ISSN 1025-7454

MARINE RESOURCES DIVISION
INFORMATION SECTION

TROCHUS

Number 5 – October 1997

INFORMATION BULLETIN

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Production: Information Section, Marine Resources Division, SPC, B.P. D5, 98848 Noumea Cedex, New Caledonia. [Fax: (687) 263818; e-mail: cfpinfo@spc.org.nc]. **Printed with financial assistance from the Government of France.**

EDITORIAL

Firstly, my apologies for the long wait you have had for this 5th edition of the *Trochus Bulletin*. Although the bulletin was originally intended to be issued twice per year, the number of articles available, together with when they are available, has made this schedule impossible to meet. I feel it is better to say that this bulletin is an 'occasional journal' and will be published periodically when enough information becomes available.

Having said that, this issue is in fact jam-packed with information, making it significantly larger than our average issue. The ACIAR Trochus workshop held at the Northern Territory University in Darwin last year has helped to swell our pages. We have included several abstracts form the proceedings, as well as an article by the workshop coordinator, Dr Chan Lee. There is also some country news included in the abstracts, notably from Vanuatu and Australia. I sincerely thank Dr Lee for taking the time to put this information together for the *Trochus Bulletin*.

Also adding considerably to the bulk of this issue is a World Bank-commissioned report on the world trochus market. This report was put together by ICECON, a consulting group from Iceland, with Bob Gillett from Suva doing much of the work on the ground in the Pacific. The report should prove an invaluable reference for those involved in trochus buying and selling in the Pacific, and readers will find the list of international buyers extremely useful. Many thanks to the World Bank for allowing us to reprint the report here, as it allows us to ensure that the information is available to the widest possible relevant audience, and not just filed away in the bottom drawer of some fisheries division's filing system.

In news from the Pacific Island producing countries, we have articles from the Cook Islands on the results of trochus introductions from over a decade ago, as well as an article on

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trochus spawning experiments at the Tongareva Marine Research Station pearl oyster hatchery. From the Federated States of Micronesia, we have an article on some recent trochus introductions to the outer islands there. Another article describes the present status of a trochus reseeding exercise in the Loyalty Islands of New Caledonia. Unfortunately, as with most other experiments of this type relating to the seeding of reefs with hatchery-reared stock, the results were disappointing. However, as usual, lessons have been learned, and success could some day be achieved.

I would like to thank all those people who have taken the time and effort to send in the details of their work on trochus. I encourage those from other Pacific Island countries and territories to follow their example, and let the rest of us know what is happening in your own countries. Articles can be as brief as you like and SPC has excellent English editors who correct anything requiring attention. For the French speaking readers and authors, SPC also has excellent translators . . .

I hope you find this edition informative, and look forward to receiving your future contributions, so that we can get another bulletin out within the next 12 months.

Kelvin Passfield

aspects of the industry, trade, and marketing of Pacific Island trochus May 1997

A report for the World Bank
Prepared by: ICECON, Reykjavic, Iceland
Funded by the Government of Iceland

Introduction

In June 1995, the World Bank issued their Third Regional Economic Report for the Pacific Islands (World Bank, 1996). The report recommended, among others, that a trochus marketing study be carried out to assess the competitiveness of Pacific Island products and opportunities for further development. This has formed the basis for the present study, which was carried out by ICECON, a specialist fisheries consultancy group, and funded through Icelandic Trust Funds.

The study's basic findings were compiled during late 1995. Visits were made to seven major supplier countries in the Pacific Islands region. Fisheries officials in the remaining countries were contacted by mail or phone.

Limited surveys were carried out in the major end-market countries (Italy, France, Germany, United Kingdom, United States and Japan) with the objective of gaining insights into market potential, future trends, demand and likely fluctuations. A review was also undertaken of the effect of competition from trochus substitutes.

The major author of the study was Mr Robert Gillett in Fiji, who assessed the trochus harvesting, processing and opportunities in the Pacific Island region. Mr Sturlaugur Dadason of Icelandic Freezing Plants Corporation, and Mr Petur Einarsson of ICECON were responsible for assessing international marketing prospects. ICECON is also grateful to the field experts who assisted in data collection in the Far East, Italy and the US.

The authors would like to express their appreciation to all government and industry representatives in the Pacific Islands, Far East, Europe and the US for the support and information provided. It is hoped that this report will contribute to a better understanding of trochus marketing prospects and opportunities for Pacific Island countries.

1. Trochus production

1.1 *Trochus production in the Pacific Islands*

Trochus *(Trochus niloticus)* shells are one of the most important coastal resources of the Pacific Islands and a key source of income for numerous coastal households. Although trochus is used primarily in the manufacture of valuable mother-of-pearl buttons, other minor uses include jewellery, handicrafts, polishing agents, and trochus meat.

Reliable information on the amounts of trochus harvested by the various countries is vital for efforts aimed at maximising production benefits. Proper resource management, marketing strategies, and evaluation of processing capacity are all dependent on the knowledge of the amount of trochus harvested. Despite their importance, the trochus statistics for most Pacific Island countries remain poor and need to be derived from a variety of sources, including fisheries statistics, export permit records, customs export data, and specialised surveys. All of these have shortcomings.

Mindful of the above statistical difficulties, an attempt was made to estimate trochus production from each of the 22 Pacific Island countries and territories during the last decade. Table 1 gives the nominal trochus production for the region. The averages are depicted in Figure 1 on next page.

Table 1 reveals that, on the basis of the best available documentation, the Pacific Island countries harvested an average of 1,845 metric tonnes (t) of trochus annually over the past decade. Allowances must be made, however, to account for the amount of unreported trochus, which is estimated at 25 per cent.

The actual amount of trochus production during the period 1985–1994 is therefore likely to be about 2,300 t annually. The current export value of this production is estimated at US$ 15 million per annum.

There is considerable annual variability in trochus production as shown by Figure 2 (see next page) which depicts trochus exports from Pacific Island countries from 1900 to 1990.

1.2 *World trochus production*

An estimate of the world-wide trochus production was obtained through available trochus harvest data from key producing countries, import statistics from Asian and European countries, previous estimates, and discussion with

Table 1: **Pacific Islands trochus harvests (t)**

Country	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**Average 1985–94**
American Samoa	—	—	—	—	—	—	—	—	—	—	**0**
Cook Islands	27	45	18	0	26	0	0	26	0	0	**14**
Fed. States of Micronesia	132	332	132	339	132	227	199	172	132	266	**206**
Fiji	294	250	250	400	250	200	n/a	n/a	n/a	243	**271**
French Polynesia	43	0	0	0	0	380	36	82	87	27	**66**
Guam	1	1	1	1	1	1	1	n/a	n/a	0	**1**
Kiribati	—	—	—	—	—	—	—	—	—	—	**0**
Marshall Islands	n/a	n/a	100	150	145	100	0	0	0	0	**62**
Nauru	—	—	—	—	—	—	—	—	—	—	**0**
New Caledonia	518	305	270	110	213	103	127	190	107	274	**222**
Niue	—	—	—	—	—	—	—	xxx	xxx	xxx	**0**
Northern Marianas	n/a	n/a	n/a	n/a	(15?)	n/a	n/a	n/a	n/a	n/a	**n/a**
Palau	104	32	87	163	257	0	0	229	29	0	**90**
PNG	437	535	441	437	275	346	164	282	392	n/a	**368**
Pitcairn	—	—	—	—	—	—	—	—	—	—	**0**
Solomon Islands	500	662	445	460	371	376	287	320	394	306	**412**
Tokelau	—	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	**0**
Tonga	—	—	—	—	—	—	—	xxx	xxx	xxx	**0**
Tuvalu	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	**0**
Vanuatu	75	75	67	86	100	170	130	150	160	107	**112**
Wallis & Futuna	n/a	n/a	15	15	18	17	34	17	16	34	**21**
Western Samoa	—	—	—	—	—	—	—	xxx	xxx	xxx	**0**
Total											**1,845**

n/a : Harvest data not available
— : Trochus niloticus does not occur
xxx : Trochus transplanted but not yet harvested
Non-commercial harvesting usually excluded. For FSM, the data given is for Pohnpei, complemented with estimates for other states.
For Solomons, figures for recent years include some PNG (Bougainville) trochus.
Sources: Miscellaneous references provided at the end of the report

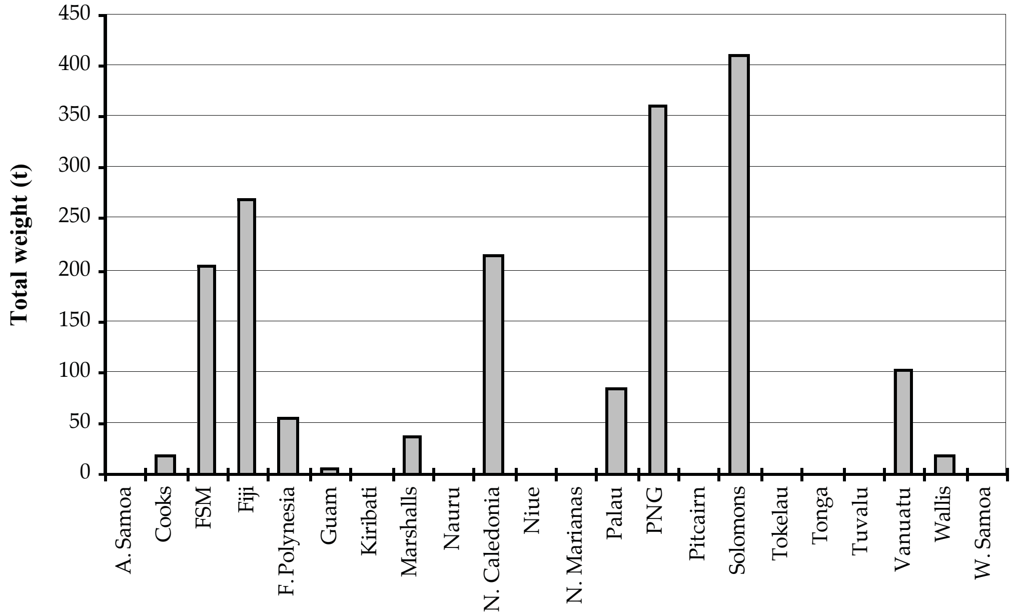


Figure 1.
Average annual trochus harvests in the Pacific region (1985–1994)

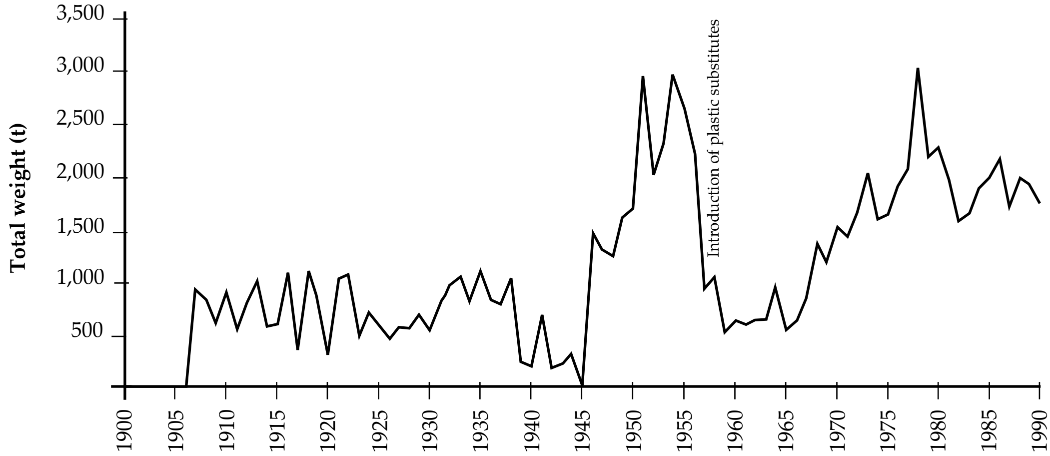


Figure 2
Trochus exports from the Pacific Islands (1900–1990)
(Source: SPC unpublished data)

individuals knowledgeable in the trochus trade. The results indicate a worldwide trochus production of 3,900 t annually (Table 2).

Although subject to revision, certain points are suggested by these preliminary estimates. **The most significant is that the Pacific Islands produce about 59 per cent of the global trochus harvest.**

It is noteworthy that Australia harvests more trochus than any other single country and that the second largest producing country is Indonesia, despite a ban prohibiting the harvesting, transport, or export of trochus.

2 Trochus processing

2.1 *Trochus processing in the Pacific Islands*

The processing of trochus involves the fairly simple production of button blanks followed by a more sophisticated processing into finished buttons. The first blanking operation in the Pacific Islands was set up in Levuka, Fiji, over 40 years ago. Since that time, 31 other trochus factories have been established in 9 Pacific Island countries. **Of these 32 factories, only 14 remain operational.**

Table 2: **Estimates of worldwide annual commercial trochus production in the early 1990s**

Area	Weight (t)
Pacific Islands	2,300
Indonesia	475
Philippines	200
Okinawa	200
Australia	500
Minor areas	225
Total	**3,900**

Sources: Official trade statistics and miscellaneous sources

Table 3: **Quantities of trochus processed in the Pacific Islands**

Country	Year	Weight processed locally (t)	Percentage of harvest processed locally (%)
Fiji	1994	200	72
Vanuatu	1993	115	72
	1994	73	68
Solomon Islands	1993	370	94
PNG	1993	138	35
FSM	1992	8	5
	1993	0	0
	1994	15	6
French Polynesia	1994	10	37

Sources: Trochus processors and fisheries officers

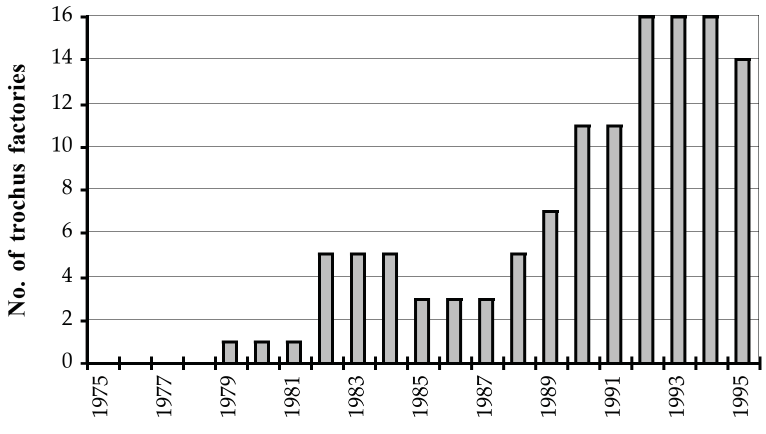


Figure 3
Number of trochus factories in the Pacific Islands region (1975–1995)

These operational factories employ a total of 213 workers. Figure 3 shows the number of trochus factories in the region over the years.

Table 3 shows an estimate of the amounts and percentages of trochus processed locally in selected Pacific Island countries.

From Table 3 it can be seen that in recent years about 800 t of trochus were processed annually within the region. This represents about 35 per cent of the total regional trochus harvest or 21 per cent of the total world harvest.

Most Pacific Island trochus processing operations produce blanks for Korea or Japan. Only two of the present factories attempt to produce finished buttons and both of these export more blanks than buttons. Many Pacific Island manufacturers state that they are unable to produce the quality of buttons demanded by the Asian and European buyers.

Information on the operational costs associated with blank production shows that raw trochus accounts for approximately 74 per cent of the total production costs, wages for 12 per cent and the other costs for 14 per cent.

2.2 *Trochus processing outside the Pacific Islands*

Although Japan has historically dominated trochus button manufacturing, many of the key Japanese shell button companies have relocated, or at least established manufacturing branches, in low wage countries. The Japanese Tomoi Company has a factory near Chiang Mai, Thailand which has 30 employees and produces one-third of Tomoi's total production. Lookwell Company manufactures on Cebu Island in the Philippines. The once-largest button manufacturer in Japan, Iris Company, has ceased domestic production and now produces in Dalian, China. There are also reports of trochus button manufacturing in Vietnam, but its affiliation is unknown.

Five or six companies are presently manufacturing trochus buttons in Korea. As has occurred in Japan, the Korean button manufacturer, Buyoung Industries, has opened a button plant in Guang Dong, China, which specialises in shell buttons. Many of the South Pacific trochus processing operations are currently affiliated with Korean firms and some of them appear to have relocated to the Pacific Islands from South East Asia.

The processing situation in Indonesia is unclear. The trochus ban in 1987 probably had an impact on the level of trochus processing, but this is difficult to quantify. Should trochus harvest become legal in the future, it could easily result in substantial in-country processing which, considering the resources available, their quality, and very low labour costs, could result in Indonesia producing a large portion of the world's button blanks or finished buttons.

There is little recent information on Taiwan, but the latest source indicates that much of the processing is oriented to shell-based accessories, rather than buttons.

The European button industry is centred in northern Italy. About 210 firms are involved in the production of buttons and 20 of these companies produce shell buttons, with two producing only blanks. The three largest button producing companies are vertically integrated and it is reported that they attempt to offset the high Italian labour costs by using advanced technology manufacturing techniques. Some Italian manufacturers have stated that, although the Asian countries can produce low-cost trochus buttons, Italy can deliver much faster and therefore cater better to the rapidly changing high fashion market.

The largest button manufacturer in Europe, TOAR, is located in Spain. One German shell blank manufacturer is listed in the catalogue of 1995 International Exhibition of Buttons. Other sources indicate a small amount of trochus button manufacturing in Austria. Market research carried out during the survey indicates that only one company is manufacturing shell buttons in the United Kingdom at the present time and may be confining production to engraved buttons. This lack of major button production is attributed to the fact that clothing, once a major industry in the UK, has largely moved offshore.

At least one manufacturer produces trochus buttons in the United States. Emsig Manufacturing Corporation has manufacturing facilities in New York and New Jersey in addition to a plant in Taijin, China.

According to European sources, there are two shell button factories in Mauritius, which reportedly use Pacific Islands raw trochus. A button factory was set up in the Seychelles soon after the trochus transplantation, but switched to making jewellery. During the market survey in France, one fashion house stated that they purchased trochus buttons from Madagascar.

2.3 *Pacific Island processing compared to other areas*

Factories in the Pacific Islands have neither the low wage structure of the newly established ventures in China and Southeast Asia, nor the high technology of the European manufacturers, nor the long-established and vertically integrated nature of the larger Japanese, Italian, and Spanish companies. Proximity to resources is not a major comparative advantage to the region in view of the relatively low transportation costs, ranging from US$ 1,700 to US$ 4,000 for a 20 foot container to Japan. Productivity tends also to be lower relative to Asian processors. These factors suggest stiff future competition for Pacific Island trochus processors. The Pacific Islands factories have few advantages except for being located in a region which presently produces 59 per cent of the world's trochus supply. It appears therefore that the region's processors, in order to compete successfully, must capitalise on this strength and use this attribute as the basis for their comparative advantage.

3 Trochus prices

3.1 *Domestic trochus prices*

Domestic buying prices for trochus shells in mid-1995 are shown in Table 4.

There is considerable variability in factory gate prices between countries. The highest price paid is in Fiji where there is domestic processing and (during the period of the quoted price) a ban on the export of raw trochus. One of the lowest prices is in Pohnpei where there is domestic processing and no export restrictions. This appears somewhat contradictory to the perception that export restrictions lower the price of raw shells to fishers. The most likely explanation is that Fiji, despite the ban on raw exports, had a higher number of buyers than in Pohnpei, with three processing operators in 1995. **Domestic competition for the purchase of trochus is therefore a major factor in determining price levels.**

3.2 *International trochus prices*

During the study, export prices for trochus were quoted by various sources in the Pacific Islands as ranging from US$ 6,000 to US$ 7,500 per tonne (presumably FOB). Trochus prices are often quoted for Indonesian 'Makassar' shell and this commodity has assumed the role of the price ref-

Table 4: **Factory gate prices for raw trochus (1995)**

Country	1995 price per kg (local currency)	1995 price per kg (US$ @ UN rate)
Cook Islands	NZ$ 8.10 *	5.30
FSM (Pohnpei)	US$ 2.53	2.53
Fiji	F$ 6.25	4.60
French Polynesia	CFP 300	3.16
Marshall Islands	US$ 2.95	2.95
New Caledonia	CFP 250	2.81
Palau	US$ 3.08	3.08
PNG	K 4.50	3.49
Solomon Islands	SBD$ 11.00	3.28
Vanuatu	VT 300	2.70
Wallis & Futuna	CFP 320	3.57
1995 average		**3.41**

* cleaned

Sources: Trochus processors and fisheries officers

Notes: The Solomon Islands has a 10% withholding tax for each transaction. Prices quoted are for fairly small amounts (less than 500 kg) of legal sized trochus. Where a range of prices is offered, the price given is the average of the range. Prices are for the first half of 1995. For Marshall Islands, French Polynesia and Cook Islands, prices are for the last available sale, adjusted to 1995 values. Prices are factory gate prices. Where no factory exists, prices are those given in the principal city.

erence point for trochus from all areas. A comparison of the 1980 Makassar price of US$ 1,070 and 1995 prices shows a nearly eight-fold increase in 15 years (in nominal terms).

During the present study, current prices for trochus were obtained from Japan and Italy. The price of trochus in Japan has followed the trend experienced in most Pacific Island countries: a peak in 1989/1990 followed by low prices for a few years and then a recovery. In mid-1995 the FOB price of Makassar in Japan rose to 930,000 yen per tonne (US$ 9,300), but later in the year stabilised at 850,000 yen. Market research carried out for this study indicates that the most likely explanation is that the fluctuation was caused by the production of blanks in trochus producing countries, resulting in a shortage in the supply of raw trochus and a subsequent price rise. **This suggests some inelasticity in the demand for trochus and serves as an indication of the impact that supply restrictions can have on market prices.**[1]

The global demand for trochus products is obviously a major price determinant. Moreover, the price paid to Pacific Island exporters for raw trochus is strongly influenced by trochus quality and shipping charges. The type of buyer/seller relationship also has a strong effect on prices. Unlike trochus quality and shipping costs, this relationship is one area where producers in the Pacific Islands can change the situation for their benefit. Overseas importers of trochus value long-term business relationships and are willing to pay a higher price for trochus purchased from a company they can trust (see Section 5.3).

Several new trochus factories have opened in Asian countries without local supplies of raw material. At the same time, the production of blanks is increasing in trochus producing countries, restricting the availability of raw trochus. **These conditions suggest upward pressure on prices of raw material.**

4. Future demand for trochus

4.1 *Perceptions from the fashion industry*

Marketing surveys were carried out in the major end-user countries. Information was obtained from 56 designers, fashion houses, button distributors, apparel manufacturers, and up-market retailers in Italy, France, Germany, the United Kingdom, the United States, and Japan.

1 An inelastic demand occurs when the change in the quantity demanded is proportionally smaller than the price change. Under these circumstances, restricting the supply of product results in higher total revenues to producers.

The main findings of the survey of the fashion industry were the following:

- the general state of the economy, fashion trends, and the use of substitutes are the dominant factors affecting demand for trochus. The relative weight of economic constraints and fashion trends varies by country. In the US, economic considerations tend to be the main factor influencing demand; in France, fashion trends appear to be dominant;
- the fashion industry anticipates a slight to moderate increase in the use of trochus in the near future;
- substitution for alternative materials is not likely to produce a major shock in the industry (see Section 4.2);
- about half of the clothing manufacturers contacted believed there is some potential for direct purchases of finished buttons from producing countries; and
- there is a possibility that consumers' environmental concerns could have a negative effect on demand.

The perceptions of many representatives of the fashion industry contacted during the survey are embodied in the statement by a French designer that '*nothing can replace the luxury and excellence of mother-of-pearl buttons*'.

4.2 *Competition from trochus substitutes*

In the history of trochus button manufacturing, the most remarkable feature has been the sharp downturn in the business in the late 1950s and early 1960s due to competition from plastic polyester buttons (see Figure 2). This state of development is indicated by an Italian fashion designer who recently stated that '*polyester imitation is nowadays done so well that a non-professional eye cannot distinguish between real and imitated mother-of pearl*'. Because polyester buttons have not displaced trochus to date, it is unlikely that any future variations will.

Two related substitution phenomena are presently affecting trochus buttons:

- Substitution to cheaper material
  This type of substitution is strongly affected by the price of trochus and the general state of the economy; and
- Substitution to more appealing material
  This type of substitution is strongly affected by fashion trends and subject to high variability.

The market surveys conducted for this study indicated both types of substitution are presently important. It is possible that the two types of substitution actually buffer changes in trochus demand. An increase in use by the high fashion industry, for example, would tend to place upward pressure on prices. This in turn tends to result in a decrease use by mid-term retailers, placing a downward pressure on prices.

The market surveys also indicated differences in the preferred substitute materials between end-user countries. Shell substitutes predominate in the UK, Japan, Korea, and Italy. Nut, wood, horn, steel, and other shells are important substitutes for trochus in the United States.

Pearl oyster, sometimes used as a substitute for trochus, is not favoured by button manufacturers due to brittleness and colouring factors. In general, according to button distributors, most of the shell substitutes are considered inferior to trochus for reasons of brittleness or uneven texture and thickness.

In summary, **substitutes for trochus buttons will be an important consideration in the future and will probably cause considerable price variations. It is unlikely, however, that competition from these alternatives will lead to a collapse in the demand for trochus.**

4.3 *Effects of tariffs and trade blocks*

The present tariff structures give only a very small advantage to the Pacific Island countries relative to other developing trochus processing countries (e.g. China and Indonesia). All developing countries have a slight advantage over Korea and Japan in the European market. Overall, however, the tariff structure does not alter significantly the existing comparative advantage amongst producing regions.

With respect to the General Agreement on Tariffs and Trade (GATT), the present special preference accorded to the Pacific Islands is so small in the trochus trade that the impact of preference erosion is likely to be insignificant. In overall terms, however, because of its anticipated trade stimulation effect, GATT should have a positive impact on trochus trade.

4.4 *Environmental concerns*

Environmental concerns may have a significant effect on the future demand for trochus products. Conraths and Schroeder (1995), in a study of the trochus trade in Italy, state the following:

> *'In the last ten to twenty years people of the industrial countries have become more and more aware of their responsibility towards the preservation of natural resources and protection of their environment. This consciousness is growing stronger and spreading to other countries. Concerning the trochus product, it cannot be ignored that a living animal has to be killed for production. Most of the consumers who can afford to buy high quality clothes, fitted with real mother-of-pearl buttons, belong to countries where this awareness was born.'*

The above study pointed out that at least one designer in Italy had stopped using trochus buttons altogether due to environmental concerns. The present United States survey, involving nine leading fashion designers, also indicated some environmental sensitivity among designers. **Environmental concerns may therefore become a future factor affecting the demand for trochus.**

5 Opportunities

5.1 *The export of raw trochus versus processing*

Several Pacific Island countries have adopted export restrictions as a way to encourage domestic processing. These are summarised in Table 5.

Restrictions on the export of raw supplies result in a reduction in the number of buyers competing for trochus supplies. This may result in lower prices to fishers than would otherwise happen under open competition, while factories obtain their trochus supplies at considerably less than prevailing market prices. It has been stated that trochus export bans result in village fishers subsidising urban factories. This policy is also likely to be a major contributing factor to the overcapacity problem experienced by local processors (see below).

The majority of the trochus processing operations established in the Pacific Islands have failed: 18 out of the 33 formed since 1950 no longer operate. Interviews with several individuals involved in those unsuccessful operations reveal that the

Table 5: **Restrictions on the export of raw trochus (mid-1995)**

Country	Restriction	Exemption	Recent raw reports
Fiji	Schedule 8 of Customs Regulations 1986 specifies a ban on the export of unprocessed trochus shells. Formerly, trochus exporters were limited to exporting an amount of raw trochus equal to the amount sold to the processors, but this policy was abandoned in January 1987.	Permanent Secretary for Commerce, Industry, Tourism, and Civil Aviation	In 1993 and 1994, 110 t of unprocessed shells were exported.
Vanuatu	Cap 158 Regulation 17 states that no person shall export trochus except with the written permission of the Minister. The policy is to discourage the export of unprocessed trochus. Raw trochus exports exports are taxed at 15%. The rate for processed trochus is 3%.	Minister of Agriculture, Forestry, Livestock and Fisheries	In 1992, 103 t were exported. Subsequent raw trochus exports included with processed trochus in customs statistics.
Solomons	30% tax on unprocessed trochus exports, none on button blanks.	Minister of Agriculture and Fisheries	In 1993 and 1994 about 90 t of unprocessed trochus were exported.
FSM	None at present. In Pohnpei State legislation was recently submitted (but not yet considered) restricting the export of unprocessed shell.	Pohnpei Director of Commerce and Industry	In 1994, 251 t were exported, all but 15 t raw.
French Polynesia	Deliberation No. 93-133 limited the export of raw shell in the period December 1993 to July 1994 to 50% of the harvest. Since July 1995, 100% of the harvest must be processed locally.	No exception possible other than the Territorial Assembly changing the law.	17 t exported raw in 1994; 10 t exported raw in the first half of 1995.

Sources: Local fisheries office and industry most common cause of failure has been inadequate supply of raw material or the related problem of industry over-capacity.

The size of a trochus processing operation in the Pacific Islands is usually given in terms of the most important piece of equipment, the blanking machine. The number of these machines largely determines the number of workers, the physical size of the factory and raw product requirements.

The managers of processing facilities contacted in the region operated factories ranging from 2 to 21 blanking machines, with an average of 11. Smaller operators cited the poor availability of raw product as a reason for their choice. Larger operators mentioned overly optimistic assessments of resource availability, which in some cases led them to acquire the assets of failed companies. The number of blanking machines used at present is therefore not a reliable indicator of optimal factory size. According to the managers surveyed, **a processing facility with 10 to 12 blanking machines would result in the most efficient operation.**

A blanking machine requires about one tonne of raw trochus per month at full operation. Allowing for maintenance and repair, an optimal-sized trochus factory in the region would require an estimated 120 t of raw trochus per year. An inspection of the annual trochus harvest in Table 1 gives an indication of the existing over-capacity. It can be seen that in only five Pacific Island countries (FSM, Fiji, New Caledonia, PNG and Solomon Islands) is the average annual harvest greater than the 120 t/year required for an optimal-sized factory. **In many countries, the processing capacity greatly exceeds the available resource.** In Fiji, for example, there are 65 blanking machines in operation requiring an input of 702 t of raw product annually. The average annual harvest is, however, only 271 t, of which 200 t are available for local processing.

The resulting over-capacity problems and the relatively small number of workers employed in trochus factories in the Pacific Islands (213 people) compared to the large number of trochus harvesters, suggests that protecting the trochus processing industry by limiting raw product exports is not justified in the region. This policy tends to create inefficiencies in the industry, and contribute to oligopsonistic[2] control over producers' prices—particularly given the small number of factories operating in each country. **It is therefore recommended that industry protection be removed over the long term.**

It is important to note, however, that Pacific Island countries harvest around 59 per cent of the world's supply of trochus. A lift of the current export bans would likely depress global prices. If further analysis can confirm that the demand for trochus is relatively inelastic, a coordinated policy of restricting the supply of raw trochus among producing countries would likely be beneficial to the region as it would help keep world prices high. The optimal mechanism for such a regional initiative needs to be examined carefully. Restrictions in the supply of only raw trochus, as seen above, may result in higher prices, but disproportionally benefit the processing industry. **A more appropriate mechanism would be the imposition of a tax, harmonised across the region, and applied at the same rate for both raw supply and processed products.** In order for the tax to be effective in the long run, careful coordinated action by major Pacific Island producing countries would be required to ensure compliance at the ports of export. In addition, the impact of substitutes and competition from other producing countries (e.g. Australia or Indonesia) would need to be assessed carefully, as it could erode the region's comparative advantage. The optimal export tax should be set at a rate that would optimise world market prices. The tax on processed products could be phased in over time to allow processors in the region to adjust to the new regime.

5.2 *Improvements in management*

There is growing recognition that the management of trochus, or any other of the inshore fisheries, cannot be done exclusively by central government authorities. Substantial local community input is necessary for effective management regimes. The central feature of this approach is that communities have a stake in the long-term future of the resource. Community involvement in trochus management and other activities which engender a long-term relationship between the harvester and the resource should therefore be encouraged throughout the region.

Trochus is arguably the best managed marine resource in the Pacific Island region. However, some effective management regimes such as the one followed in Pohnpei involve long periods of closure, followed by very short harvesting seasons. These regimes are detrimental to the domestic processing industry due to the high costs of stockpiling, and interest charges on large inventories of raw materials. In countries where trochus processing is being encouraged, long periods of non-availability should be avoided. While local governments should not sacrifice the effectiveness of management regimes to the needs of the industry, there may be scope, for example, for rotating closed seasons to increase the availability of raw material throughout the

2 Oligopsony occurs when there are only a few buyers in the market, tending to result in lower prices to producers.

year. The enforceability of such measures would need to be considered further.

There are other management-related issues affecting industry viability which deserve consideration, namely the size of the shells. There is both biological justification (larger individuals are more fecund) and support from industry (very large shells are poorly suited for blank production) for establishing upper size limits. Despite this, only about half of the trochus producing Pacific Island countries have legal maximum size regulations.

Where there is trochus management by quota, consideration should be given to having the total yield of a harvest compatible with shipping requirements. It is most efficient to ship full containers of trochus and therefore harvest sizes in multiples of 17 t should be considered.

Enforcement of trochus regulations remains a problem throughout the region. There is a need for local Fisheries Divisions to better publicise the existing regulations. The fines for contravening trochus regulations in several countries are also too low to serve as an effective deterrent. For example, the fine for possessing under-sized trochus in one Pacific Island country is US$ 29.85 or only 0.02 per cent of the value of a shipping container. Anecdotal information further suggests that individuals who have been detected violating trochus legislation are often not prosecuted. These aspects need to be addressed further to improve the overall benefit of trochus exploitation in the region.

5.3 *Improvements in the sales of raw trochus*

At present, the majority of trochus producing countries in the Pacific do not produce the amount of trochus to support even one optimally-sized factory. The sale of raw trochus by many countries will therefore continue and various mechanisms for increasing the benefit from these sales should be examined. Possible options include increasing the number of buyers and direct sales.

The price paid for trochus domestically appears strongly related to the number of buyers. Efforts to increase the number of buyers bidding for trochus where there are presently few is probably the simplest mechanism to improve local prices. The alerting of international trochus buyers to purchasing possibilities may be facilitated by the contact addresses listed in Appendix A.

Direct sales offer another mechanism for increasing benefit from the sales of raw trochus, albeit on a long-term basis. Much of the world's raw trochus is purchased by brokers based in the producing countries and then resold to processing factories in other parts of the world. Various observers suggested that more benefits would accrue to the exporting countries if trochus were to be sold directly to the factories, cutting out the wholesaler.

The market for trochus in Europe is oligopsonistic, involving one large and a few small brokers. In this situation, it is likely that direct sales could produce substantial benefits to both buyer and seller. In Italy, the prices of direct sales are approximately 34 per cent higher than those offered by local agents. The logistics of direct sales do not appear very difficult. The most convenient shipment size, a 20 foot shipping container, amounts to 17–18 t of trochus which is a manageable amount for a medium/large trochus operation.

Although it is likely that direct sales by Pacific Island firms to factories overseas can result in greater profits, it should be realised that the brokerage firms provide valuable services, such as cementing buyer/seller confidence and establishing regular communications. The latter advantage, however, will tend to become eroded with the increasing availability of fax and Internet communications in the region.

Regular dissemination of price information could help both producers and domestic processors obtain a 'fair' price for trochus. The Trade Promotion Division of INFOFISH, an intergovernmental organisation dedicated to providing marketing and technical information on various fisheries products, would be the most appropriate body to disseminate this information.

The establishment of a long-term business relationship between buyers and sellers is an important step to increase overall benefits to the region. At present, the overseas importers claim many problems in this area. For example, the Italian button manufacturer Bonetti recently stated he has had disappointing experience with Asian and Pacific business partners. A healthy business relationship, in addition to improving prices through confidence, may help overcome more technical constraints.

It has long been stressed that the reliable grading of trochus would have an overall positive effect in the long term. For this to occur, the overseas purchaser must have confidence in the exporter's quality judgements. Speed of supply is another attribute that importers value and are willing to pay for. Some of the smaller processors would also be more willing to purchase directly from Pacific sources rather than through a European-based wholesaler if they had confidence in the Pacific suppliers. In summary, there appears to be substantial potential for improvement in Pacific Island trochus prices based on the development of long-term buyer/seller relationships.

6 Conclusions

Historically the countries of the Pacific have been 'price takers', exercising little control over markets and prices. Because the region produces a large share of the world's trochus supply, the Pacific Islands are in the favourable but unaccustomed position of being able to influence an international market in their favour. To date, this has consisted largely of four major countries (Solomon Islands, Fiji, Vanuatu and French Polynesia) independently restricting trochus exports in order to encourage local processing.

The likelihood of a moderate rise in the consumer demand, together with the establishment of new trochus processing facilities in countries without domestic supplies, suggests that the Pacific Islands' major advantage in the trochus trade, control over a large portion of the supply of raw material, will grow in importance in the near future. It should, however, be noted that Pacific Island government policies on the trochus industry have rarely, if ever, been intentionally formulated to use this advantage in their favour.

A major conclusion of this study is that to maximise benefits from trochus in the future, Pacific Island countries should capitalise on their market share. One possibility would be to impose a trochus export tax at the same rate over both raw and processed products, harmonised across major producing countries.[3] The recent history of the region suggests that such an initiative is possible; fisheries cooperation among Pacific Island countries, fostered by the regional organisations, is a striking feature of the region. The US multilateral tuna treaty, the agreement over minimum terms and conditions of access, and the regional register of foreign fishing vessels are examples of complex but effective regional cooperation in the sector. It is therefore suggested that the Forum Fisheries Agency (FFA) take a coordinating role in the harmonisation of the trochus industry policies of the main Pacific Island producers. FFA could provide advice on the optimal level of a trochus export tax, encourage consultation among countries before major change in policies are effected, and facilitate the exchange of price and industry information. There may be merit in inviting New Caledonia, a non-FFA member country who is also a major producer of trochus, to participate in these discussions.

The drawbacks of subsidising the domestic processing industry through export bans or tariff restrictions on raw trochus appear to outweigh its benefits. This policy is likely to have contributed to the existing over-capacity of the industry, and lead to lower prices to village producers than might otherwise prevail under open competition. Applying an export tax at the same rate for both raw and processed products would remove the intrinsic subsidy to the industry, while enabling producing countries to capture the tax and preserving the region's control over world prices.

Management regimes for trochus could be improved by adopting best practice approaches that optimise benefits to both producers and processors. Upper size limitation should also be encouraged to prevent growth overfishing and adjust the supply to the needs of the processing industry. There appears to be considerable potential for strengthening buyer/seller relationships between Pacific Island suppliers and end-market retailers. Sales could be encouraged further through the establishment of direct links with international distributors.

Given the small number of buyers involved in the trochus market, the availability of market prices information would be an important benefit to trochus producers. By virtue of their mandate, INFOFISH would be the most appropriate organisation to carry out this task.

7 Summary of major recommendations

The study's major recommendations for domestic producers and processors are as follows:

- Long-term buyer/seller relationships could be fostered further by establishing direct sales with retailers in major end-markets. Major considerations in establishing these links are quality considerations and reliability of supply.
- Prospective processors should analyse carefully the existing capacity, management regimes, and availability of raw supply before investment decisions are taken.

Major recommendations for Pacific Island Governments include:

- Trochus statistics need further improvement to allow, among others, a more precise determination of annual harvest levels.
- In countries where domestic processing is being encouraged, there may be merit in encouraging rotating closed seasons amongst producing regions to stabilise supply and prevent a stockpiling effect on prices. Improved enforcement of existing regulations should also take place through higher fines and effective prosecution.
- Consideration should be given to removing preferential raw trochus restrictions that encourage inefficiencies and over-capacity in the domestic processing industry. Any tax imposed with the objective of increasing the region's marketing power should be har-

3 Prior to its adoption, it would be important to assess the long-term impacts of such a tax in terms of possible substitution effects.

monised across countries and set at an equivalent rate for raw and processed products.

At the regional level, the study's recommendations are:

- The South Pacific Regional Environment Programme, in conjunction with the South Pacific Commission, play a leading role in disseminating to international environmental groups and the public at large the benefits and sustainability of well-managed trochus fisheries to Pacific Island communities, in order to correct possible misconceptions of environmental damage.
- The Forum Fisheries Committee should consider the benefits of having FFA take a coordinating role in the harmonisation of the trochus policies of the main Pacific Island producers, including the provision of advice on a trochus export tax.
- Because of the major importance of trochus price information, consideration should be given to having the Chairman of the Forum Fisheries Committee request INFOFISH to regularly publish trochus price information.

References

ADAMS, T., C. ALDAN, V. ALFRED, I. BERTRAM, A. BUKURROU, J. CRUZ, T. FLORES, F. ROSA, R. SEMAN & J. TAMAN. (1994). Assessment of the Northern Marianas trochus resource and recommendations for management of the fishery. Inshore Fisheries Research Project, South Pacific Commission, Noumea.

AMOS, M. (1995). Fisheries resource management and licensing system for newly elected Provincial Governments. Fisheries Department, Vanuatu.

Anon. (1992). Pêches maritimes et aquaculture: les chiffres de 1990 et 1991. Service Territorial de la Marine Marchande et des Pêches Maritimes, Noumea, New Caledonia.

Anon. (1993). Division of Marine Resources Annual Report 1992. Bureau of Natural Resources and Development, Koror, Palau.

Anon. (1993). Fiji Fisheries Division Annual Report 1992. Ministry of Primary Industries, Suva, Fiji.

Anon. (1994a). Fiji Fisheries Division Annual Report 1993. Ministry of Primary Industries, Suva.

Anon. (1994b). Bulletin statistique du secteur de la mer. Ministère de la Mer, French Polynesia.

Anon. (1994c). Pêches maritimes et aquaculture: les chiffres de 1992 et 1993. Service Territorial de la Marine Marchande et des Pêches Maritimes, Noumea, New Caledonia.

Anon (1994d). Statistical indicators 1994. National Planning and Statistics Office, Port Vila, Vanuatu.

Anon. (1995). Trochus harvests in Pohnpei. Division of Marine Resources, Pohnpei, Federated States of Micronesia.

BERTRAM, I. (1995). The Aitutaki experience in the development of management strategies for the trochus fishery (Cook Islands). **In:** SPC and FFA Workshop on Management of South Pacific Inshore Fisheries, Vol. 2. Background Paper 34. South Pacific Commission, Noumea.

BOUR, W. (1989). Biologie, écologie, exploitation et gestion rationelle des trocas (*Trochus niloticus*) de Nouvelle-Calédonie. Ph.D. Thesis, Academy of Montpellier.

BOUR, W. (1990). The fishery resources of the Pacific Islands—Part 3: Trochus. Fisheries Technical Paper 272.3, Food and Agriculture Organization of the United Nations, Rome.

BOUR, W., F. GOHIN & P. BOUCHET. (1982). Croissance et mortalité naturelle des trocas de Nouvelle-Calédonie. ORSTOM, Noumea, New Caledonia.

CHENESON, R. (1997). Status of the trochus resource in French Polynesia. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

CONRATHS, K. & H. SCHROEDER. (1995). The trochus shell market in Italy in view of the Pacific Islands [report prepared for Icecon].

DALZELL, P. & T. ADAMS. (1994). The present status of coastal fisheries production in the South Pacific Islands. Working Paper Number 6, 25th Regional Technical Meeting on Fisheries, South Pacific Commission, Noumea.

DALZELL, P., T. ADAMS & N. POLUNIN. (1995). Coastal fisheries of the South Pacific. Background Paper 30, Workshop on the Management of South Pacific Inshore Fisheries, South Pacific Commission, Noumea.

DAVID, D. & F. CURREN. (1997). Status of trochus exploitation in Pohnpei State, Federated States of Micronesia. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

DINAS PERIKANAN. (1994). Buku Tahunan Statistik Perikanan Tahun 1993. Pemerintah Propinsi Daerah Tingkat I Maluku.

DINAS PERIKANAN. (1995). Buku Tahunan Statistik Perikanan Tahun 1994. Pemerintah Propinsi Daerah Tingkat I Maluku.

FANAFAL, J. (1997). Status of trochus exploitation in Yap State, Federated States of Micronesia. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management

Project Technical Document No. 13. South Pacific Commission, Noumea.

GILLESPIE, J. (1997). Queensland's trochus fishery. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

IANELLI, J. & R. CLARKE. (1995). Current paradigms in trochus management and opportunities to broaden perspectives. Background Paper 15A, Workshop on Management of South Pacific Inshore Fisheries, South Pacific Commission, Noumea.

ISA, J., H. KUBO & M. MURAKOSHI. (1997). Mass seed production and restocking of trochus in Okinawa. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

KATAOKA, C. (1983). The progress of the pearl shell fishery in the South Pacific [in Japanese], Memoirs of the Faculty of Fisheries of Kagoshima University, Volume 32.

KAILOLA, P. (1995). Papua New Guinea fisheries resources profile. Forum Fisheries Agency, Honiara, Solomon Islands.

KANEYASU, N. (1995). Study on the trochus market in Asia. Fuji Chimera Research Institute, Tokyo.

LEQATA, J. (1997). Trochus assessment, development and management in the Solomon Islands. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

LEDUA, E., A. SESEWA & A. RAHIM. (1997). Status of Trochus in Fiji. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

MAGRO, K. (1997). Resource statement – Western Australia. **In:** Workshop on Trochus Assessment, Development and Management (1991). Integrated Coastal Fisheries Management Project Technical Document No. 13. South Pacific Commission, Noumea.

NASH, W., T. ADAMS, P. TUARA, O. TEREKIA, D. MUNRO, M. AMOS, J. LEQATA, N. MATAITI, M. TEOPENGA, & J. WHITFORD. (1995). The Aitutaki trochus fishery: A case study. IFRP Technical Document No. 9. South Pacific Commission, Noumea.

PHILIPSON, P. (1989). The Marketing and processing of pearl shell in South Korea, Taiwan, and Japan. **In:** P. Philipson (ed.) The Marketing of marine products from the South Pacific. Institute of Pacific Studies, University of the South Pacific, Suva, Fiji.

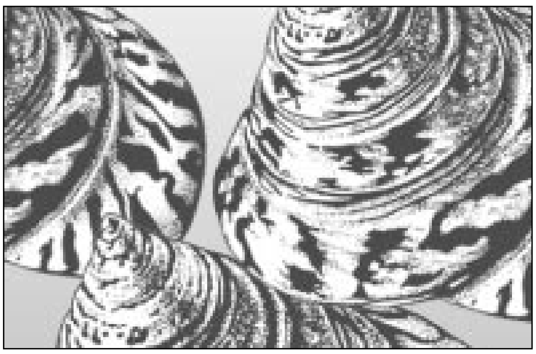
REIPEN, M. & D. KENNETH. (1990). Economic assessment of the commercial shell industry in Vanuatu. Department of Fisheries.

RICHARDS, A., L. BELL, & J. BELL. (1994). Inshore fisheries resources of the Solomon Islands. Report 94/1, Forum Fisheries Agency, Honiara, Solomon Islands.

RICHARDS, A., M. LAGIBALAVU, S. SHARMA, & K. SWAMY. (1994). Fiji fisheries resource profiles. Report No. 94/4, Forum Fisheries Agency, Honiara, Solomon Islands.

UNDP. (1989). Fishery sector review Papua New Guinea. Project PNG/88/004, United Nations Development Programme, Port Moresby.

WORLD BANK. (1996). Pacific Island economies: Building resilient economic base for the twenty-first century. World Bank, Washington, D.C., U.S.A.



Appendix A

Useful addresses in the trochus industry

JAPAN

Hirose Craft Co. Ltd (shell buyer)
38-10 Uzaki Kawanishi-cho
Shikigun Nara 636-03
Japan
Tel: 07454 4 0016
Fax: 07454 4 0023

Inana Co., Ltd. (shell buyer)
4-3-18 Daido Tenoji-ku
Osaka 543
Japan
Tel: 06 779 9031
Fax: 06 779 9099

Kiyohara & Co.,Ltd (shell buyer)
4-5-2 Minamikyuhojimachi
Chuo-ku, Osaka 541
Japan
Tel: 06 252 3497
Fax: 06 252 4377

Kobe Trading Co. (shell buyer)
3-8-15-106 Wasaka Akashi City
Hyogo 673
Japan
Tel: 078 924 1380
Fax: 078 924 1381

Kogen Trading Co., Ltd. (shell buyer)
6-17-2 Shinbashi Minato-ku
Japan
Tel: 03 3433 5837
Fax: 03 3433 5836

Koyo Shoji Co., Ltd. (shell buyer)
18-21 Chayamachi Kita-ku
Osaka 530
Japan
Tel: 06 374 2201
Fax: 06 371 4565

Kubota Trading Co., Ltd. (shell buyer)
4-13-10 Imai
Kashihara City
Nara 634
Japan
Tel: 0745 55 2025
Fax: 0745 55 2026

Tomoi Co., Ltd. (button manufacturer)
201 Toin Kawanishi-cho
Shikigun Nara 636-03
Japan
Tel: 07454 4 0066
Fax: 07454 3 1314

Lookwell Co., Ltd. (button manufacturer)
7-4 Horikoshi-cho. Tenoji-ku
Osaka 543
Japan
Tel: 06 779 7771

Iris Co., Ltd (button manufacturer)
1933 Likuka-cho Ota-City,
Gunma Pref. 373
Japan
Tel: 0276 45 3941

KOREA

Imna Mulsan Co., Ltd (button manufacturer)
824, Changnim-dong
Saha-gu, Pusan
Korea
Tel: 051 261 4905
Fax: 051 263 5841

Daochang Co., Ltd. (button manufacturer)
SI Kangnam
P.O. Box 606, Seoul
Korea
Tel: 82 2 544 2020
Fax: 82 2 514 6569

Samguk Trading Co. (button manufacturer)
San 15-5, Suha-ri, Shindun-myon
Ichon-gun, Kyonggi
Korea
Tel: 0336 34 5010
Fax: 02 757 3891

Young Nam Industries
(button manufacturer)
Busan-shi, Kita Kitani-to 1301
Kouk Dong
Korea
Tel: 051 336 1010

Sam Dong
(button manufacturer)
304, Shinseong Bldg.
589-13 Bangwa-dong
Kangseo-gu, Seoul
Korea
Tel: 82 2 756 7080
Fax: 82 2 773 1512

ITALY

Rag. Giovanni Corna
(importer, agent for Hamburgur, UK)
24060 Chiuduno, Via Trieste 46
Italy
Tel: 035 838317
Fax: 035 839263

Terzi Fratelli (importer)
24050 Palosco
Via San Lorenzo 83
Italy
Tel: 035 845461
Fax: 035 846540

Bottonificio Bonetti Francesco
(button manufacturer)
Via Marconi, 20/22 -25030 Rudiano (BS)
Italy
Tel: 030 716115
Fax: 030 716582
Telex 300324 BONETI
also: Via Lavoro e Industria 1200
Tel: 030 716361
Fax: 030 7060143

Buttons s.r.l.
(button manufacturer)
Via Vittorio Alfieri
1-24060 CREDARO (BG)
Italy
Tel: 035 927223
Fax: 035 935203

Plebani Giusseppe & C.s.n.c
(button manufacturer)
Via Franzi
12-24060 Foresto Sparso (BG)
Italy
Tel: 035 930013
Fax: 035 930503

Gritti S.p.A. (button manufacturer)
24O5O Grassobbio
Via Zanica 6/F, Italy
Tel. 035 586111
Fax 035 586112

Mauro Gaspari
(President of Italian button producers, 1995)
G. Gaspari Bottoni s.r.l.
24O6O Chiuduno, Italy
Via Pizzo Camino 1
Tel: 035 838401
Fax: 035 838786

Italian Foreign Trade Center
00100 Roma, Italy
Via Liszt 21
Tel: 06 59921
Fax: 06 59926899

SIBA
International Exhibition of Buttons, Raw Materials, Machinery and Related Items
29100 Piacenza, Italy
Via E. Parmense 17
Tel: 0523 593920
Fax: 0523 62383

CHINA

Buyoung (Dong Guan) Button Factory Co., Ltd.
(button manufacturer)
No.3, Industrial Zone, Quing 11 town
Dong Guan (Guang Dong)
China
Tel: 769 7620 732741
Fax: 769 7620 732472

Hong Kong Office
Block a 9/F, Wah Shing Ind. Bldg.
18 Cheung Shun St
Cheung Sha Wan, Kowloon
Hong Kong
Tel: 7425147 or 7452866
Fax: 7850953 or 7862767

GERMANY

Lüna Design GmbH
(button manufacturer)
Wulwes Str. 12-28203
Bremen
Germany
Tel: 49 421 72210
Fax: 49 421 701407

Shellex Germany GMBH
(shell button manufacturer)
Sudetenstrasse, 15-D-64521
Gross-Gerau
Germany
Tel: 6152 2724
Fax: 6152 3386

SPAIN

Toar S.A. (button manufacturer)
C/Rosellon 254-Pral.2a-08037
Barcellona
Spain
Tel: 488 29 80
Fax: 487 84 74
Telex: 52649 TOAR E

UNITED STATES

Adonis Buttons (button wholesaler)
39th Street
New York

Silverstein Pearls (button wholesaler)
7th Avenue
New York

Emsig Mfg. Corp. (button manufacturer)
253 West 35th Street
New York, N.Y. 10001
Tel: 212 563 5460
Fax: 212 971 0413

UNITED KINGDOM

M. Hamburger & Sons Ltd (shell buyer)
P.O. Box 9, Woking,
Surrey GU237HB
England
Tel: 44 1483 223501
Fax: 44 1483 224403

British Button Merchants Association
London
England
Tel: 44 171 403 2300

FRANCE

Yves Saint Laurent (fashion designer)
5 Rue Marceau
75016 Paris
France
Tel: 1 44316400
Fax: 1 42974880

Note:

The findings, interpretations, and conclusions expressed in this study are the results of research supported by the World Bank, but they are entirely those of the authors and should not be attributed to any manner to the World Bank, to its affiliated organisations, or to members of its Board of Executive Directors or the countries they represent.

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News from the Cook Islands

Study of trochus introduced to Penrhyn, Cook Islands: 10 years later

by Ben Ponia, Onio Terekia & Tangi Taime [1]

Abstract

A survey of a trochus population at Penrhyn lagoon, introduced from Aitutaki in the mid 1980s, was carried out. Trochus dimensions of dry shell weight (W) and basal diameter (L) can be expressed by the equation: $W = (3.4 \times 10^{-4})\ L^{2.943}$. The sex of animals was distinguishable in animals > 50 mm basal diameter . The average basal diameter of animals was 84.0 mm (compared to 100.6 mm at Aitutaki). The density of trochus was found to be significantly higher ($P < 0.05$) in the 10 m segment fringing the reef edge. This unexpected spatial niche may explain the poor success of establishment of stocks at the original transplant sites. Trochus abundance was assessed at 21 sites. High densities of trochus were found in the north-west part of the lagoon, with low densities adjacent to it. Zones for probable areas of establishment were identified. The abundance of trochus (95% c.i.) was estimated at 27,300 (14 300) animals. A sustainable harvest of 30 per cent of the animals in the 75–110 mm size range is suggested. This equates to a harvest of 5,000 animals or 1,040 kg of dry shell weight, worth an estimated CI$ 7,300 (≈US$ 4,780). Four possible management options discussed include: (1) leaving stocks undisturbed ; (2) a commercial harvest ; (3) a harvest for restocking areas where trochus do not occur; and (4) selective harvesting of wild animals to be utilised as broodstock for hatchery rearing of trochus juveniles at Penrhyn.

Introduction

Trochus (*Trochus niloticus*) are valued for their mother-of-pearl shell. Export industries to Europe and Japan utilise the shell for buttons, jewellery/curios, paints and varnish (Bouchet & Bour, 1980; Nash, 1993).

On two occasions (in 1985 and 1986), several hundred trochus from Aitutaki were introduced to Penrhyn (also known as Tongareva).

The target sites for transplant were in the southern area (see Figure 1) but it is probable that some animals were accidentally released at the wharf in Omoka village.

The Aitutaki population itself originated from just 280 shells translocated from Fiji in 1957. They were left to breed undisturbed for more then 20 years before being fished in 1981, when 200 t were harvested (Sims, 1985).

Since then, trochus have been harvested at irregular intervals of several years. The last harvest at Aitutaki in 1995 amounted to about 25 t of dry shell.

The primary purpose of this survey was to assess the stock of trochus at Penrhyn lagoon, 10 years after its introduction, to determine the feasibility of a potential harvest.

In addition, some basic biological characteristics and distribution patterns of the trochus were investigated.

1 Tongareva Marine Research Station, Penrhyn, Cook Islands. Phone: 682 42 095, Fax: 682 42 089, E-Mail: rar@mmr.gov.ck
Head office: Ministry of Marine Resources, P.O. Box 85, Rarotonga, Cook Islands. Phone: 682 28730; Fax: 682 29721; E-mail: rar@mmr.gov.ck

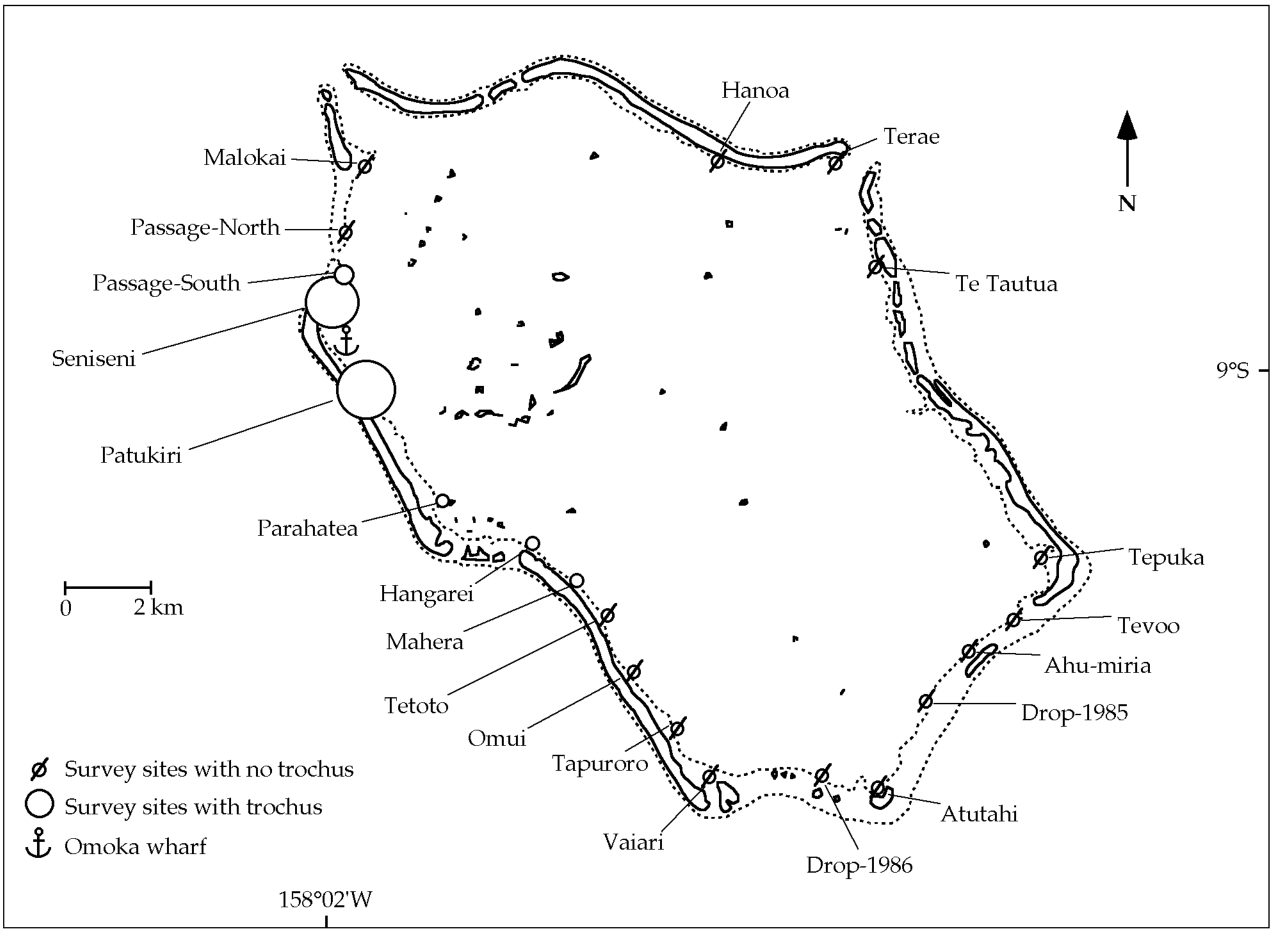

Figure 1

Map of Penrhyn showing 21 survey sites for trochus abundance. Drop-1985 and Drop-1986 were the original sites for trochus transplant, (see *Population census* section on page 21 for more details on trochus densities).

Materials and methods

The survey took place from 28 April to 1 May 1997. Field work was conducted by the Ministry of Marine Resources.

The relationship of sex and dry shell weight with basal diameter (hereafter referred to as length) was derived from a sample of 39 trochus. The morphology of the male gonad is pale brown to creamy white while the female gonad is dark green (Nash, 1993).

In addition, the size distribution of the trochus population was evaluated in a separate survey by measuring the length of 220 animals found within several random transects.

From preliminary observations it was noted that trochus were distributed with increasing density towards the edge of the inner lagoon reef. A survey was conducted at *Patukiri* site to assess the spatial distribution from the reef edge. Four replicate transects of 50 m length (with 10 m segments) were laid perpendicular to the reef edge and transects were surveyed 4 m on either side for trochus.

The census of trochus abundance at each lagoon site was assessed by laying 4 replicate 30 m long transects parallel to the reef edge in the strata where the most trochus were distributed. The transects were surveyed in a 2 m belt on either side for trochus counts. A total of 21 random lagoon sites was sampled (Figure 1).

Results

a. *Length–weight relation*

The relation between length and dry shell weight can be explained by a simple linear regression (i.e. shell weight = – 4.694 (length) – 223.3, $r^2 = 0.933$). However, upon further analysis it was found that a better fit of the length–weight relationship was provided by applying a natural log transformation of the data (i.e. ln(weight) = 2.943(ln(length)) – 7.997, $r^2 = 0.979$) (Figure 2). Therefore, weight can be simply expressed by the equation: $W = (3.4 \times 10^{-4}) L^{2.943}$ where W = dry shell weight and L = length.

b. *Sex ratio*

In the 39 trochus sampled, the female sex was first noted in those animals with a length exceeding 50 mm (Figure 3). Males were not always clearly distinguished (and were assumed to consist of those not identified as females; however it is possible that animals smaller than 50 mm were not fully matured, and the sex therefore indistinguishable). The small sample size makes it difficult to assess when a consistent ratio of male to female occurs. In this instance an even ratio occurs among animals with diameters of 50–60 mm and 90–110 mm.

c. *Size structure*

The minimum- and maximum-sized trochus were 38 mm and 118 mm (although an individual of 123 mm length was found outside the survey area). The mean (and standard deviation) of trochus length is 84.0 mm (±18.94, n = 220). Ninety-six per cent of the population are sexually mature (> 50 mm) (see shaded segment in Figure 4).

Also indicated is a portion of the population of 75 to 110 mm length (* segments in Figure 4). Using normally distributed Z scores it is calculated that this represents 60 per cent of the por-

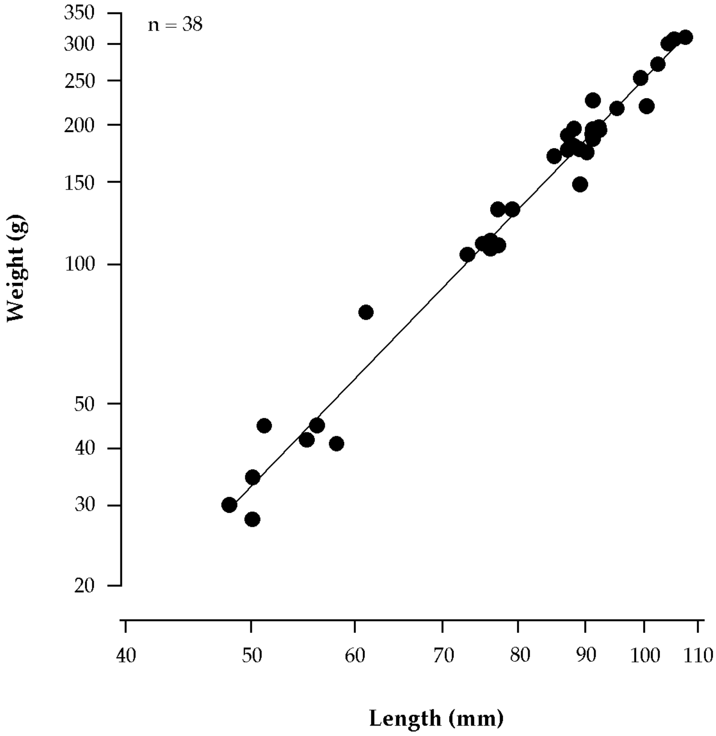

Figure 2

Relation of trochus length (L) and weight (W) after natural log transformation. The equation describing the curvilinear relationship is $W = (3.4 \times 10^{-4}) L^{2.943}$.

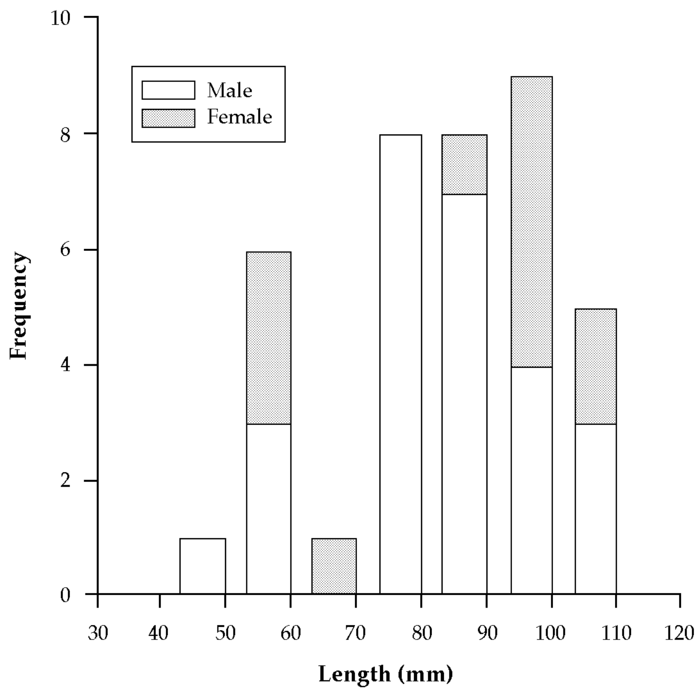

Figure 3

Trochus sex distribution, with length

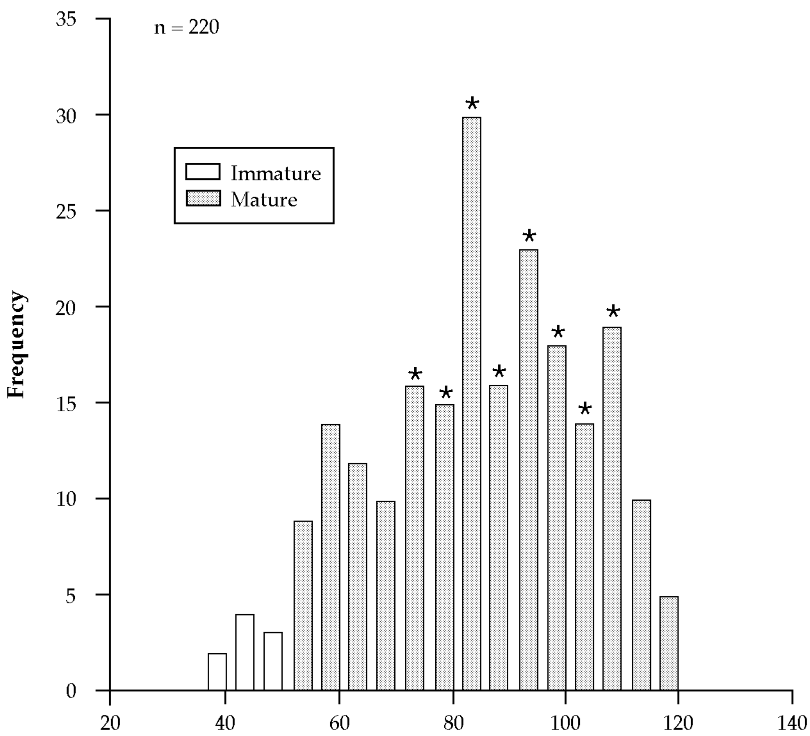

Figure 4

Trochus population size structure with a mean length = 84.0 mm. The animals considered sexually mature (i.e. > 50 mm length) (96%) are shaded. The stars (*) (60% of the population) indicate the animals within the 75 to 110 mm size range (discussed later).

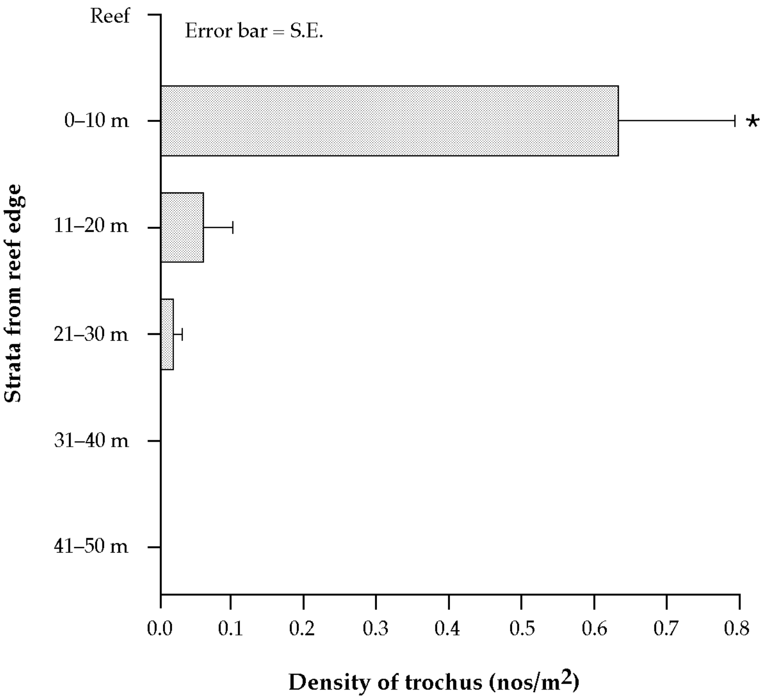

Figure 5

Spatial distribution of trochus at 10 m segments perpendicular to the edge of the lagoon reef. The high density at the 10 m stratum was significantly different (P < 0.05).

tion of population. This size range of the trochus population will be discussed later.

d. *Distribution patterns*

A clear trend of distribution emerged at *Patukiri* site (Figure 5). Most trochus were found at the 10 m segment of the transect closest to the edge of the reef. Thereafter the trochus were scarce and were not observed at a distance of 50 m perpendicular to the reef. The average (and s.e.) of density in the 10 m stratum was 0.63 (0.16) ind./m^2, which was significantly different (1-way ANOVA, Tukeys test, $P < 0.05$, *SPSS version 6.1* software) compared to the density of animals in the 20 m (0.06 ind./m^2), 30 m (0.02 ind./m^2), 40 m (0 ind./m^2) and 50 m (0 ind./m^2) strata.

At the edge of the reef, an exceptional number of trochus (130 animals) was noticed at one rock of approximately 3 x 3 m^2 area, i.e. a density of approx. 14.4 ind./m^2 (although this rock did not fall within the area of the survey transect).

b. *Population census*

Since the trochus are found mostly in the 10 m stratum closest to the reef edge, all transects to assess population abundance were laid in this stratum. At some sites without adjacent landmass, visual surveys of the atoll barrier reef area (where the animals are typically found in Aitutaki) failed to reveal the presence of trochus.

The highest trochus densities were found at *Seniseni* and *Patukiri* sites. The mean (and s.e.) of these two sites

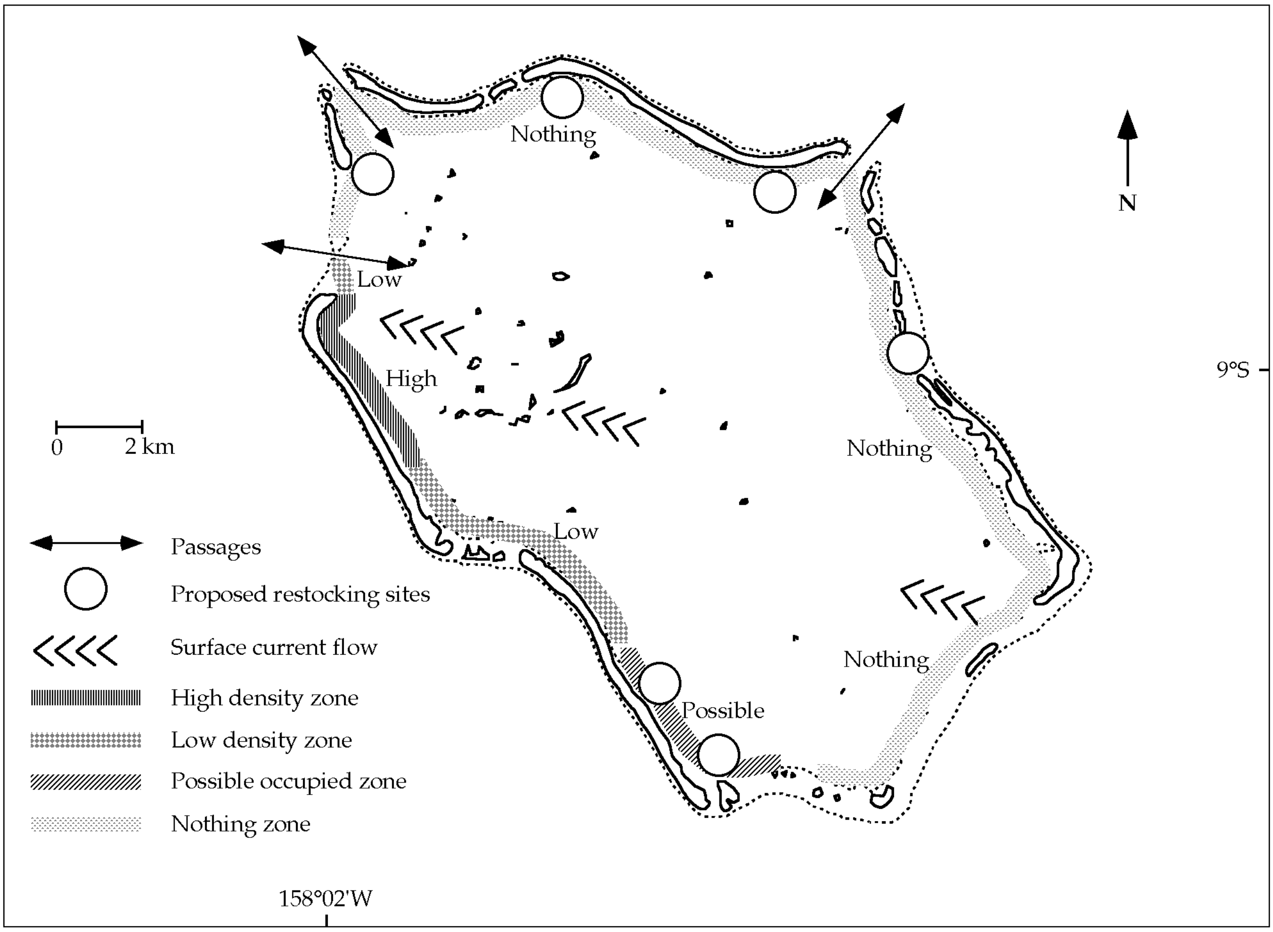

Figure 6

Zones of occupation by trochus at Penrhyn lagoon.
Also indicated are possible sites for restocking, as discussed later.

was 0.41 (0.04) ind./m^2. Low densities were observed at several sites adjacent to *Seniseni* (*Passage north*) and *Patukiri* (*Parahatea, Hangarei* and *Mahera*). The combined mean (and s.e.) of the low-density sites was 0.02 (0.01) ind./m^2. At other sites, trochus were not found.

The population was divided among four zones within Tongareva lagoon (Figure 6): firstly, a *high-density* zone in the north-west quadrat where most trochus occur. Adjacent to this area is a *low-density* zone with lesser trochus density. The third zone is named *possible* because there are reported sightings within this area. Lastly, the *nothing* zone on the western and far northern part of the lagoon is not considered to harbour animals because of the far distance from high densities of trochus, a general predominance of unsuitable habitat substrate (sandy or rubble), and the possible impediment to larval distribution caused by currents from wind-borne surface currents and passages.

The various zones are described in Table 1. The area of each zone was simply calculated as its distance (using *MapInfo 4* software) multiplied by the 10 m stratum assumed to be occupied by trochus. Based on this area a simple stratified stock assessment can be derived using the density (and 95% confidence intervals) of the high and low zones described earlier. Therefore the abundance of trochus at Penrhyn amounts to 27 300 (±14 300) animals.

Conclusions

Trochus dimensions of dry shell weight (W) and base diameter (L) can be expressed by the equation $W = (3.4x10^{-4})\ L^{2.943}$. The result is similar to that reported by Honman (1988) (i.e. $W = (7 \times 10^{-4})\ L^{2.83}$).

The onset of female sexual maturity initially occurs among animals > 50 mm length. As the male sex was not always readily distinguished, the female sex is taken to represent size at maturity. This is within the general size range (i.e. 50–70 mm) at which trochus elsewhere typically mature, although Nash (1993) reported a mature male and female measured at 53 mm and 44 mm length, respectively.

Table 1: **Area of strata occupied by trochus and abundance of animals**

Strata	Area (m^2)	Density (ind./m^2)	n	s.e.	Abundance	95% c.i.
High density	63,200	0.41	2	0.04	26,100	12,100
Low density	79,000	0.01	4	0.01	1,200	2,200
Possible	87,900					
Nothing	431,100					
Total	661,200		6		27,300	14,300

Approximately 96 per cent of the population are > 50 mm diameter, suggesting a large proportion of sexually mature animals. However, this study had a small sample size (n = 39) and was unable to clearly indicate the ratio of females/males with size classification.

The length (diameter of base) of the average trochus was 84.0 mm (n = 220). Trochus at Penrhyn appear more conical than those found at Aitutaki, which have the larger, thicker base typical of the surf-zone habitat. Only one trochus at Penrhyn was found to exceed 120 mm, whereas in Aitutaki the mean length of trochus was 100.6 mm and maximum length was 151 mm (n = 767, Ministry of Marine Resources survey, 1995). This smaller average size of animals at Penrhyn is not surprising given the recently established population. Bouchet & Bour (1980) note that it takes approx. 10 years for an animal to reach 120 mm.

The trochus at Penrhyn mostly occupy the 10 m stratum at the fringe of the lagoon reef. However, the original site of transplant was in the vicinity of the barrier reef flat (because this is where they mostly occur at Aitutaki). This survey has revealed that the trochus have unexpectedly occupied a different spatial niche (in retrospect, Sims, 1985 pointed out that Aitutaki has an unusual reef topography). The lagoon reef edge at Penrhyn where trochus occur is characterised by high wave action and rocky outcrops with filamentous algal cover which probably offer protection and food.

Based on the survey results and personal observations we suggest that the trochus population abundance at Penrhyn lagoon can be divided into four strata: *high density*, *low density*, *possible* and *nothing*. Trochus predominantly occur along the north-west quadrat of the lagoon and are most likely the offspring from animals accidentally released at Omoko wharf.

Given the density of animals (and area) occupied in the *high-density* and *low-density* strata (0.41 ind./m^2, 63,200 m^2 and 0.01 ind./m^2, 79,000 m^2, respectively) a population abundance (and 95% confidence interval) of 27,300 (14,300) animals was derived.

Three management options are proposed for further action regarding the trochus population.

Option 1. ***Continue the ban on commercial harvest of trochus and allow natural establishment of the existing population in Penrhyn.***

Option 2. ***Allow a commercial harvest of trochus in the near future.***

Sustainable limits for harvesting of trochus in Aitutaki are set at 30 per cent of the population in the 80–120 mm size range. This allows smaller sexually mature animals to breed before attaining 80 mm size as well as 70 per cent of the harvest size, and the animals > 120 mm are a reserve of broodstock for future harvest cohorts. The same principles are proposed here but instead it is suggested that the size limits be adjusted to conform with the smaller-sized trochus at Penrhyn. The suggested size range at Penrhyn is 75 to 110 mm (recalling that animals mature at > 50 mm length and the maximum length found was 123 mm). The 75 to 110 mm animals represent 60 per cent of the portion of the population (Figure 4).

Therefore knowing,

1. Population size = 27,000 animals
2. Harvest size range of 75–110 mm = 60% of the population size = 16,200 animals
3. Sustainable limit of 30% of the harvest size = 5,000 animals

(i) A total of 5,000 animals can be sustainably harvested.

Recalling the shell weight-versus-length relationship (i.e. $W = (3.4x10^{-4}) L^{2.943}$) and assuming that the average-sized trochus harvested is 92.5 mm, the average weight of animal harvested is 208 g. The harvest can be expressed in weight or per sack (assuming 75 kg dry shell per 50 kg flour sack).

(ii) A total of 1,040 kg of dry shell weight or 14 sacks can be sustainably harvested.

All trochus of 75–110 mm length for sex/size classification were graded as A grade (n = 30). Assuming a CI$ 7.00 (≈US$ 4.55) per kg for A grade product, the economic value of the harvest can be calculated.

(iii) A total value of CI$ 7,300 (≈US$ 4,780) can be sustainably harvested.

Option 3. ***Harvest trochus from high-density areas and transplant the animals to possible sites around Penrhyn lagoon so as to encourage the establishment of trochus population.***

The same amounts of animals calculated for a commercial harvest can be removed for the purpose of restocking the lagoon. Some possible sites for relocation are indicated in Figure 6. These sites acknowledge that *Te Tautua* settlement is distant from the trochus present stock, and from the potential trochus habitat in the north and southwest areas of Penrhyn lagoon.

Option 4. ***Selective harvest of suitably sized animals for use as hatchery broodstock.***

As an exercise, trochus juveniles have been reared at the pearl oyster hatchery at Penrhyn. Hatchery-reared juveniles may supplement wild stock for harvesting and also prove useful in developing growth and recruitment models for management purposes.

References

BOUCHET, P & W. BOUR. (1980). The trochus fishery in New Caledonia. SPC Fisheries Newsletter, no. 20, April 1980. 9–12.

HONMA, K. (1988). Growth of the coral-reef gastropod *Trochus niloticus* L. Galaxea, 7: 1–12. Sesoko Marine Sci. Centre, University of the Ryukyus; Nishihara, Okinawa Japan: 903-01

NASH, W.J. (1988). Hatchery rearing of trochus as a management tool. Australian Fisheries, Nov. 1988. 36–39.

NASH, W.J. (1993). Trochus, Chapter 14, **In:** Nearshore Marine Resources of the South Pacific. 710 p. (Eds: A. Wright & L. Hill) International Centre for Ocean Development, Canada.

SIMS, N. (1985). The abundance, distribution and exploitation of *Trochus niloticus* L. in the Cook Islands. Proceedings of the 5th International Coral Reef Congress, Tahiti, 1985, vol.5: 539–544.

Acknowledgements

Thanks to R. Braley for reviewing drafts of this report.

Trochus niloticus spawnings at Tongareva Marine Research Centre, Penrhyn Atoll, Cook Islands

by Dr Rick Braley (Aquasearch) - ADB Consultant Marine Biologist
Mr Mataora Bill Marsters - Chief hatchery technician
Mrs Rorangi Taime - Chief algal culture technician

The commercial topshell, *Trochus niloticus*, was introduced to Penrhyn Atoll from Aitutaki Atoll about 10 years ago. In a recent survey by the Ministry of Marine Resources, the broodstock trochus were mainly found on the west side of the lagoon, along the islet where the village of Omoka, the Tongareva Marine Research Centre [TMRC] and the airport are located. At the end of the first week of November 1996, 43 trochus were collected from the corals on the reef front outside TMRC. These were cleaned and set into a tank. The following day (8 November 1996) they were induced to spawn using the heavy aeration method in a small amount of seawater. The induction method ceased at 18.00 h and the trochus were placed into a spawning tank with clean filtered seawater (fsw). The seawater temperature was raised and lowered a couple of times until release of sperm began, followed by eggs. Large quantities of eggs were spawned, but only a small batch of eggs was kept, fertilised and placed in two hatching tanks. The following day an estimated 5,600,000 trochophore larvae had hatched and after reaching the veliger stage these were stocked in a raceway tank filled to approximately 7,000 litres. Pearl oyster spat were later placed in this raceway with the trochus juveniles and, due to movements of spat and cleaning of raceways, many of the trochus juveniles were lost down the drain. By mid-March the remaining juveniles had reached only about 5 mm basal diameter, but this was due to limited food and rather poor holding conditions in a small tank. In mid-May the juveniles were returned to a raceway along with a newly-settled batch of hatchery-reared trochus. They were subsequently placed in a raceway with trays containing blacklip pearl oyster spat of >5 mm. In late August 1997 the size of this first batch of trochus juveniles averaged 20 mm basal diameter.

The second spawning took place after 46 adult trochus were collected on 5 May 1997 along the reef front outside the TMRC. No induction method was used. Some sperm was released at the beginning of the night of 5 May but no further activity was observed later (to 23.00 h). A massive number of eggs had been spawned by the following morning (estimate 15,000,000 eggs). On the night of 6 May 1997, several females spawned eggs, but the total numbered only about 2,000,000 eggs. The counts of veliger larvae on 9 May indicated 770,000 larvae, and these were transferred into a raceway tank (7,000 litres). Once again, as pearl oyster spat was moved in and out of raceways and as raceways were regularly cleaned, many juvenile trochus were lost down the drain. On 30 August 1997 the average size of this batch of trochus was about 4–5 mm basal diameter. Both batches of trochus are foraging on raceway walls, bottom, and on trays containing blacklip pearl oyster spat. In future it is hoped that a proper study will be conducted to look at the advantage or otherwise of having trochus and pearl oyster spat in polyculture, in relation to control of filamentous algae, especially around pearl oyster spat.

First commercial trochus harvest from Palmerston Atoll

by Kelvin Passfield

Trochus were first introduced to Palmerston in the late 1960s, from Aitutaki. Further introductions occurred in the early 1980s, when about 3,000 trochus were transported to Palmerston, again from Aitutaki (Sims, 1985). A survey in September 1988 found that ' . . . only small numbers persist in limited areas of the northern reef' and concluded that it was unlikely that trochus would constitute a major economic resource for the island (Preston et al., 1995).

A recent commercial harvest in Palmerston gives an indication that this initial pessimism may have been premature. About 1.5 t of trochus shell were harvested earlier this year (1997), and sold to a buyer on Rarotonga. However, the quality was reported to be very poor, with 70 per cent of shells being badly worm-eaten. The buyer is still waiting for a price from the world market, and is reported to be still holding most of the shells.

There was some concern by some Palmerston residents and Government officials that the harvest was not properly organised and regulated. This concern is backed up by the reports of poor shell quality, which could have perhaps been avoided if the harvest had been monitored in a similar manner to the approximately annual harvests in Aitutaki.

The significance of this harvest lies in the fact that it is the first commercial harvest of trochus in the Cook Islands outside Aitutaki, and occurred nearly 30 years after the original introduction. The first commercial harvest of Aitutaki trochus occurred in 1981, 24 years after the original introduction of trochus there from Fiji in 1957.

A trochus introduction programme in the 1980s has seen trochus introduced to 13 of the 15 islands in the Cooks group. Some of these islands, for example Penrhyn, Manihiki and Rarotonga, now report trochus as being abundant. It is probable that commercial harvests of trochus in some of these islands will begin before the year 2000.

With careful management, including controls on the quality and size of trochus harvested, it is possible that the trochus fishery in Palmerston could develop into a significant economic resource for the people of the island, especially considering there are only 49 residents of Palmerston to share the benefits.

References

PRESTON, G., A.D. LEWIS, N. SIMS, I. BERTRAM, N. HOWARD, S. MALUOFENUA, B. MARSTERS, K. PASSFIELD, T. TEARII, F. VIALA, A. WRIGHT & B. YEETING. (1995). The Marine Resources of Palmerston Island, Cook Islands. Report of a survey carried out in September, 1988. IFRP Technical Document No. 10. South Pacific Commission, Noumea.

SIMS, N.A. (1985). The abundance, distribution, and exploitation of *Trochus niloticus* L. in the Cook Islands. Proceedings of the 5th International Coral Reef Congress, Tahiti, 1985, Vol. 1: 539–544.

News from the Federated States of Micronesia

An update on the Yap Outer Islands Trochus Reseeding Project

by Steven Retalmawai & Mike Hasurmai

Lamotrek and Elato Trochus Reseeding Project report

At the end of November 1996, a team of four Marine Resources Management Division (MRMD) technicians travelled on the MS *Micro Spirit* to transplant trochus on two outer islands. The assignment was to harvest 500 *Trochus niloticus* from Woleai Atoll, as previously arranged by Mike Hasurmai, for the Elato and Lamotrek Trochus Reseeding Project.

Five unemployed members from the Woleai Community had already been appointed to help preparing the 500 pieces of trochus to be transported by the MS *Micro Spirit* to Lamotrek and Elato Atolls. This was the third time trochus was to be transplanted to Elato and Lamotrek, after one transplant in the early 1980s and one in 1991.

Upon reaching Woleai, we were advised by the Field Trip Officer that the harvest of the 500 trochus could start immediately. We used the MRMD boat that we had brought with us and went to Falalus Island. There we discussed with the Chief and several community members where we could harvest 500 pieces in a short time. We were instructed to proceed to Wotegai, where trochus were known to be abundant. When we arrived there, the Chief of Wotegai suggested that we proceed to Falalop Woleai (our next planned harvest ground), while

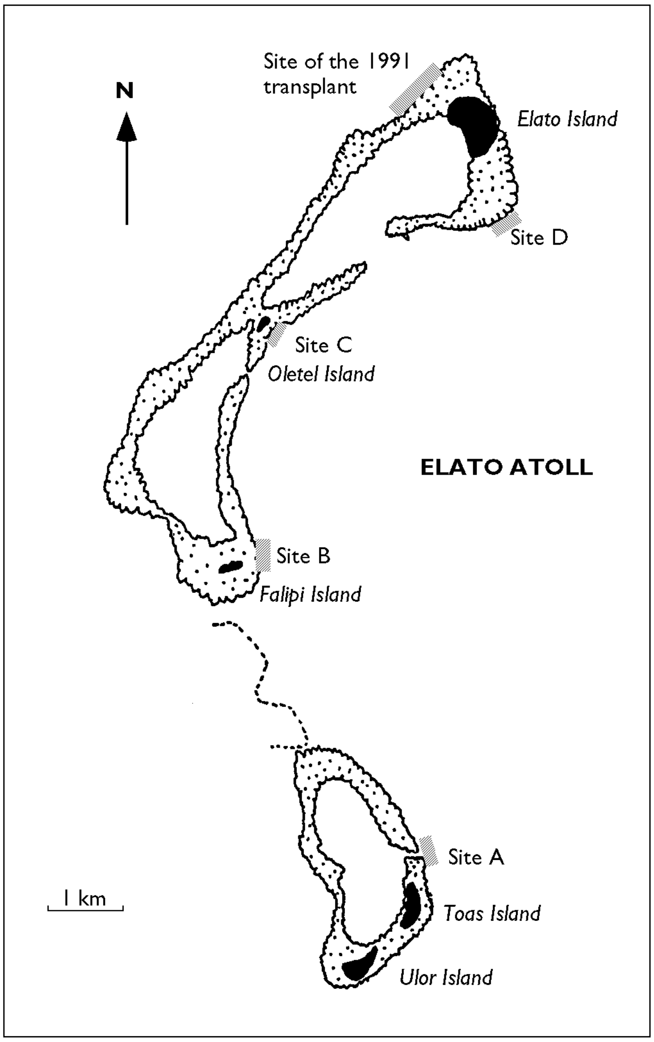

Figure 1
Map of Elato Atoll showing the 4 transplantation sites

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some of his men harvested 200 trochus for us without our help.

It took approximately three and half hours to harvest 300 trochus along Falalop Woleai; most were found on the northern part of the reef. We finally collected the 500 trochus needed for our reseeding sites within about six hours.

Trochus were counted and carefully placed in the eight transplanting tanks on the deck of MS *Micro Spirit*. We also requested permission to use the saltwater fire-pump to maintain a constant flow of clean water in the tanks. Permission was given, but the pump could only be used for one and half hours at a time to avoid over-heating.

It took 98 hours, a little more than four days, to reach our reseeding sites and the harvested stock was monitored regularly. When we reached our final destination, most of our harvested trochus were very weak.

As we approached Elato early in the morning, we made contact with the Field Trip Officer to organise the work plan. He informed us that the Field Trip Party would assist us by letting us use one of their boats for transplanting. As planned, 250 trochus were transplanted to four sites around Elato Atoll.

The first transplants were made at Site A, close to the two southern small islands (Ulor and Toas) of Elato Atoll (see Figure 1). Then we moved to Site B, close to Falipi, and to Sites C and D, closer to Elato Island. The work was completed within two hours.

When we returned to MS *Micro Spirit*, anchored in Elato's lagoon, we were informed by the Field Trip Officer that the ship was not leaving until four hours later. Of the 250 trochus left for transplanting on Lamotrek, 21 were found dead and the rest appeared very weak. They had to be put back in the ocean quickly or they would probably all die.

We therefore decided not to wait for MS *Micro Spirit* but to head for Lamotrek (approximately 13 miles East of Elato) in our own boat. When we reached Site A at Lamotrek (see Figure 2), we transplanted 100 trochus and found 20 more dead. We then proceeded to Site B and transplanted the rest. A total of 41 trochus had died on the trip due to the time limits for use of electric-fire-pump to maintain water circulation.

Two days later, after MS *Micro Spirit* had completed a round trip to Satwal, we had the opportunity to survey Sites A, B and D in Elato. All transplanted trochus were found to be alive and well.

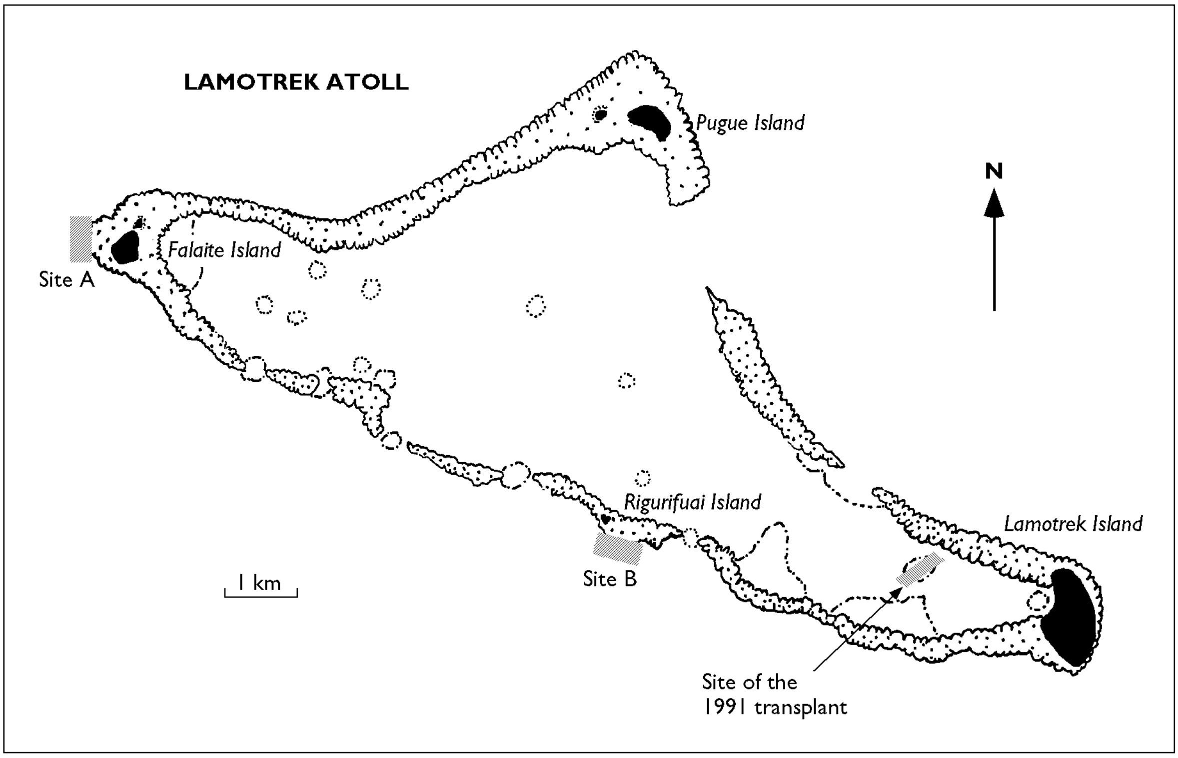

Figure 2

Map of Lamotrek Atoll showing the 2 transplantation sites

Ifalik Trochus Reseeding Project report

A team from MRMD travelled to Ifalik on the MS *Caroline Islands* to transplant trochus (*Trochus niloticus*). Two technicians and a marine research specialist were assigned to carry out the task. This was the second time trochus was to be transplanted to Ifalik.

Harvesting sites were planned and arranged with the chiefs and the community of Woleai before the trip was organised. Woleai was chosen as the only suitable harvesting site for two main reasons:

1. It is close to the reseeding site; it would therefore only take 24 hours for the trochus to be carried by boat from the harvesting to the transplanting site, so disturbance would be minimal; and
2. *Trochus niloticus* was found in abundance almost all over the reef area surveyed.

Harvesting in Woleai was very difficult as a tropical disturbance was passing through the neighbouring islands at that time. Water visibility was poor and the current was strong. We used the MRMD boat that we had brought with us, to harvest the 500 trochus we needed for the Ifalik Reseeding Project. Several Woleai community members willingly helped us collect the trochus and we were able to work using our SCUBA tanks to facilitate collection.

The 500 trochus were placed in six 1.2 m x 0.6 m water tanks on the deck of MS *Caroline Islands*. The ship's officers supported us by letting us use the seawater pump to maintain constant water flow in the tanks during the 24-hour trip to the transplanting site. All 500 trochus collected were still strong and active when they were transplanted.

Four sites were selected for replanting in Ifalik (see Figure 3). Within each site, a total of 125 trochus were planted. It took approximately three hours to complete transplanting all 500 pieces.

After 24 hours spent on shore we were able to go out with one of the local people to check on the trochus. We found them all active. Later on, we described to the community chiefs and several community members the four sites where trochus had just been transplanted, using maps.

The mission was a success. It is planned to continue checking and monitoring the transplanted trochus stock during the next three years, with the assistance of the community of Ifalik, to make sure that they can survive and reproduce.

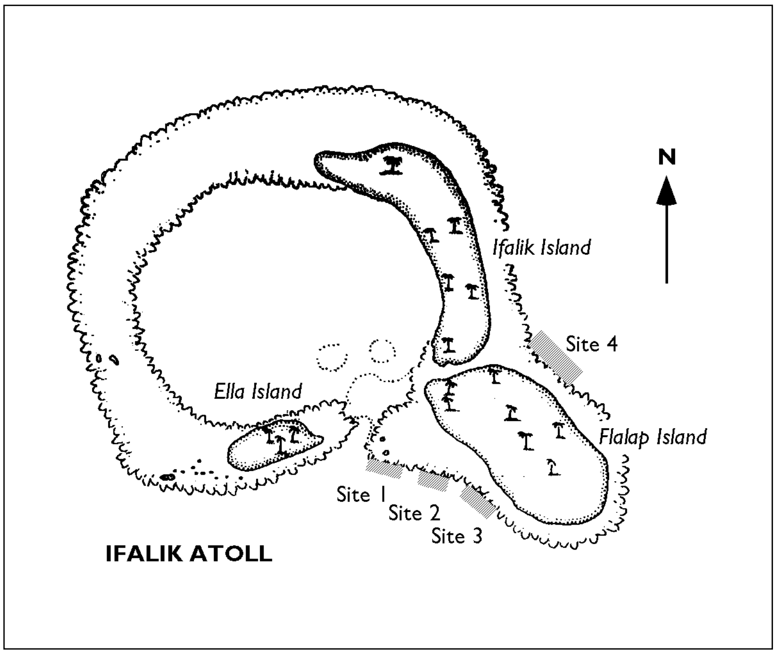

Figure 3

Map of Ifalik Atoll showing the 4 transplantation sites

news from New Caledonia

Report on the introduction of trochus (*Trochus niloticus*) juveniles to Lifou (Loyalty Islands)

by C. Chauvet [1], D. Audabran [1], C. Hoffschir [2] & H. Meité [2]

Abstract

Creation of a stock of trochus (*Trochus niloticus*) on the reefs of Lifou, where the species does not currently occur, was attempted by means of seeding with pond-bred trochus spat. A total of 5,709 juveniles, measuring 19 mm and 14 months old on average at the time of the introduction, were released in 20 different sites so as to create a breeding stock. Five years later, exploration of the reefs at low tide, both through dives and on foot, and enquiries with local residents resulted in the recapture of only a single specimen.

Background

IFREMER (French Institute of Research for Ocean Development) and ORSTOM (French Institute of Scientific Research for Cooperative Development), with funding support from CORDET (Coordination of Research in French Overseas Departments and Territories), carried out trochus (*Trochus niloticus*) production trials with the goal of seeding exploited reefs or areas where the species did not normally exist (Bour & Guelorget, 1986). During the breeding season, which occurs during the hot season (Bour, 1988) from October to May, spawners were collected and put into breeding ponds where spawning occurred on a regular basis. Several attempts were necessary to ensure production of juveniles, given the very high level of mortality in the larval stages to first settlement stages. Despite these difficulties, 5,709 specimens were pre-grown to an average size of 19 mm (range: 14–25 mm).

At the request of the Loyalty Islands Region (which has become the Loyalty Islands Province since the Matignon Accords), introduction was carried out in March 1989 on the island of Lifou where trochus have never existed (Hoffschir et al., 1989a). The juveniles, packed in aerated water, were placed in refrigerated coolers for the trip from the rearing ponds to Lifou. Twenty introduction sites were selected (see Figure 1 on next page), using criteria which were favourable to growth and which would also allow subsequent monitoring of the juveniles' establishment (Hoffschir et al., 1989 b).

Six subsequent visits allowed monitoring of changes in the numbers of specimens and their sizes. A strong cyclone which occurred some two weeks after initial introduction hindered this work by scattering the juveniles.

Growth rate and numbers of surviving specimens

From 26 to 30 March 1990 (Hoffschir et al., 1990), i.e. one year after transplantation, 19 trochus averaging 64 mm (range: 49–74 mm) in size were found. During this year in a natural environment, the growth increment was 45 mm, which is considerable in comparison to the growth increment of 33 mm obtained in rearing ponds (Fig. 2), i.e. a relative growth factor of 2.3 as compared to 1.7.

Abundance indexes fell drastically during this period, with a 20 per cent recapture rate after 2 weeks, 10 per cent after 2 months and 8.4 per cent after 3 months.

Sexual maturity and reproduction

The average size of trochus at sexual maturity in New Caledonia is 54 mm. Reproduction is 100

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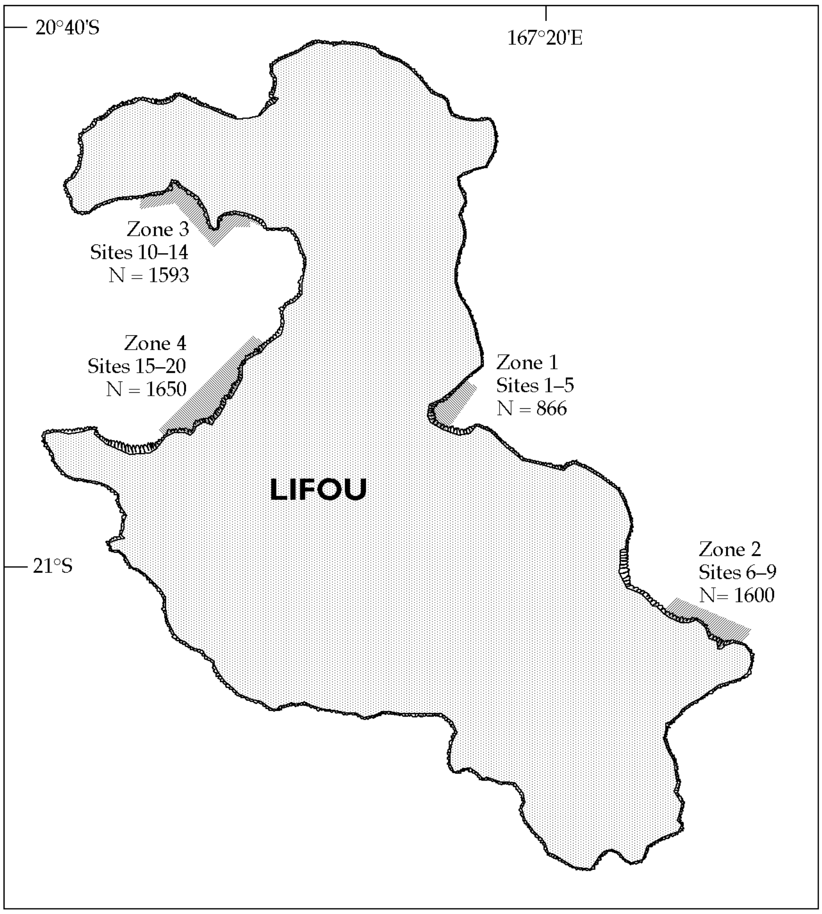

Figure 1

Map of Lifou showing the 4 zones where trochus were transplanted

per cent effective for specimens at least 57 mm in length (Bour, 1988). Thus, of the 19 trochus found, 16 probably were adults. It is possible then that these trochus, transplanted into a natural setting, spawned at the beginning of 1990, i.e. approximately 12 months after the transplantation and 23 months after their birth.

Assessment of the introduction

At the request of the Loyalty Islands Province, a visit to observe trochus stocks was made by UFP and ORSTOM from 26 July to 4 August 1994, i.e. a little more than five years after transplantation.

Sampling methods

Dives were made at the 20 introduction sites. Sampling in 100 m transects along 2 m corridors was planned, but this method had to be abandoned as no trochus were found on the reefs.

The goal of the mission was then changed. It was no longer a question of knowing how many trochus there were in Lifou, but rather if any trochus at all had survived from the introduced population.

Research was then carried out by 30-minute dives by two divers around the 20 introduction sites (Fig. 1). These dives were supplemented by two dives outside the sites (one hour on the Djoj Reef at *Cap des Pins* between Sites 6 and 7 and 30 minutes at the Dozip Reef in front of the Lifou Plaisance Hotel), as well as two hours of on-foot prospecting of the reefs at low tide (one hour near the port and one hour in front of the headquarters of the Loyalty Islands Province).

Results

1. In all the introduction sites and in spite of the fact that a large surface area was covered, only a single trochus of 126 mm was captured in a

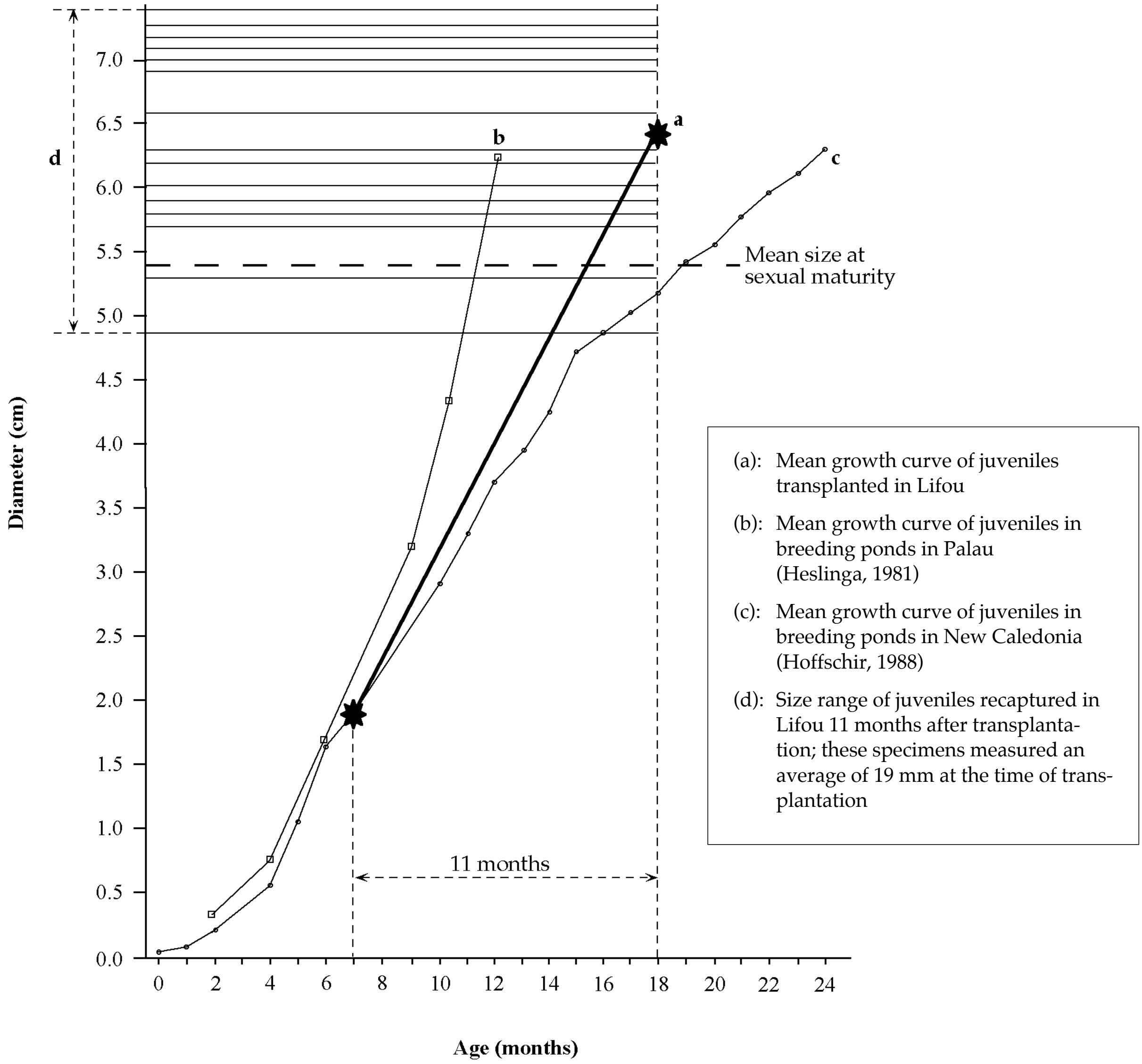

Figure 2

Comparative growth curves of *Trochus niloticus*

2 m dive about 30 m from Site 7 (Fig. 1). This specimen was marked with pencil on the inside of its shell so that the mark would be covered by a fine layer of nacre during growth. It was marked with the number 1 as well as the date of its recapture and then released at the site.

2. No trochus were found on the Djoj Reef. A sole specimen may have been caught in 1993 but its shell was broken open in order to get at the meat.
3. No trochus were found at the Dozip Reef. Two specimens may have been caught by tourists in February 1994. A single shell 130 mm in size was kept by the hotel owner.

Conclusion

A total of 27 hours of prospecting was carried out. This resulted in the recapture of only a single live trochus. Based on the abundance indexes in the first few months after introduction, which it might be recalled, fell drastically: i.e. 20 per cent recapture after 2 weeks, 10 per cent after 2 months and 8.4 per cent after three months, these disappointing results fit in well with the hypothesis that the introduced stock did not reproduce.

In fact, the virtual weekly mortality rates calculated with the recapture rates are for the following periods:

1st period (after 2 weeks)	0.302	i.e. annual rate of 15.71
2nd period (after 2 months)	0.056	i.e. annual rate of 2.91
3rd period (after 3 months)	0.015	i.e. annual rate of 0.78
Overall average:	0.076	

If a reasonable mortality rate of 0.50 per cent was applied to the entire surviving population after the third period, models show that there should have been about 30 specimens of the introduced population left after five years. It is not surprising then, that only a single specimen was found and this demonstrates that the population evolved normally but did not reproduce.

Two theories can be considered to account for this lack of reproduction: oligospermy in the population due to the low number of specimens reaching sexual maturity, or dispersal of larvae into the deep ocean due to the absence of a lagoon.

Oligospermy theory

Oligospermy is over-dilution of the sperm, which prevents fertilisation. This occurs when the distances between males and females are too great.

This theory emphasises the possible causes of mortality:

(a) The strong cyclone Lili which occurred two weeks after transplantation of the juveniles may have destroyed a significant number of the introduced specimens;

(b) Intensive fishing of most of the juveniles and breeding animals for food may have destroyed potential stock. It does in fact seem that fishing began as early as 1990;

(c) The size of the juveniles at the time of transplantation (average 19 mm) was not large enough to allow survival on a reef where there may be heavy predation.

These theoretical causes of mortality were most likely cumulative. In fact, one year after transplantation, about 20 trochus, with an average size of 64 mm, were recaptured, so a small number had, in fact, escaped destruction by the cyclone and heavy natural predation. Only a few specimens would have survived but numbers were too limited for reproduction to take place.

Larvae scattering theory

Fertilisation may have taken place, but the pelagic larvae were scattered into the deep ocean by the currents. The absence of a barrier reef would have kept the larvae from settling on the fringing reef.

This theory seems most likely, because if it is not true, it is hard to understand why trochus do not exist naturally on the Loyalty Islands.

It is obviously pointless to release juveniles in an area where normally they do not develop or where they develop very poorly. As the juveniles were obtained at a great cost, as the most difficult stages, i.e. the periods of heavy mortality, had passed, from an economic point of view it would be better to keep those juveniles in a protected environment rather than release them into a known hostile environment.

In the case in question, the best way to proceed would be to hope that the first theory was the cause of failure and repeat the experiment by introducing sexually-mature adult specimens from the main island to various sites. This group of breeding animals would have to be kept in a closed area and protected until it was sure that they had spawned.

If, after this, it was proven that the trochus did not reproduce, or more generally, that the development stages could not be carried out on Lifou, it would be reasonable to halt the introductions.

References

BOUR, W. (1988). Biologie, écologie, exploitation et gestion rationnelle des trocas (*Trochus niloticus*) de Nouvelle-Calédonie. Thèse Dr. : Océanogr. Bio.: Univ. Montepllier . 92 p.

BOUR, W. & O. GUELORGET. (1986). Caractérisation écologique du domaine lagonaire et des aires à trocas actuelles. La place de ces dernières dans l'organisation biologique du lagon. USTL et ORSTOM . 5 p.

BOUR, W. & C. HOFFSCHIR. (1985). Évaluation et gestion de la ressource en trocas de Nouvelle-Calédonie. Noumea : ORSTOM. 71 p.

HESLINGA, G.A. (1981). Larval development, settlement and metamorphosis of the tropical gastropod *Trochus niloticus*. Malacologia, 20(2): 349–357.

HOFFSCHIR, C., M. BLANC & H. MEITE. (1989a). Introduction des trocas, *Trochus niloticus* , à Lifou par transplantation de juvéniles produits en aquaculture. Nouméa : ORSTOM. Conv. : Sci. Mer: Biol. mar., 1. 23 p.

HOFFSCHIR, C., M. BLANC & H. MEITE. (1989b). Compte rendu de mission d'observation (18–22 décembre 1989) des juvéniles de trocas, *Trochus niloticus*, transplantés à Lifou. Rapp. Cent. Nouméa. ORSTOM. 4 p.

HOFFSCHIR, C., C. DUBOIS, P. HAMEL & H. MEITE. (1990). Report of the visit made from 26 to 30 March 1990 to inspect juvenile trochus transplanted on Lifou reefs. Working Paper 8. Twenty-second Regional Technical Meeting on Fisheries, Noumea, New Caledonia, 6–10 August 1990. 5 p.

trochus research in Australia

Part 1. Hatchery and nutrition research

by Dr Chan Lee [1] *– Project Coordinator*
ACIAR Trochus Reseeding Research Project

A Trochus Hatchery and Nutrition Research Project funded by the Department of Employment, Education, Training and Youth Affairs (DEETYA), Canberra, and involving the Northern Territory University (NTU), Darwin, Australia and the University Nusa Cendana (UNDANA), Kupang, Indonesia, was successfully completed in June 1996. An end-of-project conference funded by DEETYA and the Australian Centre for International Agricultural Research (ACIAR) was conducted at NTU on 6–7 June 1997. Some 50 participants, including research scientists from Australia, Indonesia and the Pacific, attended the two-day conference. During the conference, the major findings of the three-year research project were highlighted. In addition, contributions were made on trochus research carried out by countries in the region. A total of 29 papers was presented during the conference; the titles and abstracts of some are given below.

Design and operation of a land-based closed recirculating hatchery system for the topshell, *Trochus niloticus* using treated bore water

by C.L. Lee

Saline bore water high in iron was successfully treated and found to be ideal as a source of seawater supply for a land-based research hatchery for trochus. After aeration, sedimentation and dilution with freshwater, the treated saline bore water was successfully used to maintain trochus broodstock to produce juvenile trochus in the hatchery of the Northern Territory University (NTU). Wild trochus collected from King Sound, Western Australia were successfully translocated and maintained in the closed recirculating tank system developed at NTU. The wild broodstock spawned and the F1 matured and produced F2 successfully after 2.5 years, thereby 'closing' the life cycle. The closed recirculating hatchery system developed for producing juveniles was highly efficient in water utilisation and low in labour input. The system was adequate for producing the juveniles needed for the nutrition and related growth rate and reseeding studies. Over a three-year period, several hundred thousand juveniles of different size classes ranging from 1 to 25 mm were produced in the NTU hatchery. Average estimated cost of production for the smaller 1 to 3 mm size-class juveniles varies from <1.0 cents to 3.3 cts/juvenile.

Hatchery of the topshell (*Trochus niloticus*) in eastern Indonesia

by S.A.P. Dwiono, P.C. Makatipu and Pradina

The topshell (*Trochus niloticus* L.) is one of the most valuable marine resources in Indonesia. Due to fishing pressure, trochus is categorised as a threatened species. In order to enhance its population, seed production of this topshell was initiated in eastern Indonesia in 1994. Seven batches of trochus have been produced artificially. Strong aeration followed by UV-treated seawater proved effective in inducing the broodstocks to spawn. The larvae and juveniles are fed mainly on a cultured sessile diatom,

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Navicula spp. Growth rate is relatively high but the survival rate is low. In spite of good growth of the seeds, improvements of rearing techniques for this species are needed. The result of the seed production techniques is presented and discussed.

Current status of topshell, *Trochus niloticus*, hatcheries in Australia, Indonesia and the Pacific – A review

by C.L. Lee & M. Amos

One private and five institutional hatcheries for trochus, *Trochus niloticus,* are currently in operation. The research hatcheries are located at (i) the Northern Territory University (NTU), Darwin, Australia; (ii) the Indonesian Institute of Science (LIPI), Ambon, eastern Indonesia; (iii) the island of Barrany Lompo belonging to the University Hasanuddin in Ujong Pandang, eastern Indonesia; (iv) the Fisheries Department, Port Vila, Republic of Vanuatu; and (v) Sopu field station in Tonga. The sole private hatchery is located on Seram Island, eastern Indonesia. The oldest hatchery currently in operation is located in Port Vila; it has been in operation since the late 1980s. The other hatcheries were established in the early to mid-1990s. The hatchery in NTU is unique and is the only one that uses saline bore water for its water supply; all the other hatcheries pump seawater directly from the sea to supply their need. The NTU hatchery is also the only one currently in operation that uses a closed recirculating hatchery system for producing juveniles. The other hatcheries use flow-through or semi-flow-through systems for producing their juveniles. All the hatcheries have successfully produced juveniles in the last few years. It is encouraging that a private trochus hatchery is currently in operation in Indonesia. Occupying a floor space of 600 m^2, it is the largest trochus hatchery currently in operation in the world.

Fatty acid composition and proximate biochemical composition of wild and hatchery held broodstock of the marine topshell, *Trochus niloticus* (Mollusca: Gastropoda)

by F. Rebhung, S.M. Renaud, D.L. Parry & C.L. Lee

The fatty acid composition and proximate biochemical composition (carbohydrate, lipid, protein and ash) of foot tissue of adult *Trochus niloticus* (Gastropoda: Archaeogastropoda) collected from King Sound, north-west Australia (Group 1), were determined. Results were compared with those for animals from the same collection maintained for a year in the hatchery at Northern Territory University Aquaculture Centre (Group 2). The animals were mature broodstock and there was no significant difference in the total live weight of Group 1 and Group 2 at harvest. Foot tissue of Group 1 was composed of carbohydrate (3.8 % dry weight), lipid (6.1 %), protein (77.7 %) and ash (5.4 %). Animals of Group 2 had ash and protein contents similar to those of Group 1, but there was significantly lower lipid (5.3 % compared to 6.1 %; $p < 0.05$) and higher total carbohydrate (5.0 % compared to 3.9 %; $p < 0.05$). There was no significant difference in proximate composition between male and female for either group. The principal fatty acids (greater than 5% total fatty acids) were palmitic acid [16:0], stearic acid [18:0], oleic acid [18:1(n-9)] and arachidonic acid [20:4(n-6)]. Percentages of eicosapentaenoic acid [20:5(n-3)] and docosapentaenoic acid [22:5(n-3)] in Group 1 animals were lower than percentages reported for other archaeogastropods. There were changes in the fatty acid composition of Group 2 animals which included significant increases in the percentage of polyunsaturated fatty acids 16:3(n-6), 18:2(n-6), 20:5(n-3), 22:5(n-3) and 22:6(n-3) and significant decreases in the percentage of saturated fatty acids 16:0 and 18:0. The results for 16:0, 18:0, 16:3(n-4) and 20:5(n-3) reflected the fatty acid composition of the hatchery-mixed microalgae feed.

The food preference of the tropical topshell, *Trochus niloticus* fed on algae from Darwin Harbour

by G. Lambrinidis, J. Luong-Van & S. Renaud

Food preference of adult trochus, *Trochus niloticus* L., was investigated by estimating the feeding index and food consumption for ten species of seaweeds (*Halimeda borneensis*, *Symploca* sp., *Dictyota ciliolata*, *Padina australis*, *Padina boryana, Rosenvingea nhatrangensis*, *Sargassum* sp., *Acanthophora muscoides*, *Tolypiocladia glomerulata* and *Hypnea* sp.) and a mixed microalgal diet. It was found that trochus ate larger amounts of the soft filamentous forms (e.g. *Symploca* sp., *Hypnea* sp., and *Tolypiocladia glomerulata*) and the corticated *Acanthophora muscoides* than the leathery brown *algae (Rosenvingea nhatrangensis,* *Sargassum* sp. and *Padina* spp.) and the calcareous green algae (*Halimeda borneensis*). When food preference was expressed as feeding indices, it was found that there was no correlation between structural characteristics of the diets and feeding index. The mixed microalgal diet scored the highest index.

A study on density, abundance and distribution of juvenile trochus and its associated small molluscs in Kei Besar Island, Indonesia

by J.C. Dangeubun & S. Haumahu

Juveniles of top shells, *Trochus niloticus*, occurred in 20 per cent of the observations on the intertidal zone of the East Coast of Kei Besar Island, having density and abundance of 0.55 snails/m^2 and 1.83 snails/m^2, respectively. Juvenile trochus were found mostly underneath rocks or rubble along the coast at the low-tide-exposed area of the intertidal zone. There are 37 species of small mollusc (33 species of gastropods and 4 species of bivalves) occupying the same habitat as juvenile trochus. The highest densities of associated species, in decreasing order, are *Cellana radiata*, *Rissonia spirata*, *Natica sertata*, *Mitra* sp. and *Rhinoclavis* sp., while the highest abundances of associated species, in decreasing order, are *Mitra* sp., *N. sertata*, *C. radiata*, *Rhinoclavis* sp., *Notonister* sp., *R. spirata*, and *Pyramidella terebelloides*. Species that were found in the highest frequency of occurrence, in decreasing order, are *C. radiata* (85%), *R. spirata* (40%) *Epitonium lamelosa* (35%), and *Nerita albicila* (35%).

Management policy for trochus fisheries in the Pacific

by M.J. Amos

Commercial trochus fisheries started throughout the Pacific in the first decade of this century. The harvest of trochus has provided a significant source of revenue and employment in the Pacific region. Trochus has also played a significant role in fishery development in the Pacific. Its introduction into a number of Pacific Island States represents one of the more successful facets of fishery development. While the development of trochus fisheries has been successful in a number of areas, the effectiveness of management policies has been less clearly demonstrated. The status of trochus fisheries in some countries is not known because of inadequate or non-existent catch statistics. Information from fishermen or shell buyers often provides some indication of overfishing. The vulnerability of trochus to overfishing suggests that trochus fisheries may best be conserved by implementing conservative management regimes in the early stages of fishing.

Potential of remote sensing data for identifying trochus re-seeding sites

by W. Ahmad & G. Hill

During different stages of their life cycle, trochus exhibit preferences for different reef habitats. Likewise, within any reef complex there will be variation in the availability and distribution of these preferred habitats. Satellite remote sensing is able to identify and map the relevant reef types. Knowledge of the habitat base available within any proposed reseeding area will be an important consideration in reseeding activities. Where local knowledge is unavailable, or the area is remote, satellite remote sensing offers a reliable means of assessing the habitat base for trochus.

Establishing a relationship between habitat and abundance of trochus in King Sound, North-western Australia

by K.L. Magro

The habitat and abundance of trochus have never been investigated for the commercial trochus fishery in King Sound, north-western Australia, which has been operational since 1979. Estimates of trochus habitat and abundance were established from strip transect sampling of reef edge and reef flat habitats. Cluster analysis of habitat data separated the transects into 4 groups: algal pavement (56 transects), macroalgal pool (22), rubble pavement (4) and exposed rock (9). The maximum basal diameter was variable between reefs, especially between fished and non-fished reefs. Although the majority of variation was explained by reef site, larger shells were found on reef edges, and reef flats were dominated by smaller shells. There were very few trochus above the maximum legal size of 100 mm. The mean density of trochus within legal size limits (65 to 100 mm) on the reef edge (4.03 ± 0.630 se per 156 m^2, n=35) was significantly greater than on the reef flat (0.39 ± 0.107 se per 156 m^2, n=56). The high occurrence of small shells possibly indicates growth over-fishing of the trochus resource. The results from this study can be utilised (in conjunction with satellite images) to estimate the total area of habitat, standing stock and biomass of trochus in King Sound.

The papers from the conference have been published as an ACIAR Proceedings entitled: Trochus: Status, hatchery practice and nutrition. *For copies of these proceedings please contact:*

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Part 2. ACIAR Trochus Reef Reseeding Research

by Dr Chan L. Lee

Following the successes achieved in the Trochus Hatchery and Nutrition Research Project (see Part 1), the Australian Centre for International Agricultural Research (ACIAR) is funding another phase of the trochus research involving reef reseeding of juvenile trochus. The ACIAR-funded project involves three countries and six institutions; a three-year research budget of AU$ 680,138 was provided. The commissioned organisation for the project is the Northern Territory University with Dr Chan L. Lee appointed as project co-ordinator and Dr Tasman Crowe as research associate. The Australian component also involves the Western Australian Fisheries Department and the Aboriginal communities of King Sound. The two other countries involved in the research work are Indonesia and the Republic of Vanuatu. The Indonesian institutions involved in the research project are the Indonesian Institute of Sciences, University Pattimura and University Nusa Cendana with Dr Dwiono, Miss Dangeubun and Dr Rebhung respectively as country co-ordinators. Vanuatu is represented by Mr Moses Amos of the Department of Fisheries as the country co-ordinator.

There are many reasons for carrying out the trochus reseeding research over such a wide geographic region. Although there have been several preliminary studies into the potential of reseeding as a tool for the management of trochus fisheries over the last 13 years, no clear consensus has emerged. To date, the success of reef reseeding has been variable. In some cases there have been encouraging results, but hatchery-reared juveniles released into the wild have not always been recaptured in large numbers. Mortality or loss of juveniles can act to limit the impact of hatchery-reared individuals on adult populations. The preliminary nature of the studies, however, limits the scope of the conclusions that can be drawn from them. The results have been variable, there have been some methodological problems, and some issues, such as temporal variation in success of reseeding, have not yet been investigated. The study commissioned by ACIAR under the Trochus Reseeding Research Project should help to resolve some of the issues. For further discussion on the potential of reseeding with juveniles as a tool for the management of trochus fisheries, see Crowe, Amos & Lee (**In:** Trochus: status, hatchery practice and nutrition, ACIAR Proceedings, June 1997).

According to Mr Barney Smith, ACIAR Fisheries Programme Co-ordinator 'the ACIAR-funded Trochus Reef Reseeding Research Project is at the cutting edge of research on stock enhancement. It also involves training in hatchery work and on research to standardise the spawning and mass production of trochus juveniles'. Since the commencement of the research project, numerous benefits have already been derived by the institutions and staff involved in the research. Some of these are:

1. Upgrading of the trochus hatchery in all participating institutions;

2. Improved method of spawning and rearing developed in NTU has been transferred to all participating institutions, resulting in record production of juveniles;
3. The analytical skills of project staff have been enhanced by a two-week workshop on 'Design and analysis of environmental sampling and biological experiments'. These skills have been put to practical use by the project staff involved in the design, execution and analysis of reef reseeding research;
4. Development of a new technique for tagging juvenile trochus and training of research staff to use an underwater metal detector to search for tagged animals;
5. The successful hatchery work has encouraged the Aboriginal communities in King Sound, WA to come together to fund a multi-species hatchery; trochus and giant clam will be the first two species to be produced by the hatchery.

Since the commencement of the research project, the project teams have carried out research including pilot cage studies, site selection and growth and density studies involving the release of juvenile trochus of a range of sizes from 1 to 50 mm. This work should give a clear picture of the effectiveness of reseeding in a broad range of biogeographical regions. The project is due for completion in June 1998.

In Part 3 of this series of articles on rrochus research in Australia, some practical outcomes on hatchery practice and juvenile production are discussed.

Part 3a. ACIAR Trochus Reef Reseeding Research: A simplified method of induced spawning in trochus

by Dr Chan L. Lee

Introduction

Seed supply has been identified as a bottleneck for many aquaculture species and trochus is no exception. Since the first reported spontaneous spawning of trochus in the hatchery (Heslinga, 1981), all trochus hatcheries have mainly relied on this method to produce juveniles for grow-out or for reseeding research.

However, this method of spawning is dependent on ready access to large numbers of broodstock and the results of spontaneous spawning are inconsistent.

Further, although it is workable in locations where broodstock is readily available, the method is very wasteful, as it is dependent on a few females spawning from a large number of mature animals that need to be collected for spawning induction.

Out-of-season spawning is not possible using this method of spawning. A simpler and more reliable method of spawning needed to be standardised if mass production of juveniles was to be attempted.

This short communication, based on research conducted in the Northern Territory University (NTU), Darwin, Australia as part of the ACIAR-funded reef reseeding research on trochus, gives a summary of a simplified, reliable method of inducing trochus to spawn, using basic equipment readily available in the Indo-Pacific region.

Methods used for induced spawning of trochus

Since the work of Heslinga in 1981, numerous methods of spawning trochus have been attempted to improve spawning outcomes. The methods used were based on applying physical and chemical stimuli, which have been reported to be effective in spawning other molluscs. Shokita et al., (1991) and Kikutani and Patris (1991) reported that UV irradiation was effective in spawning trochus. In contrast, Dobson (1994) believed that UV irradiation did not work but physical massaging of the gonad with a jet of water produced better success in spawning induction. Dobson (1994; 1997) and Gimin (1997) tested the effectiveness of using hypersalinity, desiccation and hydrogen peroxide for inducing spawning without significant positive results. Gimin (1997) also failed to achieve meaningful spawning of trochus with application of serotonin which was highly effective in spawning giant clam.

Improved and simplified method developed at NTU

Broodstock supply

The NTU trochus hatchery is unique and also the most difficult to operate compared to other hatcheries in the Indo-Pacific region. The hatchery has no ready supply of broodstock and all spawners have to be collected from King Sound, Western Australia, and transported over 230 km of unsealed road followed by a jet flight of over 1,000 km to Darwin. On arrival in NTU, the spawners are held in treated bore water and prepared for induced spawning. More details on the method for transportation of broodstocks to NTU are given in Lee and Ostle (1997).

Water supply

NTU hatchery has no direct seawater access. The hatchery is dependent on a 100 mm diameter bore sunk at a depth of 56 m to pump saline water for its seawater supply. The salinity of the bore water is 51–52 ppt and it is high in iron. Details on treatment of the bore water and dilution to 35 ppt for growing trochus are given in Lee (1997); the quality of the water is given in Table 1. The bore water has been used for holding and spawning trochus successfully over a period of five years. Our experience at NTU indicates that saline bore water has been neglected and significantly underrated as a source for hatchery water supply, not only for trochus but perhaps for other aquacultured species as well.

Spawning tanks

200 l glass spawning tanks, each measuring 800 mm long x 570 mm wide x 470 mm high, were used for induced spawning experiments. The tanks were set up in two tiers one above the other. Up to three such tanks (one for broodstock and two for heated water) were used in each spawning trial. During the induced spawning experiment, the water in the tanks located in the upper tier was heated by 200 watt aquarium heaters to a temperature 2–3°C higher than the water temperature maintained in the lower spawning tank. When required, the heated water was siphoned into the spawning tank.

Method of spawning

On arrival at NTU from King Sound, spawners were cleaned with a stiff brush and transferred to a 200 l glass tank filled with about 120 l of fresh bore water at 35 ppt for recovery; up to 30 broodstock could be carried in each spawning tank. The spawning tank was provided with high aeration and maintained at ambient air temperature. Subsequent treatments to bring about spawning are summarised below.

- An hour before sunset, siphon out the wastes and drain the spawning tank.
- Siphon the heated water from the higher tank into the lower spawning tank immediately.
- If no spawning is observed within an hour, leave the spawners for two hours before repeating the draining and filling of the spawning tank with heated water.
- Spawning usually occurs within an hour after the second change of heated water.
- On rare occasions, a third change of water maybe required before spawning is obtained.

Using heated bore water at a temperature 2–3°C higher than the water used for holding the spawners and changing the water 2–3 times is sufficient to bring about spawning in trochus. NTU has been able to spawn the trochus using this simple procedure on a year-round basis regardless of the moon phase.

The simplified method of spawning trochus was successfully applied in Vanuatu in 1996 during the months of July, September, October and December.

This year, Vanuatu's hatchery was able to produce more juveniles in a single year than the combined production from

Table 1: Quality of bore water (before and after treatment by aeration and sedimentation) compared to quality of seawater

Components [1]	Bore water		Seawater
	Before [2]	After [3]	
Sodium	16,400	10,700	10,560
Calcium	689	447	400
Potassium	514	339	380
Magnesium	2,059	1,349	1,272
Iron	20	0.3	0.02
Silica	20	15	8.6
Chloride	30,250	20,000	18,980
Sulphate	4,800	2,850	2,560
pH	6.2	7.8	8.2
Salinity	51	35	35

1: All ions in ppm, salinity in ppt
2: Before = raw bore water
3: After = bore water after 24 hrs aeration, 72 hrs sedimentation and dilution to 35 ppt

the past eight years of operation. This method of induced spawning will also be tested in Indonesia in 1997.

References

DOBSON, G. (1994). Induced breeding, settlement and juvenile growth rates of *Trochus niloticus* (Linnaeus). B.Sc.Hon. thesis, NTU, Darwin , Australia. 112 p.

DOBSON, G. (1997). Preliminary studies on the induced spawning of *Trochus niloticus* (Linnaeus) using artificial stimuli. **In:** Lee, C.L. & Lynch, P. (eds.) 1997, Trochus: Status, hatchery practice and nutrition. ACIAR Proceeding No. 79. 187 p.

GIMIN, R. (1997). Reproduction and induced spawning of trochus, *Trochus niloticus* (Linnaeus). M.Sc. thesis, NTU, Darwin Australia. 164 p.

HESLINGA, G.A. (1981). Larval development, settlement and metamorphosis of the tropical gastropod *Trochus niloticus*. Malacologia, 20(2): 349–357.

KIKUTANI, K. & PATRIS, S. (1991). Status of *Trochus niloticus* mariculture in the Republic of Palau: Annual 1991 project summary. Micronesian Mariculture Demonstration Centre, Koror, Republic of Palau.

LEE, C. L. (1997). Design and operation of a land-based closed recirculating hatchery system for the topshell, *Trochus niloticus* using treated bore water. **In:** Lee, C.L. and Lynch, P. (eds.) 1997, Trochus: Status, hatchery practice and nutrition. ACIAR Proceeding No. 79. 187 p.

LEE, C.L. & OSTLE, C. (1997). A simplified method of transporting trochus, *Trochus niloticus* broodstock over long distances for spawning. **In:** Lee, C.L. and Lynch, P. (eds.) 1997, Trochus: Status, hatchery practice and nutrition. ACIAR Proceeding No. 79. 187 p.

SHOKITA, S., K. KAKAZU, A. TOMORI & T. TOMA. (1991). Topshell (*Trochus niloticus*), green snail (*Turbo marmoratus*), and turban snail (*Turbo argyrostomus*). Aquaculture in Tropical Areas. 276–287.

Part 3b. ACIAR Trochus Reef Reseeding Research: An improved hatchery method for mass production of juvenile trochus

by Dr Chan L. Lee

Introduction

On metamorphosis, postlarval (P/L) trochus settle on benthic substrates where they graze on benthic diatoms and grow into juveniles (Js). Most inter-tidal benthic invertebrates use the substrata as a source of food, for attachment, shelter, as well as protection either from predators or adverse environmental conditions. The effects of substrata on different groups of marine invertebrates have been reviewed by Newell (1979), Bacescu (1985), Crisp & Bourget (1985) and Dall et al. (1990); more recently, Gimin & Lee (1997) investigated the effects of different substrata on the growth rate of early juvenile trochus. The most common substratum used for increasing the surface area for growing benthic algae in molluscs hatcheries is corrugated PVC plates or fibreglass (FRP) plates (Shokita et al., 1991). This method has been universally used in abalone and trochus hatcheries. In the NTU trochus hatchery, newly settled postlarvae were allowed to feed and graze on benthic algae growing on the surface of FRP. However, it was observed that juveniles which grew in such a substratum avoided coral pieces when they were introduced into the tank. Since the juveniles were meant to be used for reef reseeding research, we were faced with the dilemma of producing juveniles which were potentially 'afraid' of grazing on the rough coral surfaces and could consider coral as hostile habitat. Based on the preliminary work of Gimin & Lee (1997), it was decided that coral pieces should be used in place of FRP as a substrate for growing juveniles.

Materials and methods

Larval tank

Fertilised eggs were produced according to the method given in Part 3a and transferred to the larval tank. Each rectangular fibreglass larval tank measured 3,500 mm long x 2,000 mm wide x 900 mm high. The tank was divided into two compartments; a smaller filter compartment (SFC) measuring 900 mm long x 2,000 mm wide x 900 mm high and a larger spawning and P/L and Js rearing compartment (LRC) measuring 2,600 mm long x 2,000 mm wide x 900 mm high. Each larval tank could carry up to 3 million eggs.

Additional details on the design, setting up and operation of the tank are given in Lee (1997).

Coral substrate

Mixed dried coral pieces up to 15 cm in diameter were collected from the beach, washed with fresh water and left to dry in the sun for three weeks before being spread across the bottom of the LRC. A water-soluble compound fertiliser 'Aquasol' was added to the LRC at the concentration of 10 ppm. Sessile diatoms, *Nitzschia* sp., initially cultured in F/2 medium, were added to inoculate the tank. Within two weeks, a thin brownish layer of diatom mat covered the coral pieces and the tank was now ready for stocking of fertilised eggs or P/L. During the Js rearing period, the diatom culture was maintained by fertilising the culture water with 'Aquasol' on a fortnightly basis.

Results

Fertilised eggs released into the LRC hatched within 5–7 days. Two to three weeks later, a thin mat of 100,000 Js or more was observed to grow on the coral pieces. As the Js grew, competition for diatoms became very severe and increasing numbers of Js could be seen moving away from the coral substrates in search of food and grazing along and up the wall of the culture tanks. At this stage, the population was thinned down to prevent the Js from suffering high mortality. This was easily done by transferring some of the coral pieces to another tank with well established diatom growth. At the end of 6–8 weeks, each tank was carrying between 10–20,000 Js, each measuring 3–5 mm in size. These Js were well adapted to live in corals and could be used for reseeding or further growth to produce larger Js. To produce larger Js, the thinning process and preparation of diatom growth on the coral pieces are repeated in another tank.

The project is presently looking at improving the coral substrate method of Js production by using FRP plates coated with small coral pieces. If this proves to be successful, it would achieve the dual aims of producing Js well adapted to grow on natural coral substrate and at the same time increasing the grazing surface area, thereby increasing the food available.

References

BACESCU, M.C. (1985). Substratum: Animals. **In:** O. Kinne (Ed.) Marine Ecology Vol I: Environmental Factors Part III: 1290–1322. Wiley Interscience, London.

CRISP, D. J. & E. BOURGET. (1985). Growth in barnacles. **In:** J.H.S. Blaxter (Ed.) Marine Biology Vol. 22: 199–244. Academic Press, London.

DALL, W., B.J. HILL, P.C. ROTHLISBERG & D.J. SHARPLES. (1990). Biology of Penaeidae: Substratum. Advances in Marine Biology Vol. 27: 341–349.

GIMIN, R & C.L. LEE. (1997). Effects of different substrata on the growth rate of early juvenile *Trochus niloticus* (Mollusca: Gastropoda). **In:** Lee, C.L. and Lynch, P. (eds.) 1997, Trochus: Status, hatchery practice and nutrition. ACIAR Proceeding No. 79. 187 p.

LEE, C.L. (1997). Design and operation of a land-based closed recirculating hatchery system for the topshell, *Trochus niloticus* using treated bore water. **In:** Lee, C.L. and Lynch, P. (eds.) 1997, Trochus: Status, hatchery practice and nutrition. ACIAR Proceeding No. 79. 187 p.

NEWELL, R.C. (1979). Biology of intertidal animals. Journal of Experimental Marine Biology and Ecology, 71: 168–179.

SHOKITA, S., K. KAKAZU, A. TOMORI & T. TOMA. (1991). Top shell (*Trochus niloticus*), green snail (*Turbo marmoratus*) and turban snail (*Turbo argyrostomus*). Aquaculture in Tropical Areas. 276–287.

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PIMRIS

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