protected areas

- Encouragement should be given to the development of community-based clam conservation initiatives.
- An assessment should be made of the extent to which existing marine protected areas contain clam populations. For some of these, species inventories are already available; elsewhere protected area managers and biologists working in such areas should be requested to assist in the provision of the necessary information.
- Additional areas for protection should be identified; proposals for their establishment should be developed with the relevant local communities. Particular attention should be paid to ensuring that there is adequate protection of the three main genetic stocks: 1. Great Barrier Reef, Solomon Islands and Philippines; 2. Western Pacific (Fiji and Tonga); and 3. Eastern Pacific (Cook Islands, Kiribati and Marshall Islands).
- Artificial aggregations of clams should be placed in marine protected areas where stocks survive, but due care given as to their provenance.

7.4. Improvement in mariculture methods and translocation procedures

- Environmentally sound mariculture programmes should be encouraged if they have a clear benefit for the remaining wild populations such as providing clams for restocking reefs and reducing pressure on wild stocks.
- The `Guidelines for hatchery managers on sound genetic practices for the cultivation of giant clams' and the `Guidelines for translocations' (Munro, 1993c), as well as the IUCN Guidelines for Re-introductions (IUCN, 1995), should be followed.
- Introductions and re-introductions should be more closely monitored and centralised records should be maintained (if not already underway through ICLARM), for example indicating whether specimens were introduced for mariculture, the aquarium trade or for re-seeding reefs.

7.5. Information gathering

- Further data are needed on the distribution and abundance of all species. Priority concerns include:
  - the status of Indian Ocean populations;
  - the status of *T. crocea* in the Philippines;
  - the status of all species and the extent of trade in Indonesia.
- Several initiatives are being developed to survey and monitor coral reefs, and participants should be requested to gather information on clams at the same time. Some programmes already require that information is gathered on large benthic invertebrates such as clams. Munro (1993b) outlines specific methods available for surveying giant clams.
- Information on size distributions and species compositions of shells in middens in the Pacific could also provide valuable information on previous distribution and abundance.

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ANNEX 1. SUMMARY OF THE STATUS AND DISTRIBUTION OF GIANT CLAMS (Tridacnidae)

Hippopus hippopus (Linnaeus 1758) **Bear Paw Clam, Horse's Hoof Clam, Strawberry Clam**

IUCN Category: Lower Risk:Conservation Dependent

Native and extant: Australia, Federated States of Micronesia (Kosrae - Extinct), India*, Indonesia, Japan (Bonin and Ryukyus - Extinct*), Kiribati, Malaysia, Marshall Islands, Myanmar, New Caledonia, Northern Marianas (Extinct?; re-introduced), Palau, Papua New Guinea, Philippines, Singapore, Solomon Islands, Taiwan (Extinct?), Thailand?, Tuvalu, Vanuatu

Extinct: American Samoa (re-introduced), Fiji (re-introduced), Guam?, Tonga (recent fossils; re-introduced), Western Samoa (re-introduced)

Introduced: Cook Islands

Hippopus porcellanus (Rosewater 1982) **China Clam**

IUCN Category: Lower Risk:Conservation Dependent

Native and extant: Indonesia (around northern islands only), Palau, Philippines (Sulu and South China seas only)

Tridacna crocea (Lamarck 1819) **Crocus Clam, Saffron-coloured Clam, Boring Clam**

IUCN Category: Removed from the 1996 Red List

Native and extant: Australia, Guam (Extinct?), India (Andaman and Nicobars?), Indonesia, Japan, Malaysia, Northern Marianas (Extinct?), Palau, Papua New Guinea*, Philippines, Singapore, Solomon Islands, Taiwan?, Thailand, Tuvalu*, Vanuatu, Viet Nam*

Introduced: United States (Hawaii - Extinct)

N.B. The information provided above derives from Munro (1989), and other sources (see Annex 2 and main text). The IUCN Threatened status listings are as per IUCN (1996).

? = presence unconfirmed but within the distributional range mapped by Rosewater (1965)
* = information requires confirmation

Tridacna derasa (Röding, 1798) **Southern Giant Clam, Smooth Giant Clam**

IUCN Category: Vulnerable

Native and extant: Australia (including Cocos Keeling Islands), Fiji, Indonesia (Extinct in central islands), New Caledonia, Palau, Papua New Guinea, Philippines (very rare, extinct in many areas), Solomon Islands, Tonga, Tuvalu (probably occurred; introduced), Vanuatu (?Extinct or may never have occurred)

Extinct: Guam (re-introduced), Northern Marianas (re-introduced),

Introduced: American Samoa, Caribbean?, Cook Islands, Federated States of Micronesia, Hawaii?*, Marshall Islands, Western Samoa

Tridacna gigas (Linnaeus 1758) **Giant Clam**

IUCN Category: Vulnerable

Native and extant: Australia, Federated States of Micronesia (Extinct in most islands), Indonesia (Extinct in E. Sumatra and Java), Kiribati (Gilbert Is. only), Malaysia, Marshall Islands, Myanmar (southern waters only), Palau, Papua New Guinea, Philippines (Extinct in many areas), Solomon Islands, Taiwan (?Extinct), Thailand, Tuvalu (?Extinct, or may never have occurred), Vanuatu (?Extinct)

Extinct: Fiji (re-introduced), Guam (presumed extinct), Japan, New Caledonia (fossils only), Northern Marianas (re-introduced),

Introduced: American Samoa, Cook Islands, Tonga (Extinct), United States (Hawaii), Western Samoa (Extinct)

Tridacna maxima (Röding 1798) **Small Giant Clam**

IUCN Category: Lower Risk: Conservation Dependent

Native and extant: American Samoa, Australia, British Indian Ocean Territory (Chagos Archipelago)*, China, Comoros, Cook Islands, Egypt, Federated States of Micronesia, Fiji, French Polynesia, Guam, India (Andaman and Nicobars, Laccadives, mainland?), Indonesia, Japan, Kenya, Kiribati, Madagascar, Malaysia, Maldives, Marshall Islands, Mauritius, Mozambique, Myanmar, New Caledonia, Niue, Northern Marianas, Palau, Papua New Guinea, Philippines, Pitcairn Islands (abundant on Oeno, uncommon on Henderson Island)*, Réunion, Saudi Arabia, Seychelles, Singapore, Solomon Islands, Somalia?, South Africa, Sri Lanka, Taiwan, Tanzania, Thailand, Tokelau, Tonga, Tuvalu, Vanuatu, Viet Nam*, Wallis and Futuna, Western Samoa

Extinct: Hong Kong

Introduced: Caribbean, United States (Hawaii)

IUCN Category: Vulnerable

Native and extant: recently described from the Saya de Malha Bank Mauritius, where its status is unknown.

Tridacna squamosa (Lamarck 1819) **Scaly Clam, Fluted Clam**

IUCN Category: Lower Risk: Conservation Dependent

Native and extant: American Samoa, Australia, British Indian Ocean Territory (Chagos Archipelago)*, Comoros, Cook Islands, Egypt*, Federated States of Micronesia, Fiji, India (Andaman and Nicobars, Laccadives, mainland?), Indonesia, Japan (Extinct?), Kenya, Kiribati, Madagascar, Malaysia, Maldives, Marshall Islands, Mauritius, Mozambique, Myanmar, New Caledonia, Niue, Northern Marianas (Extinct?)*, Palau, Papua New Guinea, Philippines, Pitcairn Islands, Saudi Arabia, Seychelles, Singapore, Solomon Islands, Somalia?, South Africa, Sri Lanka, Taiwan?, Tanzania, Thailand, Tokelau, Tonga, Tuvalu, Vanuatu, Viet Nam*, Wallis and Futuna, Western Samoa

Extinct: Guam (re-introduced)

Introduced: United States (Hawaii), Caribbean

Tridacna tevoroa (Lucas, Ledua and Braley) **Tevoro Clam**

IUCN Category: Vulnerable

Native and extant: Fiji (Lau Islands), Tonga (Ha'apai and Vava'u Groups)

ANNEX 2. GIANT CLAM DISTRIBUTIONS AND STATUS IN RANGE STATES

American Samoa (USA)

(Bell, 1993b, CTSA 1990, Killelea-Almonte, 1992; Munro, 1989)

T. squamosa: Over-exploited and unlikely to recover naturally; some stocks available around Manu'a and Tutuila.
T. maxima: Over-exploited and unlikely to recover naturally, except abundant protected stock at Rose Atoll.
H. hippopus: Locally extinct.

Introductions and re-introductions: Between 1986 and 1991, *T. derasa* and *T. gigas* were introduced and *H. hippopus* was re-introduced from MMDC (Bell, 1993b; CTSA, 1990); several populations became extinct, but further.

Australia

(Braley, 1988a, 1993)

T. gigas: Abundant on parts of the Great Barrier Reef; natural breeding populations only north of 18 degrees S; limited by cold temperatures.
T. derasa: Occurs, abundant.
T. squamosa: Occurs, abundant.
T. maxima: Occurs, abundant.
T. crocea: Occurs, abundant.
H. hippopus: Occurs, abundant.

British Indian Ocean Territory (Chagos Archipelago)

T. maxima: Occurs.
T. squamosa: Occurs.

China

(UNEP/IUCN, 1988)

T. maxima: Occurs.

Other species almost certainly occur around offshore islands.

Comoros

(IUCN/UNEP, 1984)

T. squamosa: Occurs?
T. maxima: Occurs?

Cook Islands

(Anon, in press; Sims and Howard, 1988; Research Coordination Unit, 1993; Terekia, 1993)

T. maxima: Abundant in lagoons of larger atoll islands; less common on smaller atolls (e.g. Pukapuka and Rakahanga) and more populated high islands in Southern Group where environmental constraints (small reef area) and fishing pressure may limit its abundance; heavily exploited in 1970s for local use.

T. squamosa: Mainly found in depths greater than 10m, probably due to high fishing pressure in shallow waters; rarely found on outer reef slopes of Rarotonga and Aitutaki; heavily exploited in 1970s for local use.

Introductions and re-introductions: *T. derasa* introduced from MMDC in 1986 to Aitutaki; heavy predation by *Cymatium muricinum* and only 200 survived after a year (Sims and Howard, 1988; Terekia, 1993). Hatchery-reared *T. gigas* and ?*H. hippopus* introduced to Aitutaki from JCU (Terekia, 1993). Juvenile *T. squamosa* and *T. maxima* from Aitutaki hatchery restocked on local reefs c. 1993 (Terekia, 1993).

Egypt

(UNEP/IUCN, 1988)

T. maxima: Occurs (Red Sea).

Federated States Of Micronesia

(Killelea-Almonte, 1992; Smith, 1992a)

T. gigas: Extinct in known areas, although it could be present on remote atolls; once flourished in Yap but now only an occasional living specimen is found (Price and Fagolimul, 1988), although shells are often dredged up; relict populations on Lamotrek Atoll and West Fayu; recent fossils abundant in Kosrae, Pohnpei, Chuuk, Yap (Munro, 1989); extinct in Kosrae due to overfishing.

T. maxima: Most common species but declined in areas of heavy fishing.

T. squamosa: Low to very low numbers in Yap, Chuuk and Pohnpei; no longer found in Kosrae; heavily fished.

H. hippopus: Rare in Kosrae due to overfishing; declining in Pohnpei since ommercial harvest began in 1986; very low numbers elsewhere.

Introductions and re-introductions: *T. derasa* is not reported from scientific literature (Munro, 1989), but large numbers introduced to ocean-grow out nursery in Yap in 1984 from MMDC, and distributed to 31 sites around Yap (Price and Fagolimul, 1988); c. 8% survival and low numbers of offspring found on reefs (Lindsay, 1994). Also introduced to all three other FSM states from MMDC (Eldredge, 1993). FSM National Aquaculture Centre on Kosrae distributed 3,000 *T. derasa* to Chuuk, Yap, Pohnpei and other sites in Kosrae in 1992 (Lindsay, 1993). *T. gigas* restocked on Chuuk, Yap and Kosrae from MMDC in 1991, Pohnpei from MMDC in 1990, and on some islands from Marshall Is. in 1991 (Eldredge, 1993). *H. hippopus* restocked from MMDC in 1991 and from Marshall Is. in 1992 (Eldredge, 1993).

Fiji
(Lewis *et al.*, 1988)

T. maxima: Overfished especially near population centres.
T. derasa: Overfished especially near population centres; most abundant in windward, eastern islands.
T. squamosa: Overfished especially near population centres.
T. tevoroa: ('tevoro'); rare, Lau Islands, but low abundance compared with other species (Lucas *et al.*, 1991).
T. gigas: Extinct and probably never common (or may not have occurred: last known specimens collected in 1970s and could have been confused with *T. derasa*)
H. hippopus: Extinct, only fossil records.

Introductions and re-introductions: *T. gigas* successfully introduced 1986, 1987, 1990 from JCU (Ledua and Adams, 1988; Eldredge, 1993); *T. derasa* from local hatcheries being restocked on local reefs (Ledua and Batibasaga, in press); re-introduced from MMDC in 1985 but stock died (Eldredge, 1993). *T. tevoroa* restocked from Tonga (Eldredge, 1993). *H. hippopus* re-introduced 1991 from JCU (Eldredge, 1993).

French Polynesia (France)
(Munro, 1989; Richard, 1977)

T. maxima: Heavily exploited near population centres, but local abundances, especially in atoll lagoons; scattered on outer slopes of fringing reefs of high volcanic islands.

Guam
(Munro, 1989)

T. maxima: Occurs.
T. derasa: Extinct through overfishing.
T. crocea: Presumed extinct through overfishing.
T. gigas: Presumed extinct through overfishing.
T. squamosa: Presumed extinct through overfishing.
H. hippopus: Presumed extinct through overfishing.

Introductions and re-introductions: *T. derasa* re-introduced from MMDC on several occasions. Unsuccessful re-introductions of *T. gigas* and *T. squamosa* from MMDC in 1982 (Eldredge, 1993).

Hong Kong
(Morton and Morton, 1983)

T. maxima: Extinct.

India
(Ramadoss, 1983)

T. squamosa: Andaman and Nicobars, Laccadives.
T. maxima: Andaman and Nicobars, Laccadives.
T. crocea: Andaman and Nicobars.
H. hippopus: Andaman and Nicobars?

Indonesia
(Pasaribu, 1988; Munro, 1989; Usher, 1984; Brown and Muskanofola, 1985)

T. gigas: All coastal waters; marked decline; possibly eliminated from western regions (Eastern Sumatra and Java).
T. derasa: All coastal waters except northern Sumatra; marked decline; possibly eliminated from western regions (Eastern Sumatra and Java).
T. squamosa: All coastal waters.
T. maxima: All coastal waters.
T. crocea: Many areas.
H. hippopus: All coastal waters.
H. porcellanus: North coast only; marked decline.

Japan
(Munro, 1989; Shang *et al.*, 1990)

T. gigas: Extinct.
T. crocea: Overfished in Okinawan waters.
T. squamosa: Overfished in Okinawan waters.
T. maxima: Occurs.

Shang *et al.* (1990) list *H. hippopus* (also listed by Rosewater, 1965) but not *T. maxima*.

Introductions and re-introductions: Ishigaki Island hatchery donates c. 200,000 one-year-old seed *T. crocea* annually to fishermen's co-operatives, for release into surrounding waters (Shang *et al.*, 1990).

Kenya
(IUCN/UNEP, 1984)

T. squamosa: Occurs.
T. maxima: Occurs.

Kiribati
(Munro, 1986; Taniera, 1988)

T. gigas:	Uncommon; very limited at Tarawa but moderate to good elsewhere in Gilbert Islands; absent in Line and Phoenix Islands.
T. squamosa	Gilbert Is, possibly Phoenix Is.
T. maxima:	Most widely distributed species: Gilbert, Phoenix and Line Is.
H. hippopus	Gilbert Is.

Madagascar
(IUCN/UNEP, 1984)

T. maxima:	Occurs.
T. squamosa:	Occurs.

Malaysia
(Munro, 1989; Malaysia CITES MA, *in litt.* to CITES Secretariat, 1995)

T. gigas:	Off coast of Sabah.
T. squamosa:	Islands off east coast of W. Malaysia.[peninsular m.?]
T. maxima:	Islands off east coast of W. Malaysia.
T. crocea:	Islands off east coast of W. Malaysia.
H. hippopus:	Not confirmed.

Maldives
(Barker, 1991; Lucas 1994)

T. squamosa:	Occurs, but heavily fished.
T. maxima:	Occurs.

Marshall Islands
(Munro, 1989; Smith, 1992b)

T. gigas:	Severely depleted on some atolls but still present.
T. squamosa:	Widespread but in low to very low numbers.
T. maxima:	Most common species.
H. hippopus:	Widespread but varies in abundance.

More detailed information on the northern atolls available in Thomas (1989). *T. crocea* listed in fossil record for Enewetak.

Introductions and re-introductions: *T. derasa* introduced 1985, 1989, 1990 from MMDC to various locations (CTSA, 1990; Eldredge, 1993).

Mauritius
(IUCN/UNEP, 1984; Sirenko and Scarlato, 1991)

T. rosewateri: Saya de Malha Bank.
T. maxima: Occurs.
T. squamosa: Occurs.

According to the Mauritius CITES Management Authority *(in litt.* to CITES Secretariat, 1995), *H. hippopus* also occurs in Mauritius, but this has not been confirmed in the scientific literature.

Mozambique
(IUCN/UNEP, 1984)

T. squamosa: Occurs.
T. maxima: Occurs.

Myanmar
(Munro, 1989)

T. gigas: Confined to southern waters.
T. squamosa: Occurs.
T. maxima: Occurs.
H. hippopus: Occurs.

New Caledonia (France)
(Munro, 1989)

T. gigas: Extinct; only present as fossils.
T. derasa: Present.
T. squamosa: Present.
T. maxima: Present.
H. hippopus: Present.

Niue
(Dalzell *et al.*, 1993; Bell 1993a)

T. maxima: Moderate exploitation; stock density low (89/ha), but not under threat.
T. squamosa: Moderate exploitation; stock density very low (14/ha); population may no longer be self-sustaining.

Northern Marianas (USA)
(Munro, 1989)

T. gigas:	Extinct.
T. derasa:	Extinct.
T. squamosa:	Extinct?
T. maxima:	Occurs.
T. crocea:	Extinct?
H. hippopus:	Extinct?

Introductions and re-introductions: *T. gigas* re-introduced from MMDC to Saipan 1991; *T. derasa* re-introduced from MMDC to Saipan 1986, 1987, 1988, 1991; *H. hippopus* re-introduced from MMDC to Saipan 1991 (Eldredge 1993).

Palau
(Munro, 1989; Nichols, 1991)

T. gigas:	Locally rare.
T. derasa:	Occurs.
T. squamosa:	Occurs.
T. maxima:	Occurs.
T. crocea:	Occurs.
H. hippopus:	Occurs.
H. porcellanus:	Occurs.

No recent information as no survey work has been undertaken since the early 1980s.

Papua New Guinea
(Munro, 1989).

T. gigas:	Locally rare, especially on nearshore reefs or near main towns.
T. derasa:	Not found near the mainland.
T. squamosa:	Occurs.
T. maxima:	Occurs.
H. hippopus:	Occurs.
T. crocea:	Occurs

Philippines
(Alcala, 1986; Calumpong and Cadiz, 1993; Gomez and Alcala, 1988; Juinio *et al.*, 1986; Mingoa-Licuanan, 1993 and *in litt.* to S. Wells 1994; Munro, 1989).

T. gigas:	Extinct in most areas, except extreme south; no longer found in Central Visayas; last stronghold in the Sulu Archipelago; considered endangered.
T. derasa:	Extinct in many areas; no longer found in Central Visayas; last stronghold in the Sulu Archipelago with one population at Guinan (Samar); considered endangered.
T. squamosa:	Occurs; declined in Central Visayas since 1976.
T. maxima:	Occurs; still fairly abundant in some areas e.g. Cagayan, and populations may be fairly stable.

T. crocea: Occurs; still fairly abundant in some areas e.g. Polillo and Palawan, and populations may be fairly stable.

H. hippopus: Occurs; not abundant; last stronghold in S. Palawan and population west of Zambales.

H. porcellanus: Confined to south in Sulu and S. China Seas; considered endangered.

Introductions and re-introductions: 25 sites restocked with over 20,000 juveniles of 7 species from 1986 to 1992; only 9.8% confirmed survival in 1993; include *T. derasa* from MMDC introduced to seven sites (Estacion, 1988; Calumpong and Solis-Duran, 1994).

Pitcairn Islands (UK)
(Paulay, 1989)

T. squamosa: Common on Ducie; occasional on Henderson.

T. maxima: Abundant on Oeno; uncommon on Henderson; very scarce on Ducie (but sub fossil shells indicate it was common in the past).

Reunion (France)
(IUCN/UNEP, 1984)

T. squamosa: Occurs.

T. maxima: Occurs.

Saudi Arabia
(Bodoy, 1984)

T. squamosa: Occurs.

T. maxima: Occurs.

Seychelles
(IUCN/UNEP, 1984)

T. maxima: Occurs.

T. squamosa: Occurs.

Both species notably decreased around the granitic islands.

Singapore
(Munro, 1989)

T. squamosa: Occurs.
T. maxima: Occurs.
T. crocea: Occurs.
H. hippopus: Occurs.

All species very rare.

Solomon Islands
(Govan *et al.*, 1988; Munro, 1989; Oengpepa, 1993)

T. gigas: Widespread but in low numbers and overfished in areas of high population density.
T. derasa: Restricted; only observed in Marau Sound, Nggela, Russel Is, and north Marovo Lagoon but may occur elsewhere.
T. squamosa: Widespread.
T. maxima: Widespread.
T. crocea: Widespread; probably most abundant species.
H. hippopus: Restricted, but not as rare as *T. derasa*.

Somalia

T. maxima: ?
T. squamosa: ?

South Africa
(Munro, 1989)

T. squamosa: Occurs.
T. maxima: Occurs.

Confined to extreme north-east waters; not used.

Sri Lanka
(Munro, 1989)

T. squamosa: Occurs.
T. maxima: Occurs.

Taiwan
(Tisdell and Chen, 1994)

T. gigas: Extinct, probably through overexploitation.
T. maxima: Occurs around most of the coast.
H. hippopus: Occurs only on Penghu Island and Hengchun Peninsula.
T. crocea: May still occur.

Tanzania
(IUCN/UNEP, 1984)

T. squamosa: Occurs.
T. maxima: Occurs.

Thailand
(Munro, 1989)

T. gigas: Occurs.
T. squamosa: Occurs.
T. maxima: Occurs.
H. hippopus: May occur.
T. crocea: Occurs

Tokelau
(Munro, 1989)

T. squamosa: Heavily exploited (Munro (1989) queries occurrence).
T. maxima: Heavily exploited.

Tonga
(Munro, 1989; McKoy, 1980; Langi and 'Aloua, 1988)

T. maxima: Most abundant species; overfished especially near population centres.
T. derasa: Overfished especially near population centres.
T. squamosa: Overfished especially near population centres.
T. tevoroa: Ha'apai, Vava'u and Tongatapu (Sone,1996; Lucas *et al.*, 1990, 1991; Bell *et al.*, 1994).
H. hippopus: Extinct but recent fossils.

Surveys carried out in late 1980s (Langi and 'Aloua, 1988) compared survey in 1978-79 by McKoy (1980) and found many sites with much lower abundance. *T. gigas* may once have been present but no recent records (Bell *et.al.*, 1994)

Introductions and re-introductions: *T. gigas* introduced from JCU 1991 but died out; *H. hippopus* re-introduced from JCU 1991 (Eldredge, 1993; Bell *et.al.*, 1994).

Tuvalu
(Munro, 1989; Braley, 1988b)

T. gigas: Very rare, possibly extinct (or may never have occurred).
T. squamosa: Overfished; stock densities low (0.7-1.4/ha).
T. maxima: Overfished; stock densities low (3-101/ha).
H. hippopus: Overfished.

T. derasa and *T. crocea* presence unconfirmed. All species heavily exploited near villages for subsistence purposes, but some healthy stocks.

Introductions and re-introductions: *T. derasa* introduced from MMDC in 1989; only 146 surviving by 1990 (Tacconi and Tisdell, 1992; Eldredge, 1993).

Vanuatu

(Munro, 1989; Zann and Ayling, 1990; Bell and Amos, 1993)

T. squamosa: Patchy or rare, probably naturally.
T. maxima: Common and stocks secure.
T. crocea: Patchy or rare, probably naturally.
H. hippopus: Patchy or rare; overfished on inhabited islands; most common on uninhabited Cook Reef and Reef Islands; absent from heavily populated areas such as Malekula.

T. derasa and *T. gigas* are either very rare or absent, although Vanuatu was included in their range by Rosewater (1965); no recent reports.

Viet Nam

T. squamosa: Probably occurs.
T. maxima: Probably occurs.
T. crocea: Probably occurs.

Wallis And Futuna (France)

(Tisdell, 1993)

T. maxima: Occurs.
T. squamosa: Occurs.

No survey has been carried out but no evidence of a decline.

Western Samoa

(Munro, 1989)

T. maxima: Heavily overfished throughout.
T. squamosa: Very rare through overfishing.
H. hippopus: Extinct.

Introductions and re-introductions: *T. derasa* introduced 1984 from MMDC (CTSA, 1990), but have not become established; *H. hippopus* re-introduced from JCU in 1991, and from CAC 1990 and 1992 (all died). *T. gigas* introduced from JCU 1990 and 1991 but lost in cyclones. *T. squamosa* re-stocked from Tokelau and Fiji (Eldredge, 1993; Bell, 1995).

ANNEX 3. LEGISLATION RELATING TO GIANT CLAM HARVEST AND EXPORT

(*This does not cover traditional tenure and customary rights*)

American Samoa (USA)

Fishing Regulations May 1990
For all tridacnids that are collected for sale or purchase, minimum size limit of 7ins measured across longest part of shell; tridacnids taken for non-commercial purposes have a minimum size limit of 6ins. Clams that are sold or offered for sale must be whole, with the meat still attached to the shell. A commercial fishing licence is required for the commercial harvest of all tridacnid species.

Australia

Queensland Fisheries Act 1976
Collection of all species prohibited except by Aboriginal people (Braley, 1993). Permits may also be issued to allow small-scale collection of clams for scientific purposes and to obtain new broodstock for mariculture operations.

Wildlife Protection (Regulation of Exports and Imports) Act 1982
Commercial imports and exports of specimens from wild populations of all CITES-listed Appendix II species (and native Australian species) are only permitted, under permit, if they are obtained from populations that are managed in accordance with one of two forms of management prescribed under the Act: 'approved management programmes' or 'controlled specimens'. The legislation (supplemented by the regulations of the Act), prescribes the elements that must be taken into account in approving these two forms of management schemes. The requirements for approved management programmes are stricter than those for controlled specimens. Australia does not consider any wild populations of giant clams to meet these conditions, and thus import and export of tridacnids is prohibited under this legislation.

Commercial import of captive bred Appendix I or II animal species is permitted, provided they meet the definition of captive bred as prescribed in the regulations.

Specimens are permitted to be brought into the country for the purposes of transhipment, without the granting of an import permit, provided they meet certain criteria outlined in Section 8 of the Act. Specimens are only considered to be transhipped if: they are going to an identified person in another country; delays in the goods leaving Australia are solely due to transport arrangements; and the specimens remain under Customs control while in Australia.

China

List of Nationally Protected Wild Animals, 1989
Tridacna cookiana (= ?*gigas*) listed; ?protected or possession and/or national and international trade prohibited or regulated.

Cook Islands (New Zealand)

Aitutaki Fisheries Protection By-Laws 1990
Part 1, Taking of shellfish prohibited with the exception of *Tridacna maxima* (Paua) for which a permit may be granted subject to certain conditions: a) sale within the areas to which the by-laws apply; b) consumption at any function e.g. wedding, funeral, where large numbers of the public are likely to attend; c) export for sale provided the proceeds of such sale are utilised in a project in Aitutaki or for the benefit of the residents of Aitutaki (whether such project shall be situated on Aitutaki or any other island in the Cook Islands). As stated in sections 4 and 5 of the By-laws a size limit of 3 inches and a maximum daily number of 20 is set for *Tridacna maxima*.

Tridacnids are covered by general restrictions for the Cook Islands on the harvesting and export of marine products. New fisheries legislation is being drafted for Rarotonga. Manihiki has restricted the export of giant clams from the island as a pre-emptive measure (C. Brown, *in litt.* to CITES Secretariat, 1995).

Federated States of Micronesia

Yap State Code, Title 18, Section 1006, Protection of Clams
Clam meat may not be sold commercially; the Governor is authorised to declare a harvesting season and set a size limit but this has not been done.

Fiji

Fisheries Act (Cap. 158) 1942 (Ed. 1992)
Regulations of 16 December 1988. Exports of meat of *T. derasa, T. squamosa* and *T. maxima* prohibited unless it can be proved that the meat originated in a mariculture programme. It is understood that this legislation is to apply for a ten-year period. Domestic harvesting and sale is not regulated, but exploitation guidelines were drawn up by the Fisheries Division in Fiji in 1984. These require that harvesting is restricted to Fiji nationals and to uninhabited islands and reefs, with the approval of the traditional custodians and with maximum involvement of village fishermen. Information on catch size must be supplied to the Fisheries Divisions. Before the implementation of the ten-year moratorium, exports had to be inspected, and the export of adductor only, or meat without the shell was discouraged (Lewis *et al.*, 1988).

Guam (USA)

Government Code of Guam, Title 16, Administrative Rules and Regulations, Fishing Regulations. Subchapter B.

Section 15311.3. Commercial harvesting of all *Tridacna* spp. and *H. hippopus* is prohibited, except for cultured specimens produced in a government approved culture facility.

Section 15311.4. Giant Clams harvested for personal use are subject to the following regulations: a) a minimum size limit (shell length) of 7 ins; b) a bag limit of 3 clams/person/day (and clams must be preserved whole until cooked); and c) harvesting is not permitted in designated preserves and/or sanctuaries, and in two additional areas specified in the legislation.

India

Wildlife (Protection) Act 1972
Export for commercial purposes of all Appendix II-listed species is banned under a 1989 amendment of this act.

Indonesia

Ministerial Decree No. 12/Kpts-II 12 January 1987
Harvest and sale without permits of all Giant Clams are prohibited under this decree of the Ministry of Forestry(Pasaribu, 1988). Permits are only issued in exceptional circumstances. Under the Act of the Republic of Indonesia on Conservation of Living Resources and Ecosystems (1990), intentional trade in protected species is punishable by imprisonment for up to a maximum of 5 years and by a fine of up to Rp 100,000,000 (US$50,000).

Japan

Prefecture Regulation of Fishery Adjustment, Okinawa 12 September 1972
Closed season for giant clam fishing in Okinawa from June to August; minimum legal catch size is 8 cm shell length for *T. crocea*, 15 cm for *H. hippopus*, 20 cm for *T. squamosa* and 30 cm for *T. derasa*. Fishermen must be licensed.

Prefecture Regulation of Fishery Adjustment, Tokyo, 26 June 1968
Closed season in the Ogasawa Islands is July-August; minimum size limit of 15 cm. Fishermen must be licensed.

Maldives

Commercial giant clam fishing now banned (Shakeel, 1994), although the previous commercial clam fishery was regulated through export licences.

Mauritius

Fisheries Regulation 1983
Tridacna spp. listed as 'toxic species': landing prohibited.

Palau (USA)

Title 24: Environmental Protection, Chap. 12: Protected Sea Life, Subchapter VI of the Palau National Code
Commercial export of *T. gigas, T. squamosa, T. derasa. T. maxima, T. crocea, H. hippopus* prohibited.

Section 1008 of the Endangered Species Act
Commercially cultured clams exempted from the ban.

Papua New Guinea

Export of meat and muscle prohibited in 1988

Philippines

Fisheries Administrative Order No. 168
22 May 1990: Collection of *T. derasa*, *T. gigas* and *H. porcellanus* prohibited; gathering of other giant clam species allowed under permit. Export of all shelled molluscs and/or their derivatives of species listed in the CITES Appendices prohibited, except those obtained from cultured stock.

Fisheries Administrative Order No. 168-1
15 September 1991: exempted *T. crocea* from the export ban. On 4 April 1996, this was suspended indefinitely. Subsequently, export of all tridacnid species is banned.

Singapore

Endangered Species (Import and Export) Act 1989
Trade in clams is regulated under this legislation through the issuance of CITES permits, but collection and export of wild specimens from Singapore waters is only allowed under special circumstances, e.g. for research (Singapore CITES Management Authority, *in litt.* To CITES Secretariat, 1995).

Solomon Islands

A licence issued by the Fisheries Division is required for commercial fishing of any kind, and current policy is that permits should not be issued for commercial clam fishing (Skewes, 1990). In January 1994 the Government stated that export permits would only be issued for cultured specimens.

Taiwan

On 1 March 1984, Taiwanese vessels were prohibited from harvesting shellfish, including tridacnids, from coastal waters of countries with which Taiwan has concluded coastal fishing agreements (Council of Agriculture, Taiwan *in litt.* to TRAFFIC Taipei, 1995). Import of fresh and frozen clam meat is reportedly prohibited (Tisdell and Chen, 1994).

Tonga

Fisheries Act 1989
Under Cabinet Decision No. 1863 of 22 December 1993: Harvesting of clams for commercial export is prohibited, except those produced by mariculture. Clams may still be harvested for domestic consumption and the souvenir trade. Fisheries regulations for clams, with minimum size limits have been proposed (Bell *et al.*, 1994)

USA

Clams are classified as filter feeders by the US Food and Drug Administration (FDA) and cannot be imported into the USA and its territories for human consumption from countries that do not have a shellfish sanitation programme that is recognised by the FDA (Crawford, 1992).

The Lacey Act prohibits the import of wildlife imported and/or traded in violation of the laws of the country of export.

Western Samoa

No legislation yet, but it has been recommended that a ban on exploitation should be introduced.

East Africa

T. squamosa and *T. maxima* are listed on Appendix II of the Protocol on Protected Areas and on Wild Fauna and Flora of the Convention for the Protection, Management and Development of the Marine Environment and the Coastal Areas of the East African Region (which includes the Comoros, France (Reunion), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia and Tanzania). This has not yet come into force, but when it does, parties will be required to take all appropriate measures to ensure the strictest protection of these species, which are not considered exploitable under the Protocol.

ANNEX 4. GIANT CLAM MARICULTURE PROGRAMMES

American Samoa (USA)

Department of Marine and Wildlife Resources: *T.derasa*, *T. gigas*, *T. maxima* and *H. hippopus* being cultured at government hatchery (with support from CTSA, Pacific Aquaculture Development Program, Pacific Island Network) with the main aim of establishing local farms to produce meat for local market. Principal focus is on *T.derasa* and *H. hippopus*. There are six lagoon nursery sites of which at least three are family managed. As of September 1995, 25 farms were operating (Killelea-Almonte, 1992; Lindsay, 1993; Bell, 1993a,b; CTSA 1996).

Australia

Reefarm, Fitzroy I., Queensland: privately owned operation since 1984; supply mainly *T. crocea*, *T. maxima* and *T. gigas* for aquarium trade in Taiwan and Japan; also spat and meat for sashimi market. Grow-out takes place in large tanks on land; not yet commercially viable from clam exports; deficit made up by showing tourists around; they have a permit for a grow-out facility on Arlington Reef (Sant pers. comm., 1993; Tisdell, 1992; Braley, 1993; Tisdell *et al.*, 1994).

Three other operations are now closed:

- James Cook University (Orpheus Island) (supported by Australian Centre for International Agricultural Research from 1984-1992): culture facility closed with termination of project; main focus was *T. gigas*; primarily a research operation in collaboration with South Pacific nations to develop culture technology.
- Pacific Clams Pty Ltd., Sudbury Reef: reportedly destroyed by cyclone.
- Aquasearch: held cultured F1 *T. gigas* and *H. hippopus* at Great Palm Island and Magnetic Island (Braley, 1993).

W.A. Clams: 1989 application to farm *T.gigas* in Exmouth Gulf, Western Australia in the early 1990s (Braley, 1993; Tisdell *et al.*, 1994).

Caribbean

Fundashon Marcultura, Bonaire, Netherlands Antilles: *T. derasa* from MMDC in 1988 and *T. maxima* and *T. crocea* from wholesalers in Miami for culture (Williams and Sindermann, 1992; Williams and Bunkley-Williams, 1990; Eldredge, 1993).

Clams have reportedly been cultured in Guadeloupe and S. Florida (Eldredge, 1993).

Cook Islands

Hatchery built 1990/91 at Aitutaki, with ACIAR assistance, for restocking reefs; *T.maxima* and *T. sqamosa* have been reared (Terekia, 1993), but reportedly ceased operations (Research Co-ordination Unit, 1994). *T. squamosa* and *T. derasa* successfully spawned and reared at Araura Marine Research Station, and reseeding of reefs planned (Bertram *et al.*, 1995).

Federated States of Micronesia

Kosrae: FSM National Aquaculture Center established in 1991; produced *T. gigas*, *T. derasa*, *H. hippopus* for reseeding reef throughout the FSM; no plans to produce clams for commercial sale (Killelea-Almonte, 1992; Lindsay, 1993; Smith, 1992a). 50,000 *H.hippopus* produced in 1993; several locally operated extension farms established (Lindsay, 1994).

Pohnpei: in 1992, Marine Resources Division hatchery near Kolonia had 90 *T. derasa*, 600 1 yr-old *T.gigas*, 40,000 4 month-old *H. hippopus*. *T. derasa* successfully spawned in 1992, and juveniles will be stocked in ocean nurseries; main focus is conservation although clams have been sold to two local Japanese restaurants. 5 grow-out farms run by private owners of local resorts on the barrier reef have been set up to grow out *H. hippopus* (Killelea-Almonte, 1992; Lindsay, 1993; Smith, 1992a).

Chuuk: 2 small privately owned farms on main island (Lindsay, 1994)

Yap: reseeding programme since 1984; c. 25,000 *T. derasa* reseeded; c. 8% survival; offspring of introduced stock found on reefs in low numbers.

Fiji

Makogai Hatchery: focuses on *T. derasa* for restocking local reefs, but also producing *T. maxima* and *T. squamosa* on a regular basis; parent stock from nearby islands and Lau group, with 150 *T. gigas* broodstock imported from Australia in 1980 and 15,000 *H. hippopus* in 1992; *T. tevoroa* from Tonga also in hatchery; 100,000-200,000 juveniles (mainly *T. derasa* and *T. squamosa*) being produced a year in total; clams being supplied to US aquarium company; small village farms also being established (Ledua *et al.*, 1994; Bell, 1993a; Ledua, 1993; Saqata, 1994).

Guam (USA)

Guam Aquaculture Development and Training Center: Hatchery received *T. derasa* from MMDC, but stock low due to 1992 cyclone damage (Lindsay, 1993); c. 100 specimens held in 1994 as potential broodstock but no culture programme (Fitzgerald *in litt.* to S. Wells 1994).

Indonesia

Preliminary study and unsuccessful attempt to culture clams in 1980s (Panggabean, 1987; Pasaribu, 1988); research underway in Pulau Seribu (through National Institute of Oceanology) and in Karimunjawa (through Diponegro University) (Tisdell, 1992). Hatchery at Hasanuddin University (Barrang Lompo) successfully producing *T. gigas* and *T. derasa* which have been translocated to Taka Bone Rate Atoll (Braley, 1995 a,b, 1996; Pasaribu *et al.*, 1995).

Japan

Government-run hatchery on Ishigaki Island (Okinawa) since 1988 producing *T. crocea* and *T. squamosa* for release locally through fishing co-operatives (Shang *et al.*, 1990). 453,000 *T.crocea* and 18,000 *T. squamosa* produced in 1992; former released to 16 sites and latter to 3 sites. 270,000 *T.crocea* produced in 1993 and released at 16 sites (Ishihara *in litt.* to S. Wells, 1994).

Malaysia

Fisheries Department: hatchery on west coast of Sabah had *T. gigas*, *T. squamosa* and *T. derasa* but may no longer be functioning (Ostrowski, 1993).

Maldives

Experimental culture started at Marine Research Station, Ministry of Fisheries and Agriculture for *T. squamosa* and *T. maxima* (Shakeel, 1993, 1994).

Marshall Islands

Marshall Islands Marine Resources Authority (MIMRA) on Likiep atoll: has *T. derasa* from MMDC and *T. gigas, T maxima, T. squamosa* and *H. hippopus* collected locally (Lindsay, 1993; Smith, 1992b, Dalton, 1995). MIMRA provides 3-4 cm clams for distribution to local atoll governments and private interests including MIMRA-trained farmers, to raise clams for export for the aquarium market.

Robert Reimers' Enterprises (private operation on Wau I., Mili Atoll) started in 1986; carries out land-based and lagoon farming; produces *T.gigas* for Japanese restaurants, *T. maxima* for the aquarium trade, *T. squamosa*, and *H. hippopus* for re-seeding (Killelea-Almonte, 1992; Lindsay, 1993; Smith, 1992b).

Marshall Islands Aquaculture Farmers Co-operative, Bue I., Mihi Atoll: a private company with the largest farm, producing *T. gigas*, *T. derasa*, *T. maxima*, *T. squamosa*, *H. hippopus*; trial shipment in 1991 of aquarium specimens to Los Angeles (Killelea-Almonte, 1992; Leung *et al.*, 1994; Heyman and Skinner, 1993).

Ebeye, Kwajalein Atoll: reportedly has a clam farm funded by Kwajalein Atoll Development Authority, with *T. derasa* from MMDC (Smith, 1992b).

Training courses have been held on four atolls for local clam farmers to grow out *T. derasa* supplied by MMDC and a number of grow-out farms now exist e.g. Kalalin (Majuro Atoll) has *T. derasa* and *T. gigas* obtained locally and additional *T. derasa* from MMDC (Smith, 1992b).

New Caledonia (France)

Feasibility study began in 1992 as part of programme to develop mariculture, with focus on *H. hippopus* (Galinie, 1994) and is continuing (Pham, 1996).

Niue

Assessment of costs and benefits carried out (Bell, 1993a); recommended that proper management of existing stocks would be better than introducing clams for a hatchery (Bell and Gervis, 1994).

Palau

MMDC is now closed but was the largest giant clam culture facility in the Pacific. Established 1973, funded by Pacific Development Foundation (NMFS/NOAA), USDI, FAO and other agencies; cultured seven species and potentially could produce one million giant clams a year. In 1990 produced 1,353,296 5-month old seed clams; revenue from clam hatchery sales was $122,097. Marketed clams locally in Palau; gift shop sold shell souvenirs and handicrafts; until 1992 marketed internationally for food, aquariums and seed to Japan, Philippines and Europe but ceased because of CITES problems; *T.derasa* was the main focus and were eventually produced entirely from F1 and F2 broodstock (i.e. no wild-caught clams involved). Seed and broodstock donated to all states in Palau and FSM with aim of establishing small demonstration farms and sanctuaries; mariculture training courses held (Heslinga *et al.*, 1988; Killelea-Almonte, 1992; Nichols, 1991; Leung *et al.*, 1994).

Papua New Guinea

No hatchery yet; research on giant clam farming was carried out 1984-87 at the Motupore Island Research Centre, University of Papua New Guinea and the Christensen Research Institute, Madang as part of ACIAR project (Bell and Pernetta, 1988).

Philippines

Silliman University Marine Laboratory, Dumaguete: has been providing *T. crocea*, *T. derasa*, *T. maxima*, *T. squamosa*, *H. hippopus*, *H. porcellanus* for village-managed grow-out sites (Alcazar, 1988; Calumpong, 1992, 1993).

University of the Philippines Marine Science Institute (UPMSI), Bolinao: broodstock from Luzon and the Visayas installed in 1986; *T. maxima*, *T. squamosa*, *H. hippopus*, *T. derasa* and *T. crocea* successfully reared (Trinidad-Roa, 1988; Mingoa-Licuanan, 1993). C. 4,000 *T.gigas* sent from JCU and CAC. In 1994, UPMSI sent trial shipment of 4 species to Germany for aquarium market (Knop, 1995b).

Seychelles

Praslin Ocean Farm (Pty) Ltd: produces *T. maxima* for German aquarium trade (Bauer *in litt.* to S. Wells 1994). A popular by-product is silver or gold coated shells for jewelry for locals and tourists; production trials with *T. squamosa* were unsuccessful (Nilson, 1995).

Solomon Islands

ICLARM Coastal Aquaculture Centre, Honiara, in collaboration with the Fisheries Department: set up to produce meat from *T.gigas*, which have been supplied to local ocean nurseries in several village trials; *H. hippopus* raised since 1991. 6 species now produced; focus is for the aquarium trade and establishing markets based on live clams (*H.hippopus)* for seafood trade; some exported for culture purposes; others used in village grow-out (Bell, 1993a; Bell *in litt.* to S. Wells 1993; Oengpepa, 1993; Bell and Gervis *in litt.*to S. Wells 1994; Hart and Lasi, 1996).

Paruru Giant Clam Farm, Marau Sound, s.e. Guadalcanal: privately owned, started 1994; land-based facility to hold juveniles before being placed in ocean nursery grow-out sites; larvae to be provided by CAC.

Tonga

Ministry of Agriculture, Fisheries and Forestry hatchery: set up as part of ACIAR project in collaboration with JCU, now with assistance from JICA; initial focus on native *T. derasa*; now 5 species produced including *T. squamosa, T. tevoroa, T. gigas*, and *H. hippopus* (Bell, 1993a) and seveeral ocean nurseries established (Bell *et al.* 1994, Sone, 1995, 1996). Potential markets in Japan (live clams for restaurants and for aquarium trade).

Tuvalu

Hatchery proposed but construction deferred because of limited staff in the Fisheries Division (Tacconi & Tisdell, 1993).

United States (Hawaii).

Indo-Pacific Sea Farms initiated five-year research project at Keahole Point, Hawaii, on aquaculture of ornamental marine invertebrates, including giant clams, for aquarium trade (Heslinga, 1996).

Western Samoa

Fisheries Division hatchery: Two village hatcheries on Savai'i established in 1994 and 1995 (Bell, 1995); received surplus clams from ACIAR programme when this closed down.

Namu'a Aquaculture - private hatchery/grow-out facility on Namu'a Island since 1989, assisted by Fisheries Division; not yet operating commercially - heavily damaged by cyclones; *T. derasa*, *T. gigas*, and *T. squamosa* clam seed obtained from Fisheries Division and also from overseas - c. 4,000 clams in 1993 (Tisdell, 1992; Tacconi and Tisdell, 1992a, b).