Giant Clams in Asia and the Pacific

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Giant Clams in Asia and the Pacific

Editors: **J.W. Copland and J.S. Lucas**

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Contents

Foreword

Farming giant clams, the huge bivalve shellfish found on Australia's Great Barrier Reef and the tropical reefs of the Indo-Pacific Ocean, could become a significant new industry in Australia and in countries of Southeast Asia and the South Pacific.

Results presented at a workshop at James Cook University in April 1988 indicate that the culture of giant tridacnid clams is both technically and economically viable, with markets for both clam meat, particularly in Taiwan and Japan, and for the shells. The latter are used in a variety of ways, and can be marketed through the well-established shell trade.

This publication brings together the literature and results of most of the world's research on giant clams, most of which was presented at the workshop, and is likely to be a benchmark on the knowledge and potential of giant clams for the restocking of tropical reefs, and farming clams both extensively and intensively, in the Indo-Pacific region.

Throughout much of their geographic range, giant clams have been overexploited, and in some areas of Indonesia, the Philippines, Micronesia and southern Japan some species are now extinct. Because the clams require clean, shallow, warm seawater and plenty of sunlight to survive, they are easy prey for fishermen. The research work reported here will make it possible to restock the areas where the two largest species, *Tridacna gigas* and *Tridacna derasa*, were once plentiful, and help establish a reliable additional source of valuable food protein for people throughout the region.

There are many problems to be overcome before the farming of giant clams becomes an established new industry. The research so far strongly indicates that clam mariculture has considerable potential even at this early stage of development.

ACIAR is pleased to have played a pioneering role in this exciting research, and we believe this publication will serve to stimulate further interest in giant clam mariculture. I would like to thank James Cook University for hosting the workshop, and for the strong support for the Giant Clam Project extended by the Vice-Chancellor Prof. Ray Golding. The workshop was officially opened by Mr Tony A. Burreket, MLA, Townsville.

J.R. McWilliam
Director
Australian Centre for International
Agricultural Research

Summary of Discussion and Recommendations

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i) General

1. The lack of an adequate knowledge base on the biological and socioeconomic aspects of tridacnid clams, especially *Tridacna gigas, T. derasa* and *T. maxima*, was identified as a major constraint to the management, conservation, development and protection of current and future clam resources.
2. There is a need to develop adequate communications between research and development agencies to prevent duplication of effort and to establish a data base for the restocking of reefs, conservation and mariculture of giant clams.
3. It was recommended that current knowledge on the culture and management of giant clams be made available in a manual for countries in the South Pacific and Southeast Asia who are interested in the mariculture of giant clams.

ii) Socioeconomic Aspects of Clam Culture

1. There is a need to identify the potential export market for the various products of clams to the developed countries of the Pacific Basin.
2. A better understanding is required of the reef ownership patterns, and the cultural and economic implications of clam culture need to be assessed on a country-specific basis prior to restocking reefs and the establishment of clam mariculture operations.
3. The shellfish consumption patterns and internal market characteristics of South Pacific countries need to be assessed.
4. The production costs, postharvest, transport and packaging requirements for low-cost and capital-intensive production systems need to be evaluated and export markets determined.
5. The economic benefits, if any, of polyculture need to be determined.
6. The likely social and income distributional impacts and gender roles of low-cost giant clam production systems in the South Pacific need to be evaluated.
7. Research is required to determine the degree of substitution of clam meat with low-cost products such as scallops.

iii) Biology of Wildstock

1. It was strongly recommended that the existing genetic diversity of the tridacnid species be established throughout their natural distribution, with particular reference to the following:
   (a) Genetic diversity within discrete tridacnid populations;
   (b) Relationship between growth rate, survival and desired production characteristics in areas which have a suitable number of tridacnid species.

2. A study should be made of the strains of zooxanthellae that form a symbiotic relationship with tridacnid clams, to determine the most efficient strain for survival and growth of all stages of the giant clams.
3. It was recommended that a gene bank of tridacnid species be established, particularly those of likely importance for restocking reefs and mariculture.
4. Identification of the most suitable broodstock based on the best genetic fit was considered to be a high priority for both restocking and mariculture of giant clams.
5. The identification of the genetic/environmental interactions of *T. gigas* was considered a high priority for the efficient management of wild and cultured clams.
6. Understanding the short- and long-term impact of mixing tridacnid gene pools from different populations was a high priority for further research.
7. The increased productivity of *T. gigas* by genetic selection needs to be evaluated, and suitable criteria need to be established for selection of desired characteristics.

iv) Reproduction and Early Stage Survival

1. A high research priority is the identification of the environmental and biological factors that induce spawning of giant clams.
2. Research is needed to develop techniques to extend the length of the spawning season without loss of gamete viability.
3. It was strongly recommended that research be undertaken to identify the biological and environmental factors influencing the survival of the early larval stage of development of tridacnid clams, with particular emphasis on:
   - the identification of the optimum requirements for settlement and survival of the larvae;
   - the establishment of the importance of various substrates such as colour, shape, and texture in larval settlement and survival; and
   - the development of improved, low-cost hatchery designs and techniques to improve larval survival.

v) Nutrition of Giant Clams

1. Determining the nutritional requirements of the larval stage of giant clams is a high research priority, with emphasis on the following:
   - identification of environmental factors that influence the nutritional status of larvae up to post-settlement stage;
   - evaluation of the benefits of added nutrients for the larvae;
   - clarification of the factors that accelerate or impede the development of a successful symbiosis between juvenile clams and the zooxanthellae.
2. It was recommended that techniques be developed to manipulate and replace zooxanthellae during the various stages in the life cycle of the clams, given the pivotal nutritional role of zooxanthellae.
3. It was recommended that the environmental and biological requirements for zooxanthellae be determined.
4. It is important to develop microcapsule techniques to replace the need for algal feeding of the clam larvae.

vi) Mariculture of Giant Clams

1. It was agreed that there is an urgent need to determine the most suitable environmental parameters for the culture of juvenile and adult giant clams. The parameters should be measured in such a manner that they can be reproduced elsewhere. Emphasis should be placed on water temperature, water exchange volume and rate, sunlight intensity and duration, depth of clams and other relevant oceanographic factors for nursery and grow-out sites. This will help establish the necessary site criteria for the various species of giant clams.
2. It is important to develop low-cost mariculture techniques for restocking of reefs, subsistence and artisanal mariculture.
3. Research should be carried out to develop or adapt existing growth models and techniques to monitor growth of giant clams.
4. Research is needed to identify the optimal environmental and management factors that affect the quantity and quality of clam meat and shells.
5. It was recommended that the physical markers of 'slow growers' be identified and the impact of various culling rates be evaluated in relation to the total biomass.
6. The potential of clam polyculture with seaweed and other marine organisms needs to be evaluated in biological and economic terms.

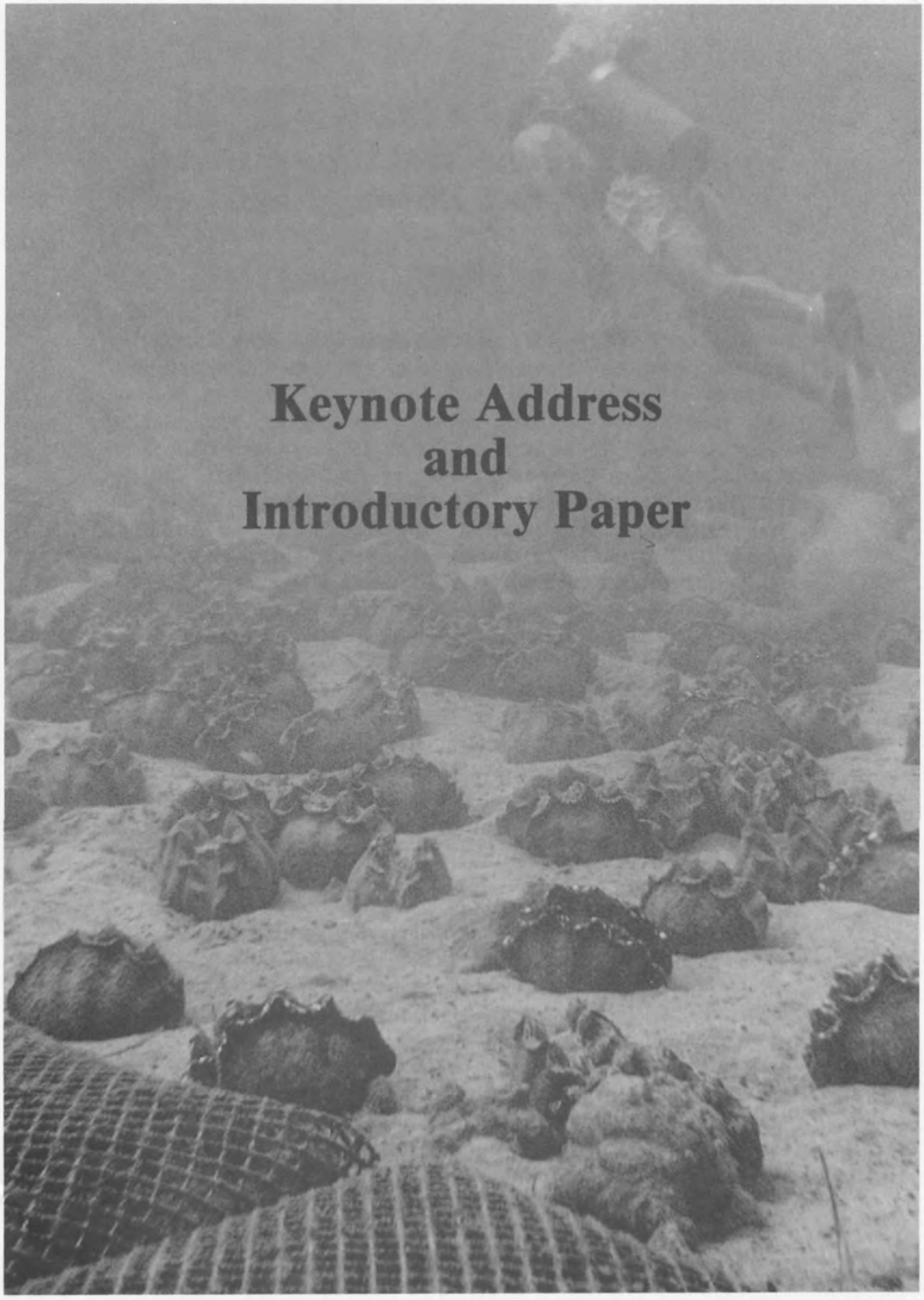
vii) Restocking and Conservation of Reefs with Clams

1. A detailed study of the existing stocks of giant clams is necessary in some countries to determine availability of broodstock and identification of the most suitable species for culture and restocking of reefs.
2. Identification of tropical reefs suitable for restocking is a high priority. It was recommended that remote sensing data be examined as a method of identifying suitable reefs.
3. Research on low-cost techniques to restock and maintain suitable reefs needs to be developed.
4. It was recommended that countries that have significant clam resources consider procedures to maintain and enhance their existing stocks.
5. It was also recommended that research be carried out on the environmental impact of clam farms on tropical reefs.

viii) Disease and Predator Research

1. A high priority research topic is the identification of existing pathogens of giant clams and their zooxanthellae, with particular emphasis on infectious agents.
2. Research activities should be conducted into the normal microbial flora of clams to allow differentiation between pathogenic and nonpathogenic forms.
3. A multidisciplinary investigation is required into monitoring of stress-inducing management processes to determine the short- and long-term impact on growth.
4. It is necessary to successfully diagnose the noninfectious and infectious disease processes and their aetiology; research is necessary to establish descriptions of the normal tissues and their response to damage.

5. It is recommended that emphasis be placed on the identification of infectious pathogenic agents that may be transported by the movement of clams from one region or country to another. This has particular relevance to the quarantine precautions that need to be undertaken for such translocations of clams.
6. The identification and control of the predators of clams during the various phases of culture, with particular reference to the nursery stage, were identified as important areas for further study.
7. It was strongly recommended that a regional centre be established for the collection, diagnosis and dissemination of information on clam diseases and quarantine procedures.



Keynote Address and Introductory Paper

Keynote Address: Scope for National and International Research and Development

J.T. Baker*

IT is a unique opportunity to sit among the pioneers in a field of study!

Certainly one can look at the bibliographies on the giant clams and find references as far back as de Blainville in 1825, but the current emphasis on farming giant clams has built on the science-based technological developments of the 1970s and revealed the late 1970s and early 1980s as the focal period for the principal early studies on clam mariculture. One can also go back to books which we in Australia treasure for their pioneering role in popularising marine research. In the book by Dakin called 'Australian Seashores,' clams do not even receive a single mention. One must admit that Dakin's book had a heavy emphasis on New South Wales. Perhaps there is a place for a newer book on 'Australia's Intertidal Regions.'

Australia became involved in this mariculture development because a new organisation called the Australian Centre for International Agricultural Research appreciated from its first days that farming the sea was at least as important as farming the land.

ACIAR built on the findings of the International Center for Living Aquatic Resources Management (ICLARM) and the Micronesian Mariculture Demonstration Center (MMDC) and entered the field by supporting a study, coordinated through James Cook University, in the development of a series of bilateral agreements with the Philippines, Fiji and Papua New Guinea.

This series of agreements depended on the interest and relevant — but not at that time direct — expertise of staff at James Cook University to allow Australia's entry into this new field of research which could be seen as having benefit to science, to the community, to entrepreneurs and to restoration of ecological balance, by reseeding of heavily exploited near-shore and reef areas.

One is tempted to name the obvious pioneers among you, at this time. Certainly they merit that recognition, but I will resist the temptation because the exploration and development are too current for me to be sure that I will not inadvertently omit a name. I would not wish to do an injustice to those younger pioneers who may, for the moment, be not clearly obvious because of the shadows in which they do, temporarily, stand.

* Director, Australian Institute of Marine Science, Townsville, Qld, Australia.

The efforts of ACIAR, ICLARM, MMDC and of several individual governments have resulted in parallel pioneering in many countries, the vast majority of which are represented here today.

In these next few days we will work among the pioneers and we face several distinct challenges:

- to share our scientific knowledge;
- to forge the bonds of trust and friendship, facilitating ongoing open exchange of information and collaboration, and thus overcome the frustrations of isolation in our practical efforts when we return to our home countries;
- to identify the place at which we stand, relative to the objective of commercial development of clam products;
- to be tolerant in developing the art of communication among scientists, policymakers, commercial developers and conservationists;
- to clearly identify the environmental and health problems which we must address, if we are to develop an international trade;
- to consider the most appropriate ways to satisfy our ongoing needs for training, information and supply of stock and 'seed,' in such a vast geographic region;
- to show maturity in all aspects so that at the end of this week we identify you not only as the pioneers of a new farming industry, but also as the statesmen of an essential, internationally important industry.

It is not our place to hide problems or to be hesitant in revealing a lack of understanding. Rather it is our duty to expose the weaknesses as well as the strengths of our understanding as we move to consolidate the foundations of a new, but potentially long-lived, industry.

One way to focus your attention as I develop my theme is to share with you my impressions of the steps to the development of this farming industry, based on the obvious products we anticipate (Fig. 1). You may well prefer alternative representations. Mine is very much a projection of a possible way to develop.

When one compares this sequence with the workshop topics that have been planned, we are still very much concerned with the scientific and technological problems involving broodstock, hatchery and nursery features, seed production and transport, stock assessment, predators, parasites and diseases.

By your efforts you have developed a better, but in no ways complete, understanding of: (i) the reproductive biology of giant clams, with particular reference to the regularity of their spawning cycles and the different methods for, and results of, induction of spawning; (ii) optimal conditions for larval survival and development; (iii) development of juveniles; (iv) understanding of predator-prey relationships; and (v) growth rates under different conditions.

Relevance of the results to different institutions has varied because of the differing types of institutions. For the universities, the ACIAR support has led to a much more rapid development of staff expertise and involvement than could otherwise have been practicable and, in the vast majority of cases, has led to improved communication between the university and the

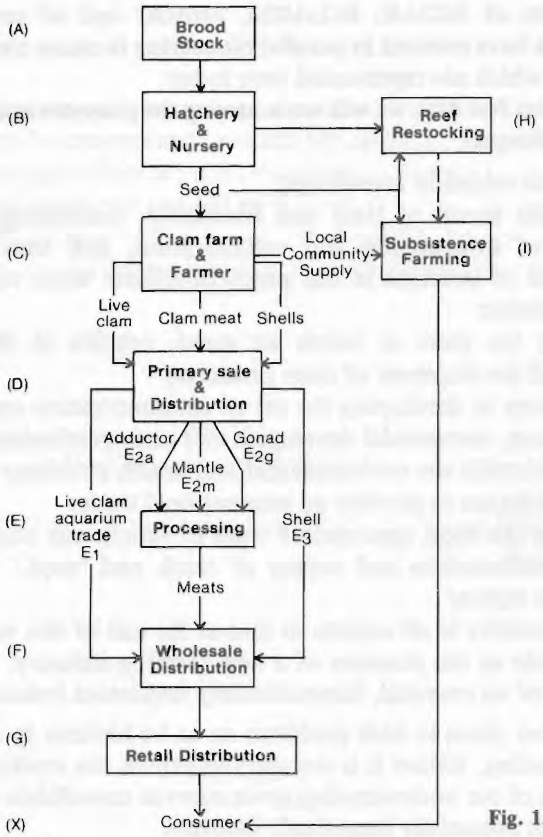


Fig. 1.

community. For the Fiji Fisheries Department, project results have stimulated the development of soundly based management strategies and encouraged the development of a field quarantine station which can be extended as a hatchery and possible 'grow-out' facility.

The spirit of scientific collaboration has been generally well developed among the representatives of the institutions. It has not been perfect and the next stage of support will require a committed effort to ensure stronger collaboration, not only across international boundaries, but also within countries, among universities, government agencies, community groups and, hopefully, commercial developers. Scientific collaboration, in the free exchange of information as soon as it becomes available, does not appear to have always been effected in the first stage of this project. Our review of the project suggests mechanisms to improve collaboration and information exchange.

Today, I await with great interest the opportunity to listen to the country presentations from Kiribati, Tonga, the Cook Islands, Solomon Islands and the Federated States of Micronesia to compare their priorities with those of the Philippines, Fiji, Papua New Guinea and Australia.

The priorities may well differ greatly but I do suspect that there will be interest emerging on the status of 'need' to move to an ability to restock reefs, to develop subsistence farming, and to define the essential features of

a successful clam farm. From these will emerge the demand to know what are the 'saleable' products, how should the products be processed and packed and where can they be sold?

In parallel, there will be the need to understand the challenges and impacts of high-density clam farming, the country requirements of export and import of live animals, the conservation issues, and the legal requirements associated with each country's laws as they affect the suitable areas for farms.

The final session of the workshop receives reports from discussion sessions, and will also consider and develop specific recommendations on future research priorities.

This is where the challenge of statesmanship clearly emerges and there is a need to carefully consider the differing requirements of each country and how such requirements may best be met. From these recommendations, ACIAR will distill the essential focal areas for a new program, perhaps not by itself this time, but in collaboration with industrial or other government partners.

There is no doubt in my mind that the recommendations must reveal a transition from a principal science and technology support to consideration of socioeconomic factors, and to consideration of the applications of the research to date for conservation, for community and for commercial benefit.

ACIAR, like all Australian Government agencies, must be encouraged by you to follow these at first apparently diverging paths, seeking industry collaboration and financial involvement in the commercial areas, and government support in the community and conservation areas.

There is a need for very clear policies to be developed in the different countries if profit-making clam mariculture is to be developed in parallel with practices of subsistence farming and restocking reefs. 'Regional planning' of marine areas will probably be a natural consequence of these different types of objectives. The need for such regional planning should be a feature of further ACIAR support of giant clam research.

From our experience we believe that there is scope for consideration of a number of subregional centres for several different functions, shown in Table 1. Perhaps you would have a different perspective and I would respect your advice. You are the people who can best evaluate your own country and regional requirements.

From the technical viewpoint it is clear that clam mariculture can be viable on a continuing and very long-term basis.

If one compares the clam-farming industry with the early days of wheat, sugar cane or sheep farming, your scientific knowledge on clams is greater than was the knowledge on any of those other farm products when they were first introduced. We must expect the commercial pressure and we must establish long-term interactive associations with the industries that develop from clam mariculture.

The rate of acceptance of the technology of clam mariculture will be determined more by its appropriateness to local social, cultural and economic conditions than to technical and technological factors. Understanding of the different local cultures and expectations is essential.

TABLE 1. Possible subregional 'centres' for development of giant clam mariculture.

Country	Short-term (3–8 years)	Long-term (> 8 years)
Philippines	Own-country needs	Asia and World markets
Palau	Philippines Micronesia USA aquarium trade Specialty shell trade International training function	As for short-term
Solomon Islands	Own-country needs	Add Vanuatu Kiribati
New Caledonia	French Territories	South Pacific
Fiji	Own country and Tuvalu, Tokelau, Samoa, Tonga, Cook Islands	As for short-term — seek export markets
Australia[a]	Own country Plus research of general regional value and training function	As for short-term
Papua New Guinea[a]	Own country needs	Seek export markets

[a] Likely commercial venture funding.

Therefore it is equally essential that a strong and more extensive local involvement in the project development be ensured, to build indigenous ongoing research competence.

It is now the stage of development in which we must ensure the closest practicable association between the technical experts and policymakers in each of the countries.

In this workshop we must all further develop the awareness and skills that will make us more efficient communicators to our decision-makers. In our review team experience at the government level in virtually all countries involved, there was an evident general apprehension about the prospects of mariculture and on the wide applicability of clam mariculture in particular. There remains a general and erroneous belief that clam growth is so slow that the species will be continually susceptible to human overpredation and unsuccessful as a commercially farmed species. You must correct such impressions — not by science but by communication.

A high priority must be placed on ways to ensure personal involvement of decision-makers in awareness of the advances made in clam mariculture. Once clam farms overcome the first 5 years or so of limited financial return, the crop is continuous, and the analogy may well be drawn to coconut farming which is well known to most Pacific countries.

Now I leave you to your own thoughts during these important days. You will learn a great deal. You will also have the opportunity to help each other in that learning. As pioneers, be not afraid to ask your questions freely and to seek a clearer understanding of the differing challenges and opportunities in this emerging truly biotechnological industry. As statesmen of the emerging industry be considerate of the differing needs of your fellows, and plan for the long-term security of the clam species involved, and of the industries which will be based on them.

I wish you well in your deliberations.

Giant Clams: Description, Distribution and Life History

John S. Lucas*

Abstract

The seven species of giant clams are briefly described and a key provided for their identification. Giant clams are unique among bivalved molluscs in having symbiotic algae in their mantle tissues. Being dependent on this symbiosis for at least some of their nutrition has profound effects on their morphology and ecology. The larval development of giant clams is quite typical of bivalved molluscs, but soon after metamorphosis the symbiosis is established and the clams are thereafter phototrophic. Growth is rapid in the larger species. Giant clams have been overexploited in recent decades by local and foreign fishermen. Recognition of declining stocks of giant clams and of their potential for mariculture has given recent impetus for research.

THERE is a dramatic difference in perception of giant clams between Western people and the peoples of the Pacific Islands and Southeast Asia. Pacific islanders and some Southeast Asians eat giant clams as one of many foods gleaned from coral reefs. Chinese regard the adductor muscle tissue from giant clams as a highly prized delicacy with aphrodisiac properties. However, westerners' perceptions of giant clams are from lurid adventure stories and films of the hazards of coral reefs. For example, one account of giant clams in a serious natural history magazine described how 'It is *not unusual* for a diver to be caught in the jaws of one of these giant clams, which clamp shut with the *suddenness* and strength of a bear trap' (my italics) (Cobb 1939). These stories have led to giant clams being called 'killer clams,' a title which is totally inappropriate for these benign, phototrophic animals.

Partly because of this strange perception of giant clams, but mainly because of their occurrence in tropical waters far from the main centres of marine science, there has been surprisingly little research on giant clams until quite recently. The great British marine biologist, Sir Maurice Yonge, was one of the few who took a long-term interest in giant clams (e.g. Yonge 1936, 1980).

* Zoology Department, James Cook University, Townsville, Qld 4811, Australia.

Species

Rosewater (1965) revised the confused taxonomy of the giant clam family, Tridacnidae, recognising six living species in two genera, *Tridacna* Bruguiere and *Hippopus* Lamarck. He subsequently described another *Hippopus* species to bring the total to seven species (Rosewater 1982). Rosewater's taxonomy of the giant clams has been universally accepted; however, it is possible that there are taxa as yet unrecognised (see Lewis and Ledua, This Monograph).

Giant clam species range in size from adult shell lengths about 15 cm to greater than 1 m. Only one species, *T. gigas*, usually grows to more than 50 cm shell length and is truly gigantic. It is the largest bivalved mollusc that has ever existed.

The seven living species of giant clams are described on the following pages (see Govan, This Monograph, for the names of the species in various Pacific languages).