Bay of Bengal Programme

Fisheries Resources

GIANT CLAMS IN THE MALDIVES
- A Stock Assessment and Study
of their potential for culture

BOBP/WP/72

FOOD AND AGRICULTURE ORGANISATION OF THE UNITED NATIONS

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BAY OF BENGAL PROGRAMME

Reef Fish Research & Resources Survey

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GIANT CLAMS IN THE MALDIVES

— A stock assessment and study of their potential for culture

By

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Tuna fishing is the major fisheries activity in the Maldives. However, fishing for non-traditional organisms is becoming popular, as it provides fishermen with new areas of employment or alternatives when tuna fishing is poor.

One non-traditional fishery in the Maldives is that for giant clam. This fishery is only a year old, but so considerably has the resource been exploited that different non-fishery professionals — tourist resort owners, divers and, of course, environmentalists — have already shown great concern about its long term effects.

It was this concern that led to the Ministry of Fisheries and Agriculture undertaking an assessment of the status of giant clams in the Maldives through their Reef Fish Research and Resources Survey Project (RAS/88/007). The assessment was executed by the Food and Agriculture Organization of the United Nations through the Bay of Bengal Programme, with funding from the United Nations Development Programme.

This paper is based on the report submitted by the consultant to the Government of Maldives in April 1991 and describes the findings of the assessment and discusses the possibility of developing a viable mariculture project to ensure a continued existence of the giant clam in the Maldives.

The author wishes to thank all the team at the Marine Research Section of the Ministry of Fisheries, particularly Maizan Hassan Maniku and Charles Allism, for their detailed backgound information, Hassan Shakeel of MRS, for putting up with many questions and providing logistic assistance, Bill Allison for field assistance in counting of clams and John Lucas for helpful comments on the final report.

The Bay of Bengal Programme (BOBP) is a multi-agency regional fisheries programme which covers seven countries around the Bay of Bengal — Bangladesh, India, Indonesia, Malaysia, Maldives, Sri Lanka, Thailand. The Programme plays a catalytic and consultative role: it develops, demonstrates and promotes new techniques, technologies or ideas to help improve the conditions of small-scale fisherfolk communities in member-countries. The BOBP is sponsored by the governments of Denmark, Sweden and the United Kingdom, by member-governments in the Bay of Bengal region, and also by UNFPA (United Nations Population Fund), AGFUND (Arab Gulf Fund for United Nations Development Organizations) and UNDP (United Nations Development Programme). The main executing agency is the FAO (Food and Agriculture Organization of the United Nations).

NOTE

The Government of Maldives, on receipt of the report, noted that the giant clam resources df the Maldives were being overexploited and that the fishery was not sustainable. The need was recognized to preserve the remaining stocks of giant clams, both as a reserve for potential mariculture activities and as a valuable aesthetic resource for the tourist industry. The Government of Maldives, therefore, acted swiftly to halt the giant clam fishery. In July 1991, the Ministry of Trade and Industries stopped issuing new licences for the export of giant clam products and also announced that existing licences would not be renewed once they expired.

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1. *INTRODUCTION*

A preliminary assessment of the giant clam stocks and the status of the fishery was conducted in the Republic of the Maldives in 1991. Only two species of giant clam were found, *Tridacna squamosa* and *T. maxima.* The major target species of the fishery is *T. squamosa,* though the smaller *T. maxima* is occasionally taken. Reefs that are known to have been fished have low densities of *T. squamosa* and frequently (67 per cent of reefs surveyed) NO *T. squamosa.* On the other hand, *T. squamosa* is present on 93 per cent of the unfished reefs and, on average, are three times as abundant as on fished reefs. Standard tow techniques were used to assess the stocks on fished and unfished reefs in four atolls, Raa, Shaviyani, Lhaviyani and Kaafu. The mean number of *T. maxima* for fished reefs was 29.9 clams/ha and for unfished reefs was 39.6 clams/ha. *T. squamosa* population densities were lower, with an average of 3.4 clams/ha on fished reefs and 10.6 clams/ha on unfished reefs.

The giant clam fishery started in the Maldives in June 1990 and continued until a month before the start of Ramadan, February 17, 1991. Two buyers have been operating and have had a collective catch of something greater than 90,000 individuals. One of these buyers has exported, on license, 9.8 t of frozen adductor muscle, valued at almost MRf.l. 3 million*, to a Taiwanese buyer. The other has stock piles of 0.5 t each of dried adductor muscle and mantle tissue. He does not have an export licence and has sold nothing to date.

The exporters believe that the clam stocks will sustain the current level of fishing pressure. But their reasoning is flawed, as it is based on misinformation. They believe that the smaller clams seen on the reef are juvenile *T. squamosa* and will replace those that have been fished. This is incorrect, for the smaller clams are, in fact, the other species, *T. maxima.*

At present it takes about six months to fish an atoll to the point where it is uneconomic to continue collecting. Thus, at the current rate of fishing, the stocks of *T. squamosa* – and, consequently, the business – will only last a few more years. It is going to take eight or more years for fished stocks to recover in places where there are enough adults left for natural recruitment. Frequently, even this will not be possible, for, as noted above, there are no longer any *T. squamosa* left in the exploited atolls.

T. squamosa shells were sectioned to assess age from a count of the seasonal growth lines. They showed a slowing in growth after an age of approximately ten years, with an expected life span of more than 25 years. This suggests a recovery time of more than eight years in a fished area, assuming the density of clams is not too low.

There is, however, potential for successful culture of giant clams in the Maldives. *T. squamosa* is the most obvious species to be cultured. It occurs naturally in these waters and has an established export market. Furthermore, juveniles could be imported from the research team at the University of the Philippines. Prior to import, a quarantine facility will need to be established. It is suggested that the Marine Research Section be in charge of this facility to keep control over any introductions and, thus, reduce the potential for the import of disease. It may be possible to import *T. gigas* or 7'. *derasa* juveniles, the two fastest growing species of giant clam. Careful quarantine procedures and the monitoring of these animals should take place if this option is adopted.

From discussions with political, industrial and village representatives, it appears that there is a conscnsus of opinion that regulation of the fishery is required and that a culture programme is a logical and necessary step for the long-term continuance of the giant clam industry in the Maldives. Before introducing restrictions and developing a culture programme certain steps should be taken.

Surveys need to be carried out in the southern and most northern atolls prior to them being fished. This will provide a quantitative baseline account of the standing stocks in these areas and will aid in future management decisions. A resurvey of the total area should be conducted in 3-5 years to provide on-going information on the recovery of fished populations and the status of the fishery.

* MRF 10 = US $1.

The education of both buyers and fishermen on the differences between *T. squamosa* and *T. maxima* is necessary to prevent the complete eradication of the larger species from fished reefs.

Different possibilities exist for the regulation of the fishery, *e.g.* a complete ban on fishing of giant clams in atolls that are currently designated as suitable for resorts, and a restriction on the size and number of clams taken elsewhere.

A certain number of adult *T. squamosa* should be collected and placed in areas off-limits to fishing to ensure the future conservation of the species and for possible use as broodstock in a culture programme. These sites should be closely monitored by, for instance, the Marine Research Section of the Ministry of Fisheries and Agriculture.

A detailed analysis will need to be conducted prior to committing funds to a culture programme. It is recommended that immediate emphasis should be placed on the identification of suitable localities for the siting of a hatchery facility and the establishment of ocean nursery systems. For the latter, satellite imagery could be used, followed by on-site monitoring. A sociological assessment would also need to be conducted tD establish whether culture, as opposed to harvest, is acceptable to the people.

2. *BACKGROUND*

2.1 ***The** Ma/dives*

The Maldives, an archipelago stretching 764 km from just south of the equator, at 0°41‘48”S to 7°6’30”N, and centred about longitude 73°E, rests on a submarine mountain range in the west Indian Ocean. It comprises between 1100 and 2000 islands, depending on whether an island is defined as with or without vegetation. All are formed from coral sand and rubble and each is no more than a few metres high (Webb 1988).

The British Admiralty charts, little changed from the original 1839 printing, indicate the position of the islands at that time. Some islands have since disappeared and others have been created by the forces of wind and wave. The islands are grouped in 26 geographic atolls. For administrative purposes, the Maldives is divided into 19 units, each governed by an Atoll Chief.

The Maldives has a tropical climate, with an ambient temperature range of 25.5 - 30.4°C. The Southwest Monsoon blows from May to late November, followed immediately by the Northeast Monsoon until April. Rainfall averages 2100 mm per year, with the heaviest falls occurring during the Southwest Monsoon and early Northeast Monsoon.

The two industries most important to the Maldives’ economy are tourism and tuna fishing. Fishing is an important part of life in the Maldives and, although exploitation has been limited mainly to tuna, some other species have been targeted in recent times. Lobsters are caught and sold, predominantly to the tourist resorts, sea cucumber is dried and exported to eastern Asia, and there is a shark fishery.

2.2 *Giant clam biology*

Giant clams have been the subject of a large amount of research internationally, over the last decade. Much of this work is reviewed in Copland and Lucas (1988).

The giant clam, *Tridacna gigas,* is the largest bivalve mollusc known to have existed. Other members of the bivalves include oysters, mussels and scallops. The distinctive character of the Class Bivalvia is the presence of one shell made from two hinged valves. The giant clam is extraordinary in the bivalve group in that much of its nutritional requirements come from symbiotic dinoflagellates, (zooxanthellae) that are resident in its expanded mantle tissue (Fitt 1986). These are the same unicellular algae that live in association with coral polyps and are of the genus *Symbiodinium.*

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As a result, giant clams require high levels of sunlight to satisfy the photosynthetic process of the algae. They also require clear, full salinity seawater and a reasonably sheltered environment.

Giant clams are predominantly found in coral reef areas. This can be attributed to the similar environmental requirements of corals and giant clams and the protection afforded by the coral against predators, during the early life of the clam. The larger species of giant clam will frequently be found in areas of branching coral, particularly *Acropora* species. The growth habit of this coral allows penetration of sunlight as well as protection against the intrusions of large fish and other predators. Two of the smaller species of clam burrow into blocks of coral, often massive corals such as *Ponies* sp.

Rosewater *(1965)* revised the taxonomy of the giant clams, recognizing six living species, one *Hippopus* sp. and five *Tridacna* spp. Subsequently, a further species of *Hippopus* was recognized (Rosewater 1982). Lucas, Ledua and Braley (1990) have more recently described a new species, *Tnidacna tevoroa,* fouhd in deep water around Fiji and Tonga. Thus, a total of eight species of giant clam are recognized at present.

Edgar A. Smith refers to an account of Gardiner's expedition, 1899 and 1900 (Gardiner 1906), and from it documents the presence of giant clams in the Maldives. The clams were found 'on K. Hulule between I and 6 fathoms and he called them *Tridacna cumingii.* This species has subsequently been treated as a junior synonym of *T. maxima* (Rosewater 1965).

A modern review of the species distribution indicates that there are two species of giant clam found in the Maldives, *7". squamosa* and *T. maxima* (Lucas 1988). *T. squamosa* is described as being distinguished by its large, well spaced scutes, and the shell length can reach about 40 cm. The mantle tends to be mottled in various mixes of green, blue, brown, orange and yellow". This species tends to be found loosely attached to coral or on sand.

Lucas describes *T. maxima* as - distinguished by its close-set scutes, and elongate byssal orifice compared to a short hinge, so that the shell is strongly asymmetrical about the umbo. It tends to bore into the reef - This burrowing habit is a particular characteristic of another species, *T. crocea,* but this species is not found in the west Indian Ocean.

2.3 *Exploitation of giant clams in the Ma/dives*

The Dhivehi term for giant clam is *Gaahaka* and this refers to all species. Traditionally, the giant clam has not been fished in the waters of the Maldives, as the local people rarely consume it (Maniku, pers. comm.).

An initial investigation into the fishery, by R.C. Anderson (1990), concluded that the export of giant clams began only in June 1990. That was when one company started buying the clams for their adductor muscles, which were sought by a Taiwanese buyer. Fishermen of particular atolls would retrieve whole animals and bring them ashore, whereupon the local buyer would grade them and pay the fishermen. The tissue would be removed and prepared for shipping to Male, prior to export. The shells were stockpiled, particularly on R. Ugoofaaru and K. Thulusdhoo, for potential future sale. A second buyer operating in Male atoll began fishing giant clams at the end of 1990. He stockpiled dried adductor muscle and mantle tissue for export.

With this the only fishing of giant clams known to have taken place, there are, potentially, areas that can be considered completely natural with respect to clam stocks.

2.4 *Aims of the survey*

The 1991 survey was intended to assess the current status of the giant clams in the Maldives. It was meant to study the extent of the fishery, the species involved, the size frequency of clams taken etc. While its emphasis was on stock assessment, the economic significance of the fishery was also to be evaluated. The suitability of various atolls for clam culture was to be examined and recommendations were to be made on the future of the fishery and mariculture potential.

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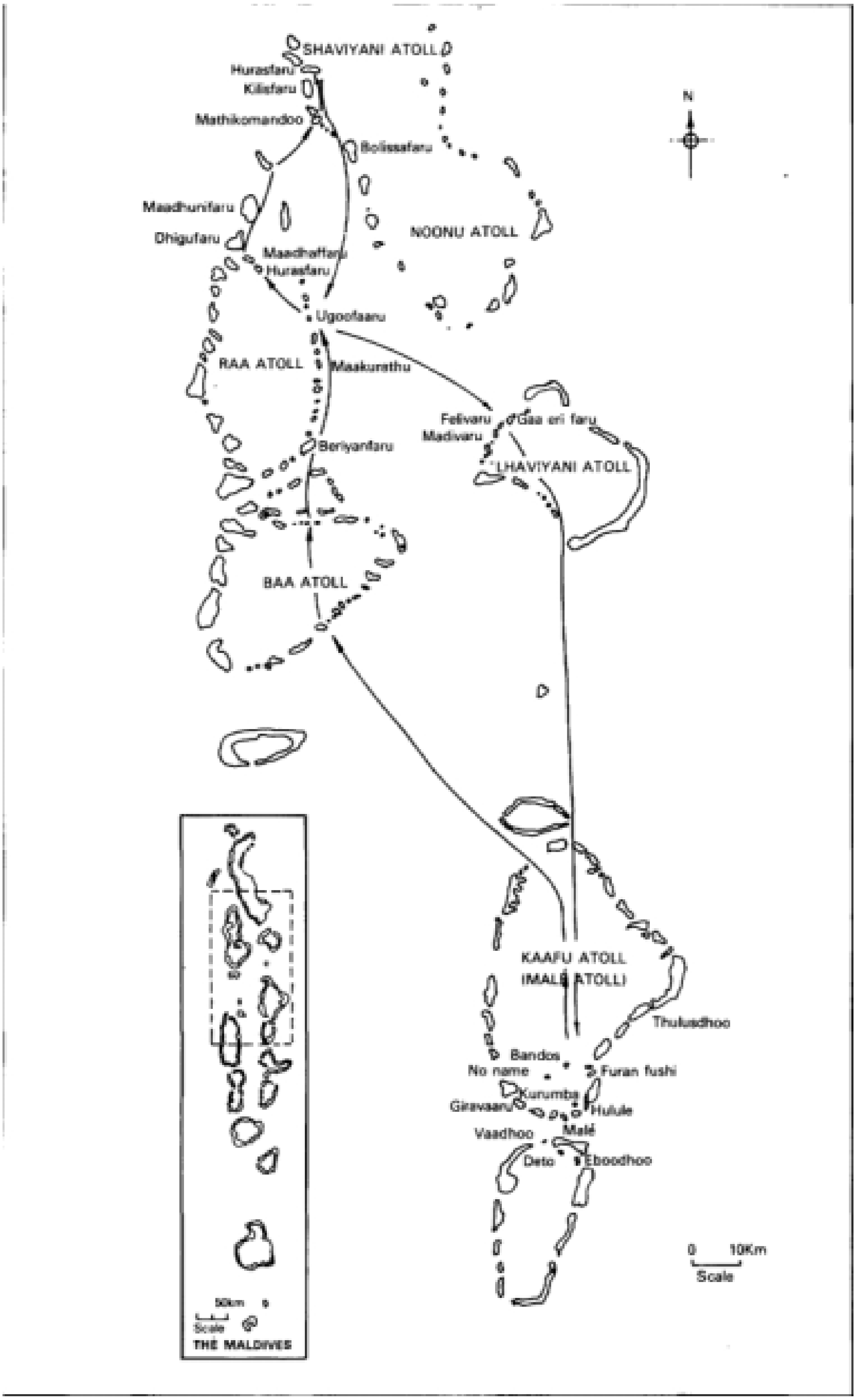
Figure 1. Map of the Maldives showing reefs and route taken



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The survey was also meant to assess the extent of environmental damage to the reefs.

Following the initial discussions with Marine Research Section personnel of the Ministry of Fisheries and Agriculture, Male, a route was chosen that would allow comparison of fished and unfished areas. A yacht *dhoni,* was organized for an eight-day trip, from March 7 to March 14, 1991, to visit the northern atolls where the, fishery started (Figure 1). The route chosen included the island of R. Ugoofaaru, the initial centre of the clam fishery. Visiting this island enabled analysis of the shell middens and discussion with the fishermen involved. A separate trip was undertaken on March 31, within Kaafu atoll.

(For the purposes of this study all atoll names will follow the administrative nomenclature, with island names being taken from the map of Maldives, 1979, except for K. Vihamanaafushi, which is known as K. Kurumba, and K. Bodu Bandos, which is known as K. Bandos.)

2.5 Assessment of the giant clam fishery

The shell middens on R. Ugoofaaru were analyzed to assess the number of shells stored there. A random section of known volume was removed and the number of shells counted. The overall sizes of the middens were measured using a 50 m measuring tape. From the overall dimensions and the volumetric calculation an estimate of the total number of shells was made. Size frequency analysis was also performed on 100 *T. squamosa* shells chosen randomly from the pile.

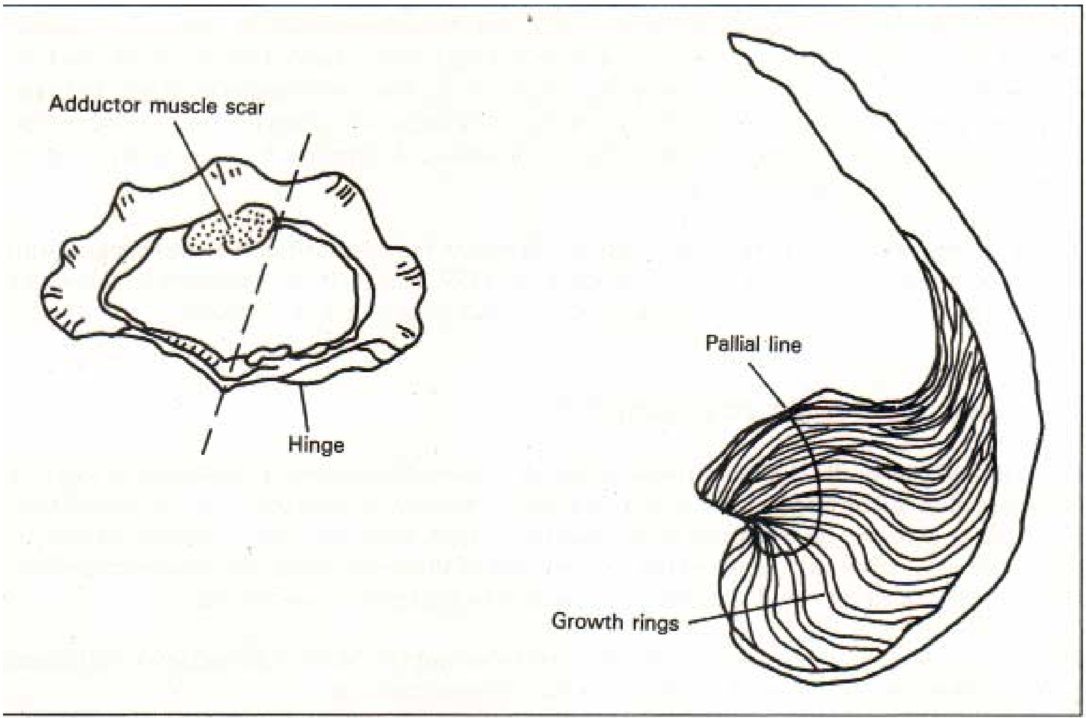
Discussions were held with fishermen from R. Ugoofaaru and Sh. Dhashukomandoo to understand their incentive for collecting giant clams and their fishing methods.

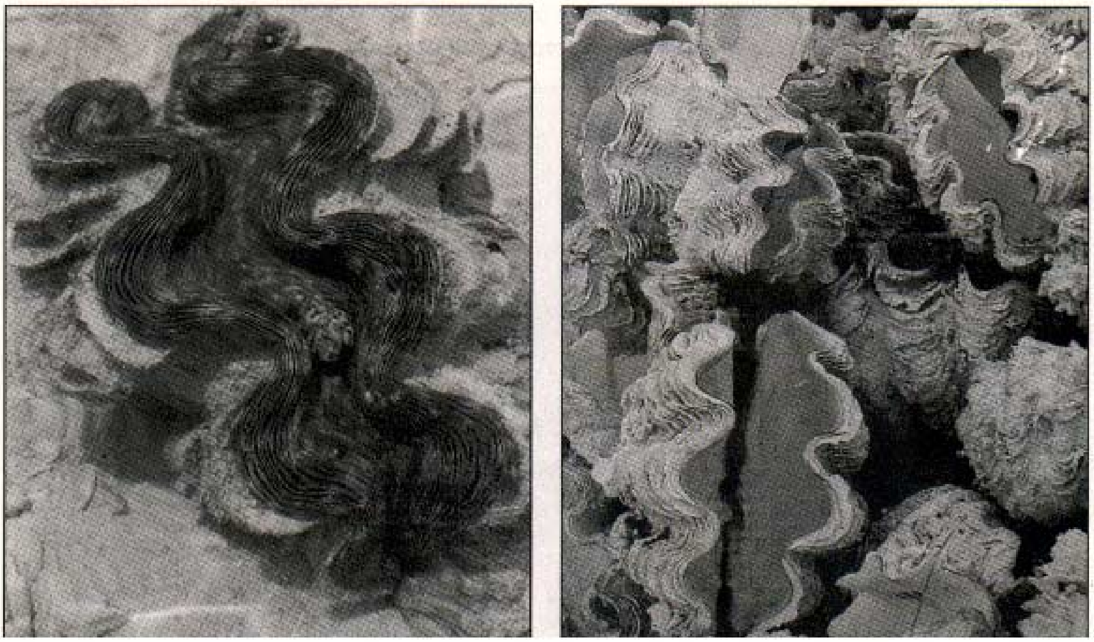
Meetings with all the relevant government departments were conducted to assess the extent of any regulations governing the fishing of giant clams, the net worth of the industry, official viewpoints and significance to the Maldives economy.

It was known that there were two local buyers. One collecting dried clam tissue and the other collecting frozen adductor muscles. The two local buyers were interviewed and statistics concerning the extent and economic value of their involvement were obtained.

Shells removed from the pile stored on K. Ugoofaaru to make a count and facilitate measurement.

Figure 2. Position of saw cut through the valve and the position in the section for counting the growth rings





On the left, a living T. Squamosa *in shallow water; on the right, close-up of a* T. Squamosa *shell.*

3. *METHODS*

3.1 *Stock assessment*

The giant clam stock assessment technique of Munro (1986) was employed with a minor variation. It followed a standard manta tow technique, but had two in-water observers, one on either side of the boat. Munro used a 5 m pole across the bow of the boat with an observer holding onto each end. As the boat used in this survey was a yacht *dhoni* and somewhat larger than that used by Munro, a line secured to either side of the boat and off the stern was used. This minimized the potential danger of injury to an observer from either the hull or the propeller. The space of a few metres between the observers was similar to the original technique. The centre line of the boat was used to delineate the edge of the area scanned by each party, limiting the potential for replicate counting of a clam situated close to the centre of the navigated track.

The boat speed was regulated so that the observers were towed at approximately 1.3 $m.s^{-1}$. The distance of the tow was measured using an optical rangefinder (Rangefinder 1200) focused on a group of bright orange buoys anchored at the start of the tow. The rangefinder was calibrated on land prior to, and following, use. When the on-board assistant recorded a distance of between 400 m and 500 m, the observers in the water were informed. They would then tell the person on board the numbers of clams seen and other data. A swathe of between 6 and 10 m, combined width of the two observers, could be checked using this technique, depending on the depth and visibility.

Most tows were taken along the edge of the reef crest, thus covering the reef flat and the top of the reef slope. Underwater visibility varied between 10 m and 30 m and was enough to enable assessment of all the areas chosen. As almost all the reefs were closed, with a shallow rim, it was not possible to take the boat inside, to the lagoon. However, following most tows, a swim was done perpendicular to the reef edge and into the central lagoon area. During the swim, clams were noted and coral cover estimated. Length frequency measurements were taken at sites where reasonable numbers of *T. squamosa* were seen.

During Ramadan, the Islamic holy month of fasting, all trips were restricted to single days. Five reefs were visited close to Male, in south and north Kaafu atoll. These were usually associated with resort islands. Transport was *via* a ferry ***dhoni,*** which meant that tows were not possible. Assessment was by swimming along sections of the reef. The extent of the swims ranged from 1-4 hours, depending on conditions. All the *T. squamosa* seen during the swims were counted and measured. *T. maxima* was not counted, although relative abundance was noted. Length frequency measurements were also taken at these sites.

The reef surrounding K. Vaadhoo was assessed using both tows and swims to validate the accuracy of counts taken during tows. The count of *T. squamosa* was equal for both methods, but the *T. maxima* counts were higher during the swim. Thus, all *T. maxima* data from the tows should be treated as a lower value only.

3.2 *Length frequency measurements*

At sites with reasonable numbers of *T. squamosa*, standard shell length measurements were taken. This involved diving using scuba, randomly selecting individuals and taking a length measurement with calipers. Both species were measured at these sites, with up to 50 *T. maxima* and as many *T. squamosa* as were seen during the period of the dive.

When scuba was not available, length measurements were restricted to those clams found in less than 14 m of water, although very few were seen beyond this depth. The restriction occurred only on reefs associated with resorts in Kaafu Atoll including Bandos, Kurumba and Vaadhoo.

3.3 *Age determination*

A number of *T. squamosa* shells, of varying sizes, were removed from the stockpile on R. Ugoofaaru and taken back to Male for sectioning. The techniques developed by Shelley (1989) for aging giant clams found on the Great Barrier Reef, Australia, were used. A cross-section was taken, using a rock saw, through one valve. The cut was made from the umbo to the outer margin of the shell on the hinge side of the adductor muscle scar (Figure 2, facing page). A second cut was made to produce a section approximately 1 cm thick. This was polished on one side, progressively using 250, 500 and 1000 grit waterproof sandpaper. Paired growth bands were then clearly visible and could be counted to estimate the age of the clams. They were counted from the region of the inner shell layer. This region is unaffected by erosion, commonly seen in the outer shell layer, thus allowing greater accuracy of the estimate. Each couplet was taken to represent one year.

One *T. maxima* was taken from a shipwreck which had occurred in June 1985 and sectioned. This enabled the validity of using this technique for this area to be checked, as this animal could be no older than the wreck. There were five growth band couplets in this shell. This suggested that the technique was suitable for estimating the age of clams taken from this area.

4. *RESULTS*

4.1 *Species composition*

From careful observations of natural clam stocks and the groups of shells that remained on R. Ugoofaaru, after the fishing of clams, it was confirmed that the only two species of giant clam found around the central and northern atolls of the Maldives are *Tridacna squamosa* and *T. maxima.* No other species of *Tridacnidae* were seen during the survey.

The distribution of *T. squamosa* appears to be patchy and restricted to more sheltered areas, from the flat reef in shallow waters, down the reef sloping to the bottom, to approximately 15 metres depth. It is the larger of the two species, reaching a maximum of 54 cm standard shell length in these waters. *T. maxima* is found in all areas of the reef, down to approximately 15 metres, although it is more abundant on the reef flat and crest. Individuals up to 25 cm were seen, although there are reports of 35 cm animals in the Pacific.

4.2 *Stock assessment by tows*

During the eight-day trip, eleven reefs in four atolls were checked with stock assessment tows taken in three atolls. The second trip employing the tow technique was taken in Kaafu atoll, where six reefs were visited. See Table 1 for a list of reefs and atolls visited.

Table 1
Location and number of tows taken for stock assessment

Atoll	*Reef*	*Fished*	*Tow Number*
Raa	Beriyanfaru	+	1,2
Raa	Hurasfaru	+	3-5
Raa	Maadhaffaru	+	6,7
Raa	Dhigufaru	+	8-10
Raa	Maadhunifaru	+	11-13
Shaviyani	Hurasfaru	—	14-16
Shaviyani	Kilisfaru	—	17-20
Shaviyani	Bolissafaru	+	21,22
Shaviyani	Mathikomandoo	—	23
Lhaviyani	Gaa en faru	—	24-26
Lhaviyani	Madivaru	—	27-29
Lhaviyani	Felivaru	—	30
Kaafu	Vaadhoo		31
Kaafu	No name		32.36
Kaafu	Bandos	?	37-39
Kaafu	Furan fushi		40,41
Kaafu	Hulule		42,43

Tows were taken on both fished and unfished reefs. Two 'house' reefs of resort islands (the reefs belonging to these islands) were checked. Resort islands protect their reef against fishing, although there have been complaints to the authorities about surreptitious fishing occurring on some of these reefs.

See tables in Appendix I and Appendix II for a summary by atoll of the original stock assessment data based on mean figures across reefs.

4.2.1 FISHED REEFS

These included six of the reefs that had been most heavily fished by the people from R. Ugoofaaru. Five were within Raa Atoll: the other was in Shaviyani Atoll. It was found that on these reefs very few, and frequently NO, *T. squamosa* were seen. *T. squamosa* were seen during only five of the 15 tows (33 per cent).

A total area of 38,700 m2 was surveyed on these reefs. The highest density was found on R. Maadhunifaru, with a calculated figure of 18.8 *T. squamosa* per hectare (1ha = 10,000 m^2 = 2.47 acres). Of the three tows (Nos. 11, 12 and 13) conducted on this reef, *T. squamosa* was present in only one. The mean number of *T. squamosa* for all fished areas surveyed was 3.4 clams/ha.

T. maxima was reasonably abundant in all areas surveyed and had an average density of 29.9 clams/ha.

4.2.2 UNFISHED REEFS

These were primarily in the Shaviyani and Lhaviyani Atolls. *T. squamosa* was seen during 14 of the 15 tows (93 per cent), covering 44,050 m2 of reef. In areas where *T. squamosa* was found, densities ranged from 2.8 clams/ha to 65.6 clams/ha. The mean for all unfished reefs in the area assessed was 10.6 clams/ha.

As for the larger species, *T. maxima* numbers were higher for the unfished reefs. Densities ranged from 2.8 to 171.9 clams/ha. The average for the unfished areas was 39.6 clams/ha.

4.2.3 UNKNOWN STATUS

It was not known if the five reefs assessed in Kaafu had been fished, although from discussions with the local buyer it seemed that some of them may have been. A total of 42,400 m2 were covered by 14 tows. *T. squamosa* was present on 35 per cent of the tows. At least one of these reefs, Unnamed reef, to the west of K. Aarah, showed during tow Nos. 30 and 31 evidence of fishing, with a number of recently dead *T. squamosa* present. The average density of *T. squamosa* for this reef was 1.4 clams/ha. If the empty shells represent the stocks prior to fishing, then the density would have been 10.3 clams/ha for this reef.

The other reefs, in the areas checked, averaged densities of *T. squamosa* ranging from 1.8 - 20.0 clams/ha. The lowest average of 1.8 was found on K. Hulule, which is the site of the airport and subject to a large amount of human disturbance. The overall average for the areas covered within Kaafu Atoll was 3.8 *T. squamosa/ha.*

T. maxima was found on all these reefs in similar densities to other reefs; however, the overall mean is less than the northern atolls. This species was found on all tows except No. 40, which was taken adjacent to the end of the runway on K. Hulule. A lot of silt was present on the reef flat in this area and may be the reason for the lack of clams. The one *T. squamosa* seen on this tow was large and presumably more resistant to smothering by silt.

Table 2

Summary of stock assessment tow data by fished status

Tridacna squamosa

Status	***Number of tows***	***Mean ±S.E.* per tow***	***Mean ±SE. per ha***
Fished	IS	1 ± 0.45	3.4 ±1.5
Unfished	15	3.2 ±1.26	10.6 ±3.9
Unknown	14	1 ± 3.74	3.8 ± 1.4

T. maxima

Status	***Number of tows***	***Mean ±S.E. per tow***	***Mean ±S.E. per ha***
Fished	15	8.3 + 2.4	29.9 ± 8.4
Unfished	15	11.6 ±3.2	39.6 ±10.1
Unknown	14	5.6 ±0.9	20.6 ± 3.7

* S.E. = Standard ennor.

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4.3 *Relative stock assessment by swimming*

T. maxima was present in all the reefs which were surveyed by swimming. Table 3 summarizes the findings from these areas. A score of high relative abundance was considered to be equivalent to the higher density northern reefs seen whilst towing. Relative abundance that was scored as low meant that considerable time was spent searching an area, with few animals being encountered.

Note that on K. Vaadhoo only seven *T. squamosa* were recorded. This was due to the restricted time spent there because of gear failure. However, it is known from a previous trip that this reef has many *T. squamosa,* often in shallow water on the reef flat.

Table 3

Summary of data collected whilst swimming

Atoll and reef	*Duration of swim (mins)*	*Number of T.s seen*	*No. T.s per mm*	*Relative abund. T.m*
R. Maadhunifaru	70	6	0.09	low
Lh. Gaa eri faru	50	0	0.00	med
Lh. Madivaru	40	8	0.20	high
Sh. Kilisfaru	45	16	0.36	high
Sh. Mathikomandoo	80	27	0.34	high
K. Bandos	190	2	0.01	med
K. Kurumba	240	0	0.00	low
K. Deto*	54	0	0.00	med
K. Eboodhoo	80	13	0.16	high
K. Vaadhoo	60	7	0.12	high

* The name used for this reef comes from a sign which is on it; otherwise it has no recorded name. It is approximately 3 nautical miles southeast of K. Vaadhoo.

No *T. squamosa* were seen on two of these reefs, Kurumba and 'Deto'. Kurumba is the site of a large resort and, although no live animals were seen, a single shell was. Thus, it appears that *T. squamosa* was present in the past and may still be present in other parts of the 'house' reef. This reef also has very low numbers of *T. maxima* and so there may be unknown environmental reasons why there are no clams here.

K. Deto is a narrow patch reef with a vertical reef slope that is not protected from heavy wave activity during times of inclement weather. Thus, it is not considered a likely site for the success of *T. squamosa.*

4.4 *Comparison with giant clam stocks in the Pacific*

The people of the island nations of the tropical Pacific have traditionally used clams as food, unlike the Maldivians. Thus the clams in these nations have frequently been severly depleted, even to the point of extinction in the case of some of the larger species.

T maxima numbers in the Maldives are lower than those seen on many Pacific reefs, where up to 60,000 per hectare in Tuamotu Archipelago, French Polynesia, have been recorded (Richard 1978). Densities found in Abiang Atoll (Kiribati) - 100 *T. maxima* per hectare (Munro, 1986) - and 63-101 clams per hectare in Tuvalu (Braley, 1988) are similar to those found in the Maldives.

Due to the draft of the vessels used for the tows, the shallow reef flat areas were not assessed using the tow technique. This is the most likely habitat for T *Maxima* and may explain the low number of this species seen during the tows.

Munro's (1986) technique has also been used for giant clam surveys in Tuvalu (Braley 1988), Tokelau (Braley 1989) and Niue (Daizell and Lindsay; in prep.). Therefore the results in the Maldives can be compared to the Pacific findings.

T. squamosa numbers are very low on the fished reefs in the Maldives. They compare directly to figures reported for Tuvalu and Tokelau, where it was 0.68 - 1.4 clams/ha and less than 6 clams/ha, respectively (Braley 1988, 1989). Clams have traditionally been heavily fished in these areas in the Pacific.

Dalzell *et al* report an average of 14 *T. squamosa* per hectare on the Niue reefs. This is comparable to the overall average of the unfished areas of the Maldives (10.6/ha). However, there are particular areas in the Maldives, such as K. Vaadhoo and Sh. Mathikomandoo, which have high densities of *T. squamosa.* There are likely to be more areas within the Maldives that have similarly high densities, particularly in unfished areas, such as near resorts or in outlying reefs.

4.5 Length frequency data

Mean (standard) shell length, taken from populations of *T. maxima* on ten reefs, is presented in Table 4. Data for *T. squamosa* for seven reefs are also presented.

There is little point in comparing length frequencies with respect to fished and unfished areas. This is simply because the fishery is so young and any *T. squamosa* that are seen are taken. Thus, there is likely to be no difference in the population mean shell lengths as has been shown in fished versus unfished areas of the Pacific (Braley 1989, 1990).

Table 4

Mean standard shell length for clams on different reefs

Atoll and Reef	*Status*	*T. maxima* *mean shell length (cm)*	*T. squamosa* *mean shell length (cm)*
R. Maadhunifaru	Fished	14.1, n=7	32.7, n=6
Lh. Gaa cr1 faru	Unfished	8.9, n= 16	sp. not seen
Lh. Madivaru	Unfished	13.1, n=31	23.9, n=8
Sb. Kilisfaru	Unfished	10.1, n=50	18.5, n= 16
Sh. Mathikomandoo	Unfished	14.7, n=50	23.8, n=27
K. Bandos	**Resort**	**11.0, n=30**	*25.5,* n=2
K. Kurumba	Resort	10.7, n=50	sp. not seen
K. Deto	Unknown	14.5, n=14	sp. not seen
K. Eboodhoo	**Resort**	**12.1, n=24**	**40.2, n= 13**
K. Vaadhoo	**Resort**	**11.7, n=30**	**34.8, n= 14**

n = Sample number

As *T. maxima* is not targeted whilst fishing, the mean shell length for this species is reasonably similar across most of the reefs. The reduced mean for *T. maxima* found on Lh. Gaa en faru is a consequence of the overall age of the population. This group was sampled from a wreck that had been sunk deliberately in June 1985, so the clams on it would be no older than 6 years.

Combining the data for each atoll shows no significant difference between population mean shell length for *T. maxima* (p = 0.49) (Figures 3 and 4, see pp. 13 and 14). However, there is a difference for *T. squamosa* populations (p = 0.0) (Table 5 and Figures 5 and 6, see pp. 15 and 16).

Table S

Mean standard shell length for populations of clams combined by atoll

Atoll	*T. maxima* mean shell length ± S.E. * (cm)	*T. squamosa* mean shell length ±S.E. (cm)
Raa	**14.1** ±2.7	32.7 ± 2.9
Lhaviyani	**11.7 ±0.9**	**23.9 ±3.9**
Shaviyani	**12.4** ±*0.5*	21.9 **±1.4**
Kaafu	**11.5 ±0.4**	**32.7 ±1.6**

*S.E. = **Standard error**

When the means for *T. squamosa* are compared amongst atolls, using Turkey's test, two groups are seen. Kaafu and Raa population means are not significantly different. Lhaviyani and Shaviyani population means can also be treated as homogeneous.

The first pair both have populations with greater mean standard shell length than the second. There is no obvious reason why this should be the case, as there is no associated geographic pattern or long-term fishing pressurt. However, there may be environmental conditions, such as sea water temperature or current flows that are limiting their size. An alternative is that the Shaviyani and Lhaviyani populations have a higher number of recruits than the Raa and Kaafu populations.

4.6 *Age determination and shell morphometrics*

T. squamosa shells taken from middens on R. Ugoofaaru were sectioned and polished for aging. The oldest one sectioned was 22 years and the youngest *5.5* years. There is clear association between standard shell length and age, with a theoretical maximum shell length approaching 45 cm (Figure 7). Smaller animals were not sectioned, as no empty shells were seen. If shells from young individuals are available, this could be done to assess the early growth pattern of this species in the Maldives.

(over top 17)

Figure 7. Size versus age for *T. squamosa* shells taken from the middens on *R. Ugoofaaru.* (Age determined by growth ring analysis).

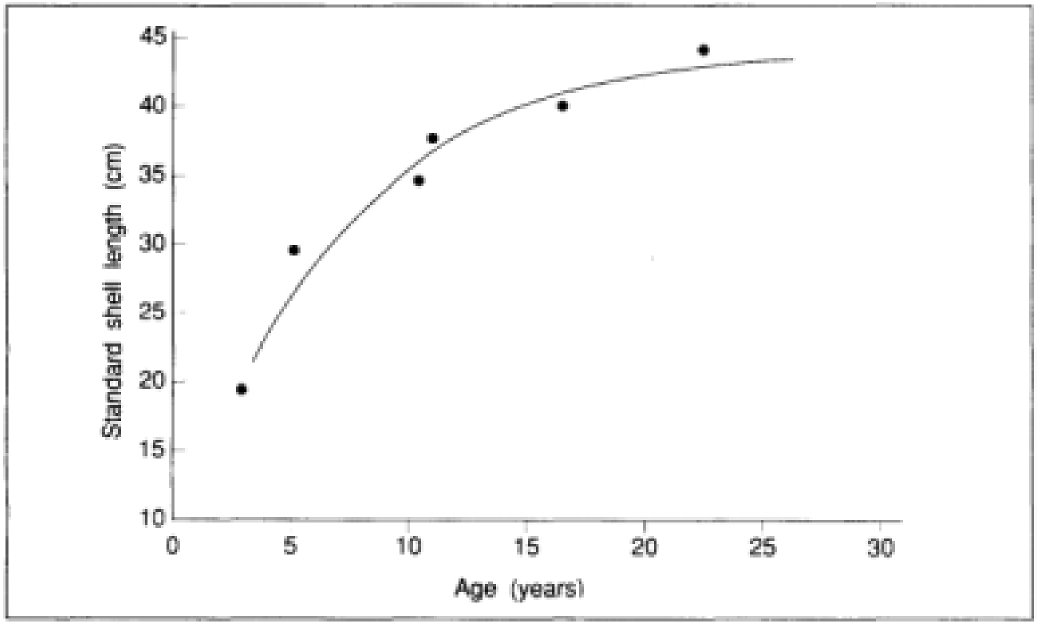

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Figure 3. Length frequency histograms of *T. maxima* **from Kaafu and Lhaviyani Atolls**

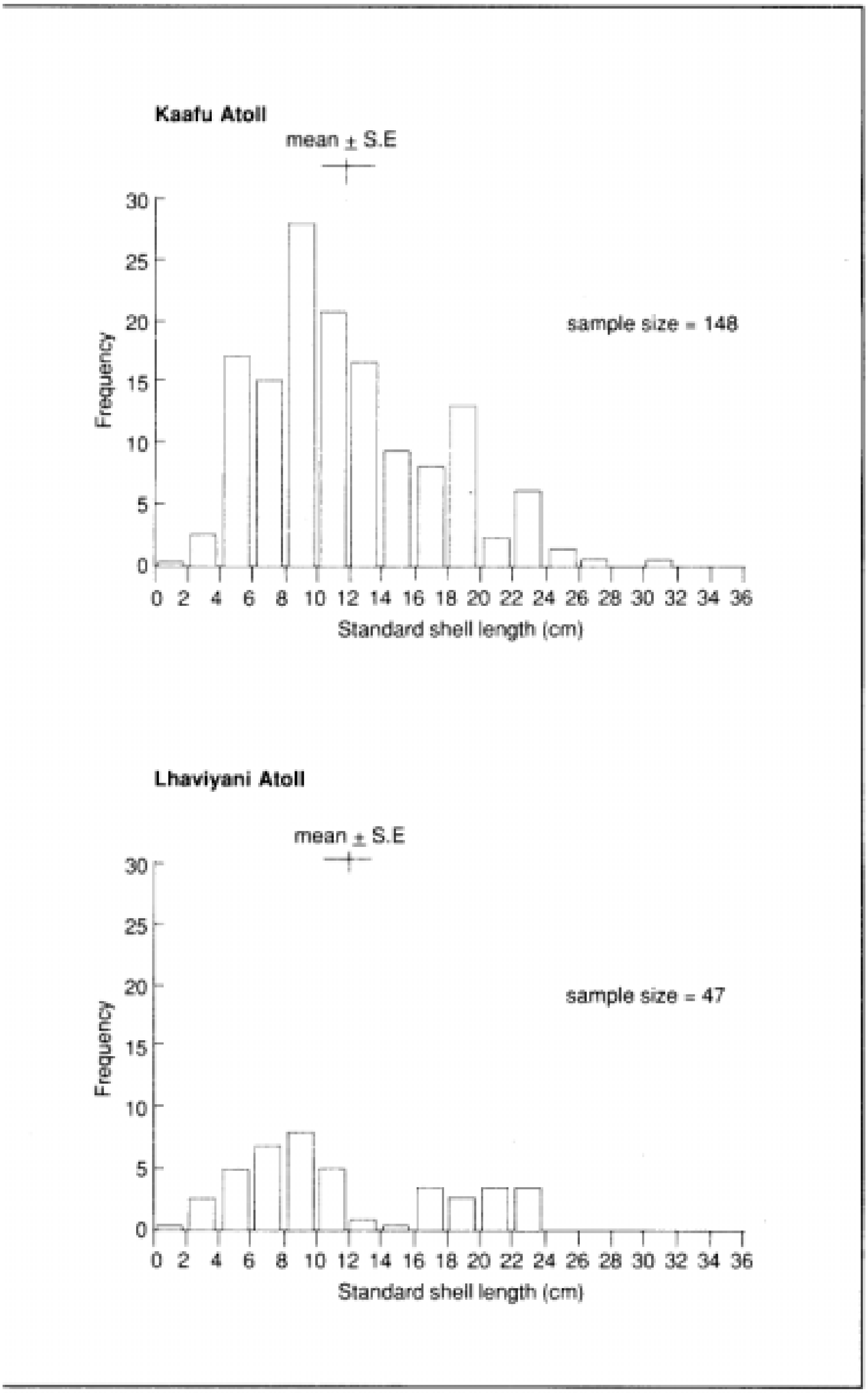

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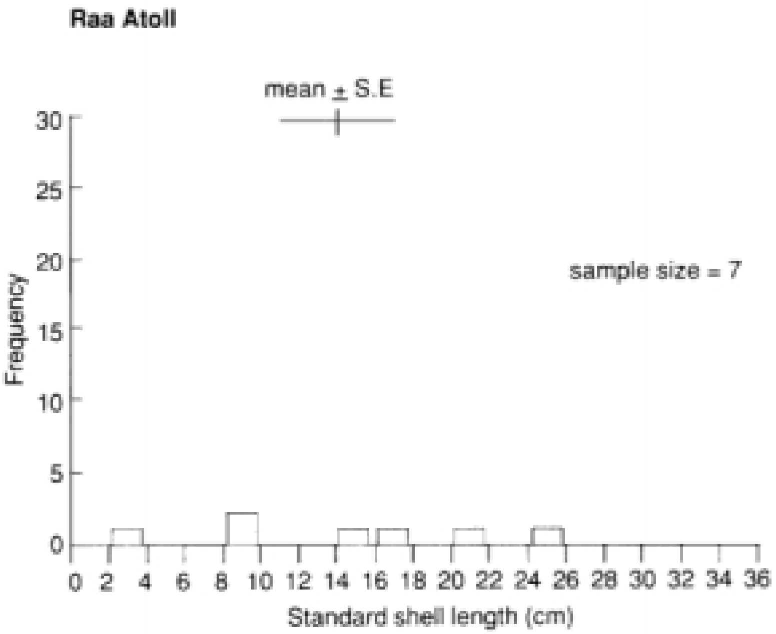
Figure 4. Length frequency histograms of *T. maxima* from Raa and Shaviyani Atolls



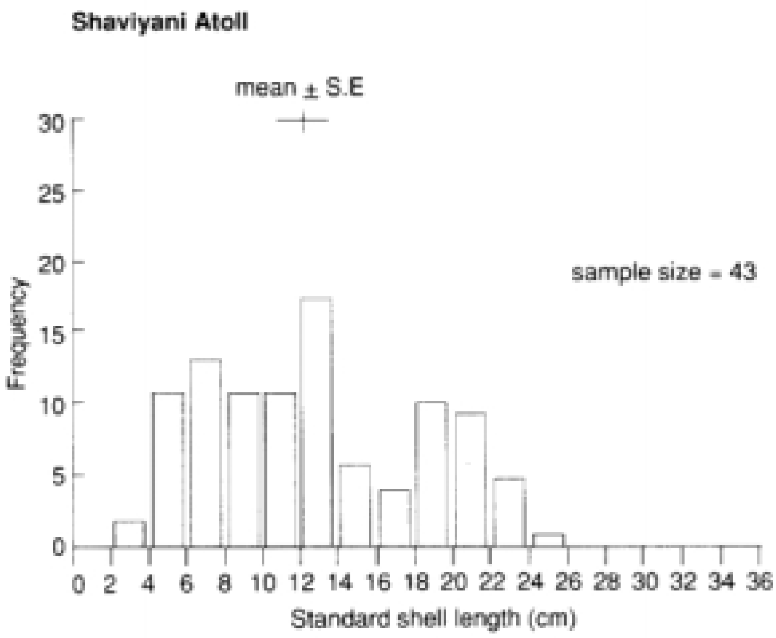


Figure 5. Length frequency histograms of *T. squamosa* from Kaafu and Lhaviyani Atolls

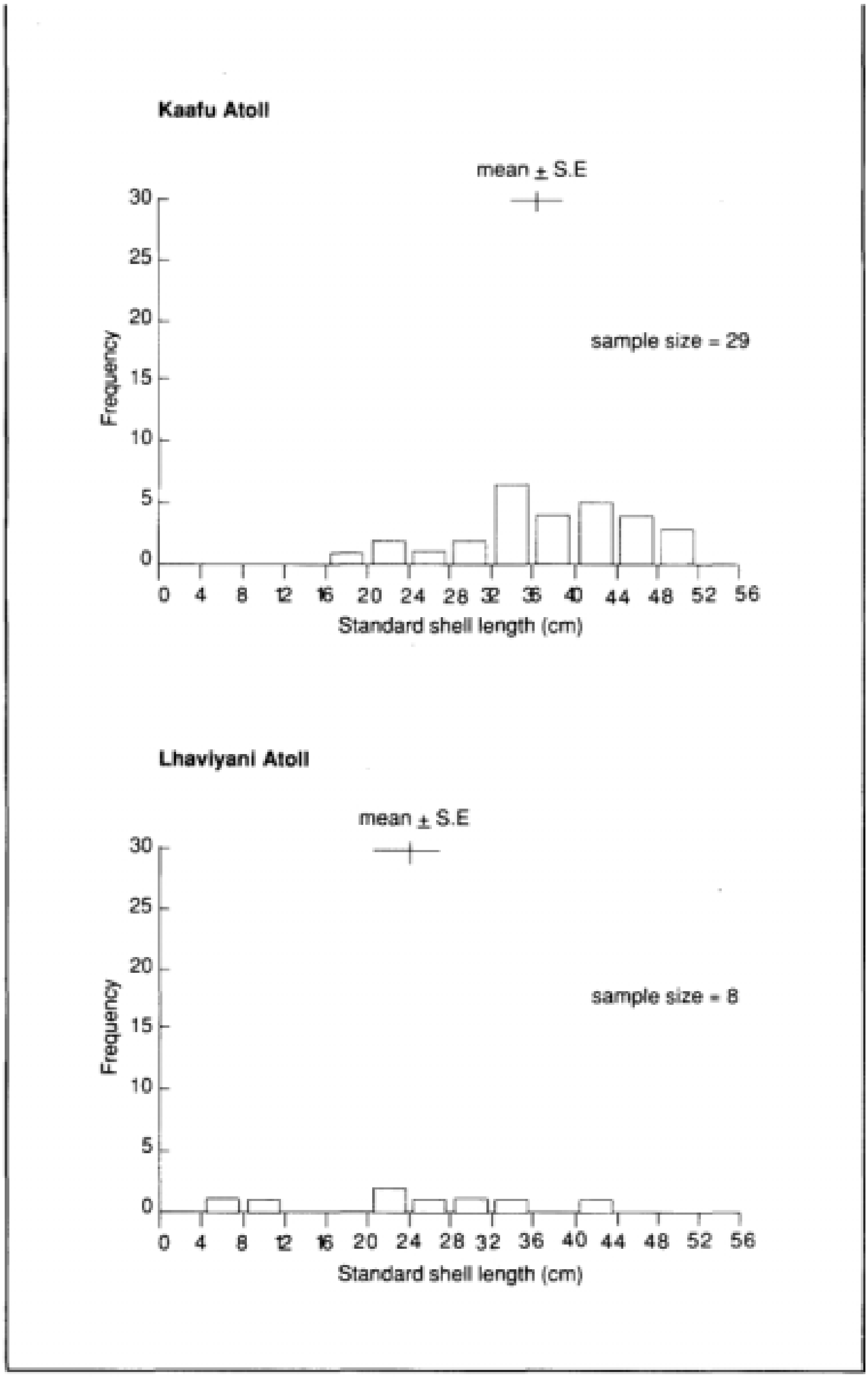
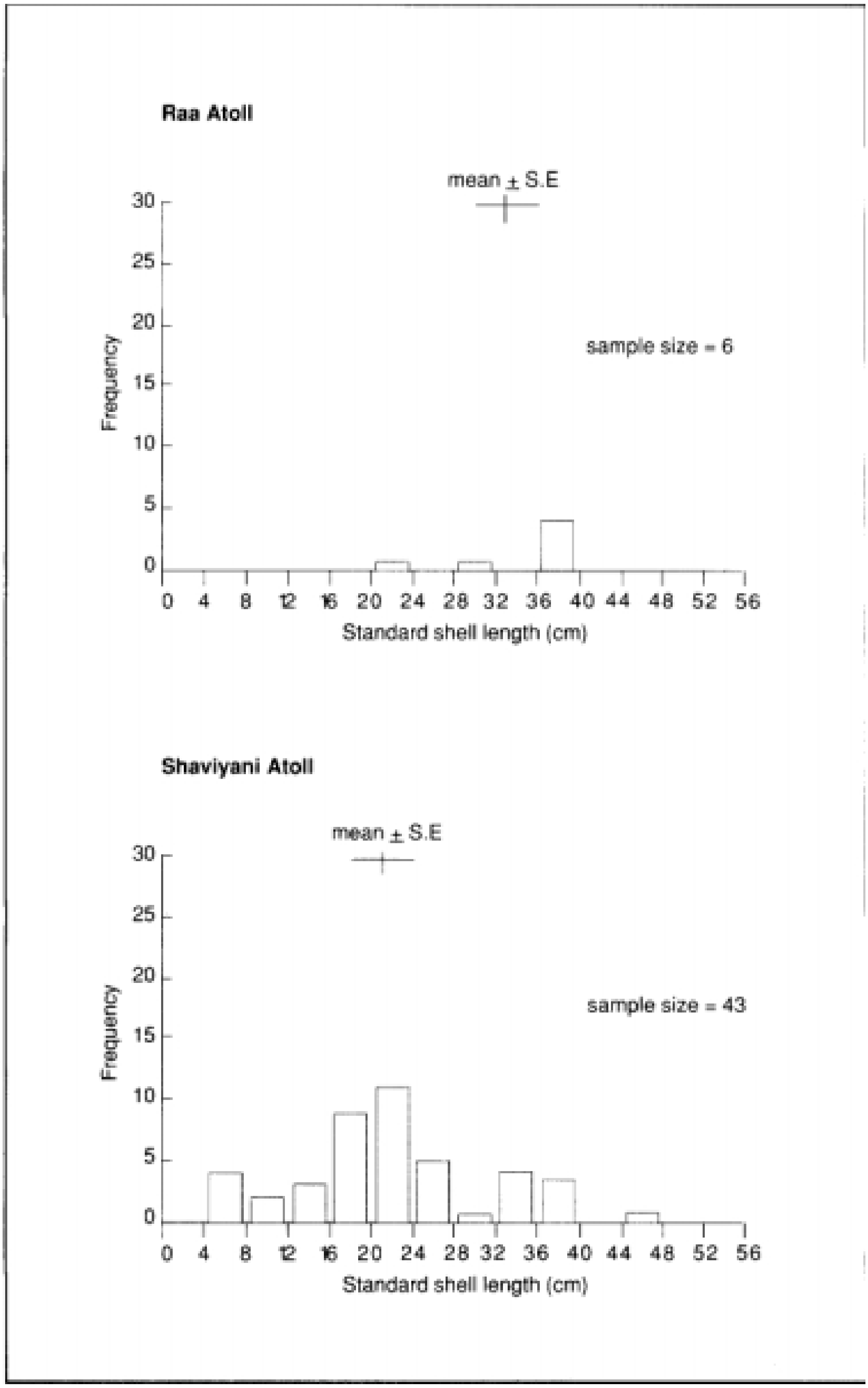


Figure 6. Length frequency histograms of ***T. squamosa*** from Raa and Shaviyani Atolls



The increase in shell length is quite rapid in the first few years, with a gradual slowing from about 8 years on. This pattern of growth is in accord with the findings for other species grown in the Pacific region (Munro 1988, Heslinga and Watson 1985). The growth rate, as indicated by shell length, of giant clams is thought to slow following the onset of full female gametogenesis. This was speculated by Jones *et al.* (1986) for *T. maxima* and shown to occur in *T. crocea* (Murakoshi and Kawaguti 1986). For *T. derasa* this occurs at about 4 years and for *T. gigas* at approximately 7 years.

4.7 *The giant clam fishery*

The fishery for giant clams started in June 1990 and proceeded to the present with a pause one month prior to the start of Ramadan, February 14, 1991. The intention of the local buyers was to recommence collection following the fasting month.

The fishermen of R. Maakurathu said that the fishery started there in 1990 and lasted for two months. The local buyer, they added, then moved his facilities back to Male and then on to R. Ugoofaaru, where there were more clams. As they were dependent on the buyer being within reasonable proximity to their island, they stopped fishing for clams on R. Maakurathu.

The fishermen on this island said that about 80 clams per trip (three people in three hours) were taken during those eight weeks. They were paid 9OMRf/kg for dried adductor muscle. A single *T. squamosa* dissected on this island had the following statistics

Shell length	31 cm
Overall weight	10 kg
Whole tissue weight (drained)	790 g
Adductor muscle weight	115 g
Adductor muscle (diameter x length)	47 x 280 mm

The major centre of the fishery was R. Ugoofaaru. At the start of the fishery, according to the fishermen from this island, they collected in the lagoonal areas of local islands. Then they realized that the large clams were also to be found in the shallow areas, so they concentrated their efforts there. As the numbers of clams dwindled, they were forced to move back to the deeper water.

Once one reef was exhausted, they would move on to the next. As they progressed further from the base island, they had less time for fishing and, so, less animals would be collected in the day.

A senior fisherman on R. Ugoofaaru said, "We have stopped fishing because we are not getting enough". By this he meant that there are not enough clams left in the areas from which they were collecting, Raa and Noonu atolls and Sh. Bolissafaru. He did say that they had fished all the atolls in the north, including Kaafu Atoll, although during the entire survey period no mention was made about fishing in any of the atolls north of Shaviyani Atoll.

The general opinion of the fishermen was that Raa originally had the highest densities of clams. Shaviyani was second and Kaafu third. From discussions with the fishermen, it was noted that the relative abundance of clams from different reefs within Raa also varied even prior to fishing. Of the most heavily fished reefs, Dhigufaru had the highest abundance of clams originally, while Maadhaffaru had medium abundance and Maadhunifaru the least. A second buyer organized a fishery in Male atoll, but has had to stockpile his collection of dried adductor muscles and mantle tissue.

4.8 *Licensing*

There has only been one licence issued for the export of clam meat so far. This licence is for MRf 2 million worth of export of *15,000* kg of meat and is valid for one year. There have been three other applications for export licences lodged with the Ministry for Trade and Industry.

Licences are issued for the cost of the stamp duty, currently levied at 0.01 per cent of the expected export value of the product in Maldive Rufiya (MRf). An export licence is issued for a total maximum weight and value of the product and for a limited period. This is currently the only control over the fishery, and, legally, the Ministry is obliged to issue an export licence if someone lodges an application.

4.9 Commercial operations

4.9.1 FISHERY STATISTICS FROM THE EXPORTERS

The holder of the current licence has sold 9.8 metric tonnes valued, Free on Board (F.O.B), at almost 1.23 million MRf (Table 6).

Table 6

Export statistics for frozen clam meat

Year	Month	Country	Quantity tonne	Price (MRf)
1990	August	Singapore	3.1	456,408
1990	September	Singapore	1.1	151,536
1990	October	Singapore	1.2	122,031
1990	November	Singapore	1.2	120,897
1990	December	Singapore	2.2	237,657
1991	January	Singapore	0.0	—
1991	February	Singapore	1.0	139,300
Total			9.8	1,227,829

* Source Ministry of Fisheries and Agriculture, Maldives, Statistics and Accounts Records.

This exporter has commissioned fishermen to collect whole clams, with an emphasis on large individuals. His buying price is IOMRf for clams greater than 35 cm shell length, 8MRf for 20-35 cm animals and 3MRf for anything smaller. He is constrained by his Taiwanese buyer who will not accept adductor muscles weighing less than 100 g when frozen. Therefore he only buys *T. squamosa.*

The only product that this exporter sells is the adductor muscle, removed and frozen on site in the atolls. He grades the muscles prior to selling, as they command different prices.

Grade A	100 - 200g pieces	12	US$*/kg
Grade B	200 - 300g pieces	14	US$/kg
Grade C	300g pieces	16.50	US$/kg

* 1 US$ = 10 MRf appx.

His last shipment during this study was of 1 t (50 boxes). The ratio of grades of this shipment was 8 : 34 : 8. From his sales figures, it would appear that 1 t comprises of between 6000-7000 pieces. Thus, till April 1991, he had harvested between 58,800 and 68,600 clams.

He had a stock of shells in R. Ugoofaaru but has no buyer for them. During the two months prior to this study, he was discarding the shells back into the ocean.

This sole exporter says he had seven chest freezers and generators operating prior to Ramadan. His initial investment was US$ 100,000, of which US$ 20,000 was an initial loan from the Taiwanese buyer to cover the capital cost of freezers etc., as well as the cost of the 72 labourers employed to clean the clam tissue.

The labourers may have been fishermen from the island; he stated that there were eight or nine per *dhoni* and indicated that twelve *dhonis* were used. An earlier report (Anderson 1990) stated that six *masdhonis* and six *kudadhonis* were used to collect giant clams.

The other local buyer for clam meat has a stockpile of dried adductor muscle and mantle tissue in his warehouse. He has been buying dried clam meat from late 1990, paying 50 MRf/kg for adductor

Dried a4ductor muscle stockpiled in a warehouse in Male

muscle and 25MRf/kg for mantle tissue. The dry weight of meat in stock is 515 kg of adductor muscle and 520 kg of mantle. Anticipated selling prices were 10 US$/kg for adductor muscle and 6 US$/kg for mantle.

Random samples of each tissue were weighed and revealed that 14 pieces of mantle or 26 pieces of adductor muscle equalled 1 kg. This equates to between 7280 and 13,520 individuals, respectively.

This trader buys whatever is brought to him, which may not be both parts from the same animal. This explains the discrepancy between the equivalent weights and dissimilar number of pieces per kilogram. During drying, the adductor muscle reduces to about 22 per cent of its original wet weight (Barker *et* al. In prep).

This buyer purchases clams, by the dry weight of the tissue and is particular about the size that he gets. Recently, he had advertised on the radio that he would purchase clam meat. Although he discourages the taking of small clams, it would appear that he has little or no control over what sizes or species are actually fished.

He also has a stock of shells in his warehouse on K. Thulusdhoo, but, again, no buyer. During discussions he said that a buyer in Singapore had offered him 0.50 US$/kg for the shells ex-Malé. He awaits the issue of an export licence to complete the sale. He reasons that he will be allowed to sell what he has collected already, even if a future restriction is put on the fishery.

Both traders have indicated having a profit margin of 30 per cent. For the trader who has sold stock, this amounts to approximately US$ 35,000 since June 1990. His last shipment before this study concluded was, however, valued at US$ 14,000 and his stated profit was US$ 3000 – or 21.4%

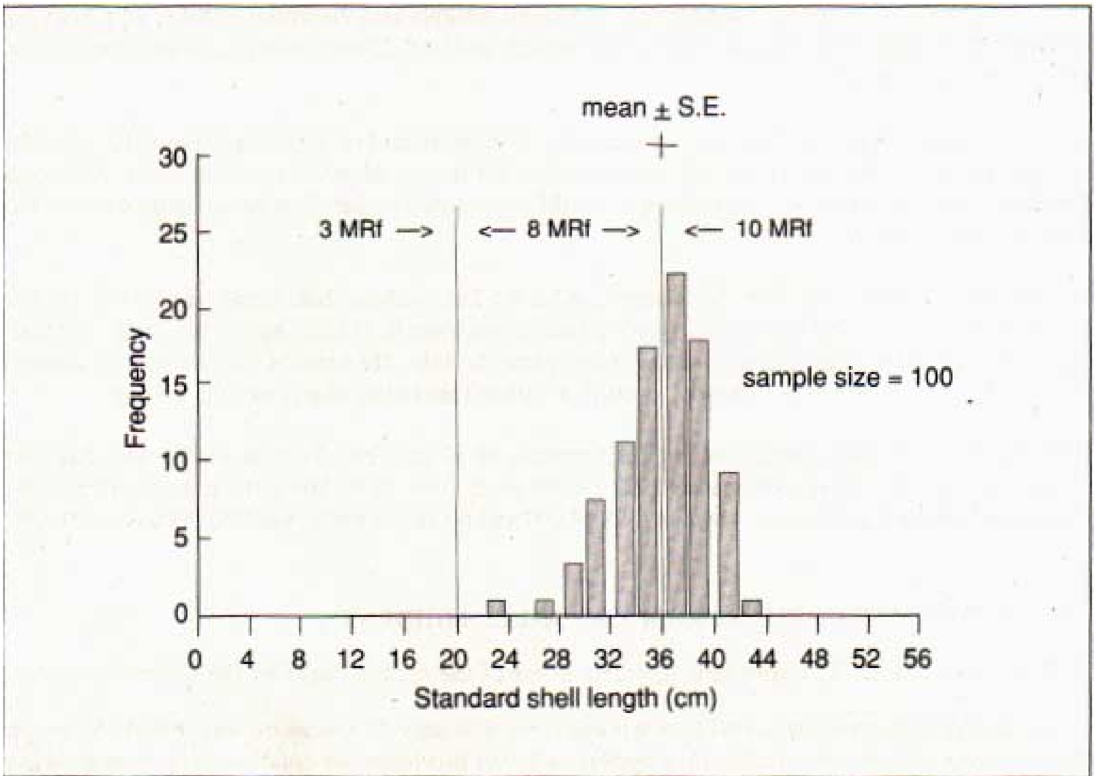
4.9.2 FISHERY STATISTICS FROM THE SHELL MIDDENS

The shell middens on R. Ugoofaaru represent some of the catch bought by the successful trader.

From an examination of these middens it is apparent that only *T. squamosa* was fished. Although there are some *T. maxima* shells, they appear to be an incidental by-catch – they were growing on iarger 1 *squamosa* that were fished. Figure 8 shows the length frequency of shells taken from an area where the middens representing an early part of the fishery are stocked. The average length

Shell middens on R. Ugoofaaru

Figure 8. Length frequency histogram of *T. squamosa* shells from the middens on *R. Ugoofaaru* showing divisions of purchase price



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Measuring the length of shells on R. Ugoofaaru

of 100 *T. squamosa* shells taken from these middens was *35.65* cm. Sixty per cent of those measured were more than the 35 cm in length, the dividing line between the MRf8 and MRfIO purchase price. All the others were in the MRf8 bracket.

Overall size measurements were taken of the middens. A 2 m long representative section was removed to determine the number of shells in a given volume. The volume of this section was calculated at 10.56m3 and it was estimated that there were 642 shells in the section. The combined volume of the middens was calculated to be 633m3. This equates to 38,619 shells. It can be safely assumed that this is a minimum figure for the number of shells on the island, given the margin of error and accounting for shells used for other purposes, such as in the foundation for the tower supporting the island's navigation light.

The second trader also has a stock of shells. This is reputed to weigh 100 tonnes and suggests approximately 12,500 shells (@8kg each). This is in accord with the earlier estimate of his catch.

The middens on R. Ugoofaaru represent only some of the total catch of clams taken from local areas till April 1991. During the two months prior to Ramadan, the shells were being left on the reef and no longer added to the middens on shore.

4.10 *Environmental considerations*

No operators were collecting clams at the time of the survey. Observation of their methods could not, therefore, be made to assess the effects on the coral during collection. However, there is the potential for damage to the reef structure during the harvesting of clams. As *T. squamosa* grows loosely attached to coral or in sandy areas, its collection may cause localized structural damage to the reef. When the clam is found in areas of staghorn coral, *Acropora* species, its removal would necessitate smashing the coral.

T. maxima has a semi-burrowing growth habit with a strong byssal attachment to coral. To remove this species requires a hammer or similar tool to break the surrounding coral. Thus, any harvesting of this species too will cause serious damage to the reef. From discussions with the two commercial buyers it appears that one may have been recovering tissue from some *T. maxima.* There could, Technically it seems that the giant clam can be cultured successfully in the Maldives. This is, however, subject to finding suitable sites, protected from severe weather activity. At least one potential site was identified in Shaviyani Atoll at Sh. Mathikomandoo. Discussions with fishermen and the Island Chief in this area suggest that culture would be sociologically acceptable and that they consider it “a good idea”. An official connected with inter-atoll development also made the comment that there are certain entrepreneurs who would look at the long-term rather than the short-term gain. This is important, as the general attitude of the Maldives entrepreneur is one of quick returns on their investment. This official made particular reference to two people on Hanimaadhoo in Haa Dhaalu Atoll. This island has an airport, freezing facilities and a large lagoon. The island is approximately four nautical miles long and may offer protection to an ocean nursery system on the west side. This site should be checked more fully.

For culture to work in the Maldives, it would be best to include the village communities in the ocean nursery and grow-out phases. This would help to ensure that the protective systems and the clams are regularly checked. It would also help to prevent possible theft. Employment opportunities in the villages would be increased and income sources would become more diversified. The fishermen could still continue tuna fishing, but they could tend the clam crop on a regular basis and more intensively in times of poor fishing. There is also the potential for the involvement of women in these activities.

T. squamosa is the obvious candidate for culture in the Maldives. It is the larger and faster growing of the two species found in these waters. It is likely to take at least five years to reach marketable size. It is not as fast-growing as *T. gigas,* but it has the advantage of having been successfully exported.

T. gigas could, possibly, be imported into the country. But there are a few problems associated with this. First, is the question of whether the species will grow in local conditions, although there is no obvious reason why it should not. Secondly, there is the danger of importing a unique species into an area that has never seen such a species. The dangers associated with the introduction of a new species include unchecked population growth and the introduction of disease. The giant clam is, however, quite benign and if careful quarantine procedures are followed then there may not be a problem.

For culture to proceed, there must be a steady supply of juveniles. Seed stock can be obtained from two sources. They may be imported from hatcheries overseas or produced locally. The first option may be the best initially in terms of cost effectiveness and the immediate establishment of the farming system. An isolated quarantine system on land would have to be established to prevent the import of disease or noxious pests. This would require a seawater system, tanks, filtration, waste-water processing and controlled access. The suggested protocol that should be followed for the import and export of live clams is presented in Appendix III and IV.

Establishing a local hatchery has the advantage of using local broodstock to produce seed which do not require quarantining and are acclimated to the local environment. The Ministry of Fisheries and Agriculture would have to establish and control the quarantine system and it may be preferable for it to do the same for a hatchery. Juveniles could be sold to villages for growing to harvest size in ocean nursery systems and grow-out areas. They, in turn, would sell to individual buyers for marketing overseas, as is currently happening.

The cost of production in the Maldives would have to be carefully checked. Economic analyses have been done on the major sections of giant clam culture for Australian conditions and have shown the culture to be potentially profitable (Tisdell ***etal.*** 1990, Tisdell *etal.* 1991) even if everything is bought with borrowed money, If money is to be borrowed locally, the lending rate of the Bank of Maldives is set at 3.5 per cent above the New York prime rate and, at the time of the survey, was 12.5 per cent. The Bank of the Maldives prides itself on being “behind the development of the Maldives and the people and would support an enterprise such as this,” said one of its senior executives. With local ingenuity and products, the chances of economic success of a culture project in the Maldives for giant clam appear reasonable. Further analysis, however, would have to be conducted to fully assess the potential prior to establishment.

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5.2 *CITES convention*

In recognition of the potentially endangered status of the giant clam, seven species are listed in Appendix II of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES) (IUCN 1983). The recently described *T. tevoroa* (Lucas *et a!.*, 1990) is not listed as yet, but may soon be. The listing restricts the sale of giant clam products between member countries, but "..... would not interfere with mariculture efforts or attempts to improve harvests for local people, but would enable international trade in shells to be monitored and controlled" (Lucas 1988). The Maldives is not a signatory to CITES, though some of its trading partners may be.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 ***The** fishery*

This survey was conducted in limited areas of the country and precludes an exhaustive account of the status of the current standing stocks of giant clam. Relatively small sections of each reef were surveyed, so, as a measure of standing stocks, it is an approximation only. However, it does allow a relative comparison to be made between surveyed areas.

Further work should be carried out to assess the stocks in the other central atolls to assess the full extent of the areas that have been fished. If a survey is carried out in the most northerly and the southern atolls prior to them being fished, it would provide a quantitative baseline account of the original standing stocks. This can help in future fishery management decisions. A re-survey in approximately 3-5 years would provide continuing data on the status of the natural populations and the fishery.

There is a need to preserve and maintain significant numbers of *T. squamosa,* to be used as potential broodstock for future culture operations and to restock reefs where this species has been eliminated. To this end, it is suggested that areas with high densities of this species be identified and closed off to fishing. Other adults may be brought into the same area to further the potential for successful natural spawning and recruitment. These sites should be monitored closely by, for example, the Marine Research Section for mortality and potential theft.

From discussions with the fishermen and the local buyers, it appears that they believe that all the small clams seen are juvenile 7'. *squamosa* which will drop off the coral and replenish the stocks. This is incorrect, as most of the small clams are *T. maxima.* Thus, there needs to be an education programme to enlighten both the buyers and the fishermen, particularly on the dangers of overfishing. This was done during the course of the survey, but needs to be extended.

There is the danger of fishing *T. squamosa* to below a critical population density, whereby natural recruitment will not occur. During spawning, gametes are released into the water column. This means that only individuals in reasonable proximity to each other will produce fertilized eggs. It seems likely that this critical density has been exceeded in heavily fished areas with, in some cases, no *T. squamosa* being found. As areas of high population densities were fished first, the unfished stocks in fished atolls may represent low natural densities. Even in areas where there are sufficient individuals for natural recruitment, it is going to take eight or more years before the area can be fished for animals currently valued at 10MRf.

T. squamosa is known to have been particularly heavily fished in certain atolls. Other atolls, not visited, may also have been heavily fished. One buyer has noted that it takes approximately six months to cover an atoll to the point where, logistically, it becomes too expensive to recover any more clams. The natural population densities will sustain the current fishing pressure for only a few more years. Therefore, some restrictions need to be put in place if the fishery is to last longer than that.