Fish. Res. Bull. Tonga, 3: 1-10 (1995).

Results of the Field Surveys on Giant Clam Stock in the Tongatapu Island Group

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Abstract

A series of surveys was conducted on the giant clam stocks in the Tongatapu Island group by the towing, free swimming, transect line and scuba diving methods. The density of *T. maxima* was high at Ha'atafu and Hakauiki Reef. The giant clam stock seems to have greatly decreased around Hakau Mamao Reef since 1979. Some decrease of the giant clam stock seems to have occurred at the northwestern side of Fafa Island too. On the other hand, the stock of *Tridacna maxima* seems to have substantially increased at Ha'atafu, probably due to the designation of the location as a marine reserve.

Introduction

It has been said that the giant clam stock in the Kingdom of Tonga has been depleted due to over fishing effort, in many cases without any scientific evidence. However, there has been only scattering reports dealing with the stock condition of the giant clam in the kingdom, for example Mckoy (1980) and Langi and 'Aloua (1992). Therefore, much more data should be accumulated to obtain sufficient information for the scientific management of the giant clam resources in the kingdom. The present study deals with the data obtained in a series of field surveys conducted during 1992-94 under the joint Tonga-Japan Aquaculture

Research and Development Project.

Materials and Methods

In this study, the towing method was mainly used, however, the free swimming method was used when shallow water conditions made towing impossible. The transect line and scuba diving methods were used only once.

In the towing method (Braley, 1992; Munro 1993), a 5 m long pole was attached to the bow of the boat (FRP 30 feet Japanese type fishing boat with a 55 Hp outboard engine). Ropes were tied to both ends of the pole and one wooden board was attached to each side of the pole. The observers held the board and were towed by the boat. They reported the species and number of giant clams to the recorder on board whenever they found them. The boat ran along the reef at the speed of about 2 knots (3.6 km per hour) for a set time. Each observer concentrated on scanning approximately a one meter width along his side of the towed line. However, the width of the scanned area became uncertain in deep areas. The observed number of giant clams was then converted to the number observed during a 30 minutes tow by one observer.

In the free swimming method, observers swam freely for a set time and recorded the number of giant clams by species. Then the number of the observed clams was converted to the number observed during a 30 minutes swim by one observer. The transect line method was used only at the western side of Malinoa Island. A 200 m transect line was set from the middle of the western shore of the island toward offshore at an angle of 90 degrees to the west. Two observers swam along the transect line and looked for the giant clams. The width of the search was 2 m on both sides of the line. Therefore the total area surveyed was 800 m^2. The number of clams found in the survey was then converted to the density per ha. The scuba diving survey was conducted at the northeastern side of Atata Island for 30 minutes for the comparison of data between the scuba diving and free swimming methods.

Table 1 shows the date, location, depth and method of the survey and Fig. 1 shows the survey locations.

Table 1. The date, location, depth and method of survey.

No.	Date	Location	Depth (m)	Method
1	28-29. 9. 93	E Atata	1-10	Towing
2	"	NE Atata	0-5	Free swimming
3	"	"	"	Scuba
4	"	NW Fafa	0-4	Free swimming
5	"	"	1-6	Towing
6	"	E Hakau Mamao	1-7	Towing
7	"	NW Hakau Mamao	1-20	Towing
8	"	SE Hakau Mamao	1-22	Towing
9	16-17.11.93	Niutoua	1-20	Towing
10	"	Haveluliku	1-20	Towing
11	"	Monotapu	1-20	Towing
12	"	Ha'atafu	1-20	Towing
13	"	Hakauiki	1-20	Towing
14	1. 6. 94	W Malinoa	0-6	Free swimming
15	"	"	"	Transect
16	"	N Malinoa	2	Free swimming

Results

Table 2 summarizes the results of the surveys. The details of the observations at each location are given below.

Eastern reef of Atata Island

Two *T. maxima* were found during 30 minutes of towing by two observers. The number of clams found per 30 minutes per person was 1.0.

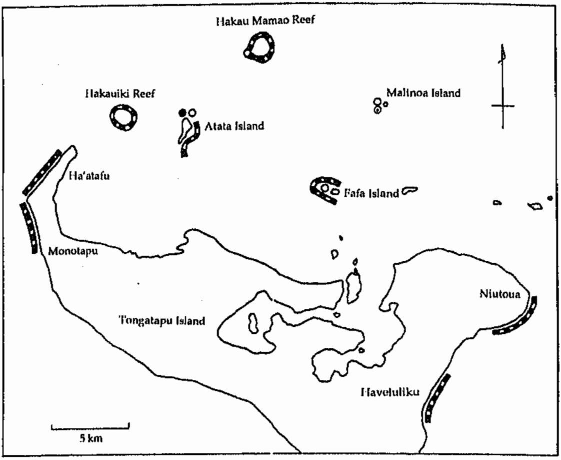

Fig. 1. The map showing the survey sites and methods.
▬ : towing, ○ :free swimming,
● : scuba, ⊙ : transect line.

Northeastern inner reef of Atata Island

One observer found two *T. maxima* and two *T. squamosa* during 30 minutes of free swimming. The other observer conducted a scuba diving survey and found nine *T. maxima* and two *T. squamosa* during 30 minutes. Therefore, it can be said that the scuba diving method found 2.8 times as many giant clams as the free swimming method did.

Northwestern side of Fafa Island

Two observers found two *T. maxima*, one *T. squamosa* and one *T. derasa* during 30 minutes of free swimming. During 40 minutes of a towing survey, two observers found eight *T. maxima*, two *T. derasa* and four *T. squamosa*. The number of clams found per person per 30 minutes towing was 5.3. As the two survey areas are almost the same, it can be said that the towing method found 2.7 times as many giant clams as the free swimming method did.

Eastern side of Hakau Mamao Reef

Two *T. maxima* and one *T. squamosa* were found by two observers during 30 minutes towing. The number of clams found per person per 30 minutes was 1.5.

Northern to western side of Hakau Mamao Reef

Two observers found seven *T. maxima* during the 30 minutes towing survey. The number of clams found per person per 30 minutes was 3.5.

Southeastern side of Hakau Mamao Reef

Two observers found eight *T. maxima* and one *T. squamosa* at the depth of 3 m and four large *T. derasa* at the depth of about 20 m, during the 30 minutes towing survey. The number of clams found per person per 30 minutes was 6.5.

Niutoua

In this area, the ocean bed is lime stone and 5% to 30% of the bed was covered with live coral and brown algae, *Sargussum* sp. Two observers found only one *T. maxima* during the one hour tow. The number of clams found per person per 30 minutes was 0.3.

Haveluliku

Up to 50% of the ocean bed was covered by live coral. Two observers found three *T. maxima* and one *T. squamosa* during the one hour tow. The number of clams found per person per 30 minutes was 1.0.

Monotapu

The ocean bed was about 80% covered, mostly by live coral, which then gradually decreased toward Ha'atafu to as low as 5% coverage. Two observers found eight *T. maxima* and six *T. derasa* during the one hour towing survey. *T. maxima* were found at 3-5 m depths in the holes of lime stones, while *T. derasa* were found in much deeper drop offs or in the margin of sandy bottom of spar and groove at the reefs edge at more than 20 m depth. The number of clams found per person per 30 minutes was 3.5.

Ha'atafu

Two observers found 63 *T. maxima* and two *T. squamosa* during the one hour towing survey. The number of clams found per person per 30 minutes was 16.3.

Hakauiki Reef

The southern to eastern part of Hakauiki reef was 0.5-3.0 m deep and was fully covered by live coral while the northern part of the reef was covered mostly by dead coral with only scattered live coral of about 10 % in coverage. Tow observers found 67 *T. maxima* during the one hour towing survey. The number of clams found per person per 30 minutes was 16.8.

Western side of Malinoa Island

One observer conducted the free swimming survey within the area 100 m from the shore line. He found three *T. maxima* during the one hour survey. The other observer conducted the free swimming survey between 100 m and 200 m from the shoreline and found three *T. maxima* during the one hour survey. The number of clams found per person per 30 minutes was 1.5. In the transect survey, one *T. maxima* was found at 29 m from the shoreline and another one at 180 m from the shoreline. The estimated density of the giant clams was 25/ha.

Northern side of Malinoa Island

Four observers conducted the free swimming survey. Two observers found no clams and the other two found one *T. maxima* each during the 30 minutes survey. The number of clams per person per 30 minutes was 0.5.

Table 2. Number and species of giant clams observed at each location.

No.	Number of clams (clams/30 min)	Species m	d	s
1	1.0	1.0		
2	4.0	2.0		2.0
3	11.0	9.0		2.0
4	2.0	1.0	0.5	0.5
5	5.3	3.0	0.8	1.5
6	1.5	1.0		0.5
7	3.5	3.5		
8	6.5	5.2	0.7	0.7
9	0.3	0.3	0.5	
10	1.0	0.8		0.2
11	3.5	2.0	1.5	
12	16.3	15.8		0.5
13	16.8	16.8		
14	1.5	1.5		
15		25.0/ha		
16	0.5	0.5		

m: *Tridacna maxima*, d: *T. derasa*, s: *T. squamosa*

Discussion

Comparison of the results obtained by the towing surveys shows that the density of the giant clams was low at the eastern side of Atata Island, the eastern side of Hakau Mamao Reef, Niutoua and Haveluliku, but high at Ha'atafu and Hakauiki Reef, and average at other locations. Further surveys on ecology and the condition of the clam fisheries should be conducted to explain the reason for this distribution pattern of the clam. The high density of the giant clam at Ha'atafu may be explained by the designation of the location as a marine reserve.

The free swimming survey results can be compared with the data for 1979 (Mckoy, 1980) and 1987 (Langi and 'Aloua, 1988) shown in Table 3. The number of clams observed per person per 30 minutes free swimming decreased from 4.4 in 1979 to 2.0 in 1987 and 1994 at northwest Fafa. This may suggest that the giant clam stock decreased between 1979 and 1987 and then maintained the same level later on at that location. On the other hand, at the west of Malinoa, where only *T. maxima* was observed, the numbers increased from 0.7 in 1979 to 4.5 in 1987 and decreased to 1.5 in 1994. These figures may suggest that the stock of *T. maxima* has not been subject to constant and strong fishing pressure there.

The ratio between the towing and free swimming surveys results was 2.7 at the northwestern side of Fafa Island. If this ratio is applied to the conversion of the towing survey results to the free swimming results for data obtained at the Hakau Mamao area, the number of clams found per person per 30 minutes of free swimming is estimated at 0.5-2.2. A comparison of this to those figures for 1979 and 1987 indicates a consistent decrease in the giant clam stock in this area. A comparison of data obtained at Monotapu also indicates some decrease of giant clam stock from 1979 to 1994. These decreases in the giant clam density may be explained by the effects of fishing pressure. On the other hand, a comparison of data obtained at Ha'atafu shows an increase in the giant clam stock from 1979 to 1994. This may be explained by the designation of the location as a marine reserve.

However, a direct comparison between the data obtained should have a limited scientific meaning, since the discovery rate of the giant clam must vary greatly according to the observer's skill, survey method, weather conditions, sea depth, sea bottom configurations, nature of bottom deposits and vegetation. Among the four methods used in this study, the towing method seems to be the most efficient as it can cover a wide area and also can find as many clams as the scuba diving method can.

Table 3. Results of free swimming survey conducted in 1979 and 1987 (Mckoy, 1980 ; Langi and 'Aloua 1988).

Location	Depth (m)	Number of clams/30 min	
		1979	1987
NW Fafa	0-4	4.4	2.0
Hakau Mamao (5)	0-6	19.0-22.8	7.0-9.5
Ha'atafu	0-7	1.7	
Monotapu	0-3	3.0	
W Malinoa	0-6	0.7	4.5

Table 4 shows the giant clam landing statistics for 1974-1978 (Mckoy, 1980) and for 1992-1994 (obtained by the Inshore Fisheries Statistics Program under the joint Tonga-Japan project, see Tulua *et al.* (1994)). It seems that the giant clam fishery started to enjoy a boom with catches up to 150 tons in 1978. Although there are no landing statistics available between 1979 and 1991, the landings declined to the 40-50 tons level in recent years. This decline in the landings may bear some relationship to the decline in the giant clam stock at the Hakau Mamao area shown in this study.

Table 4. Annual landing of the giant clams for 1974-78 and 1992-1994 (Mckoy, 1980; Tulua *et al.*, 1994).

Year	1975	1976	1977	1978	1992	1993	1994
Landing (tons)	41.3	83.5	88.1	153.3	49.9	52.3 1)	39.6 2)

1): estimated from March-December data.
2): estimated from January-July data.

However, the speed of depletion of the giant clam stocks seems not to be critical so far, as the fishermen still enjoy reasonable harvests in the Tongatapu area. Nonetheless, recently introduced hookah gear seems to be way too effective in harvesting large sized giant clams which have been escaping from skin diving fishermen by living in deeper waters. These large sized clams seem to play an important role in reproduction of the stocks. If these stocks are lost, then the Tongan giant clam resource will face the danger of rapid depletion. Continuous efforts to monitor the stock conditions in the field, as well as the landings at the fish markets are essential. Also, proper management of marine reserves are badly needed. Public awareness will be the key factor for the success of conserving the important giant clam resources.

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Fishing Pressure on the Resource of the Elongated Giant Clam, *Tridacna maxima*, in Tonga

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Abstract

The size distribution of *T. maxima* landed at Vuna Wharf fish market indicated that the stock of *T. maxima* was subjected to stronger fishing pressure in 1992-94 than in 1979. The stock of clams larger than 100 mm SL has decreased to such a low level that the catch of larger clams can not be increased by intensifying fishing effort. The shape of the size distribution of the clam, for the range larger than 100 mm SL, became a reversed-J shape of a sharper angle as fishing pressure became stronger. When a comparison was made for the same year, the angle of the reversed-J shape was sharper for natural stock than for landed clams, as fishermen actively catch larger clams.

Introduction

The elongated giant clam, *Tridacna maxima*, is the most abundant giant clam in Tongan waters and thus plays an important role in the diet of the Tongan people. Mckoy (1980) states "there is a good indication that the present level of fishing is having a significant effect in reducing clam stocks at a rate greater than the clam population can adjust" based on the data obtained in 1979. However, there has been no study on the resource of this species after Mckoy's study. This study was conducted to assess the effect of fishing pressure on the resource of *T. maxima* based on the size frequency distribution data obtained in 1992 and 1994.

Materials and Method

The landing of giant clams fluctuates widely, from zero to several hundred in number, according to weather conditions and magnitude of the demand. The present data was taken when the landings of the giant clams were large in quantity at Vuna Wharf fish market on August 14 in 1992 and October 5 in 1994. Shell lengths were taken on all giant clams landed at the fish market. The numbers of *T. maxima* were 305 in 1992 and 188 in 1994.

Results and Discussion

Fig. 1 shows the shell length frequency distribution of *T. maxima* landed at the fish market in 1992 and 1994. The mode was 80-90 mm SL and the mean was 103.0 mm SL in 1992 while the mode was 100-110 mm SL and the mean was 118.2 mm SL in 1994. The mean shell length in 1994 was larger at the 5% significance level than that in 1992. However, the shapes of the frequency distribution are almost the same for both years in the range larger than 100-110 mm SL. This is an indication that the catch of only small clams is increased when the total number of landed clams increases due to the relative scarceness of large clams in the natural stock. Therefore, the increase in mean shell length in 1994 does not imply a real and significant increase in the mean shell length of natural stock during 1992-94.

Fig. 2 shows the shell length frequency distribution of *T. maxima* in percentages for 1979, 1992 and 1994. The frequency distribution for 1979 is constructed from shell length data of 1,492 shells taken at Vuna Wharf fish

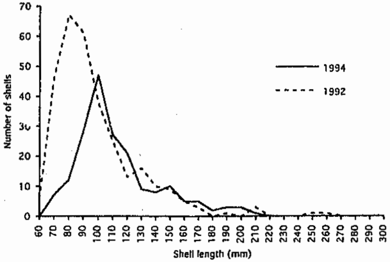

Fig. 1. Size distribution of *T. maxima* landed at Vuna Wharf fish market in 1992 and 1994.

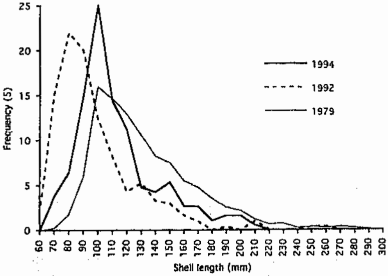

Fig. 2. Size distribution (%) of *T. maxima* landed at Vuna Wharf fish market in 1979, 1992 and 1994.

market in January, February and March (Mckoy, 1980). The figure shows that the percentage of shells smaller than 100 mm SL is very low, only 0.8%, in 1979 whereas the percentage is much higher in 1992 (59%) and in 1994 (25%). The mean shell length was 137.3 mm SL in 1979. Fig. 3 shows the frequency distribution in percentages for shells larger than 100 mm SL in 1979, 1992 and 1994. The frequency distribution is a gentle downward slope to the right in 1979. However, the frequency distributions are almost the same reversed-J shape in 1992 and 1994 . The percentage of shells larger than 130 mm SL was much lower in 1992 and 1994 than in 1979. It is indicated, therefore, that the stock of large *T. maxima* was scarcer in 1992-94 than in 1979.

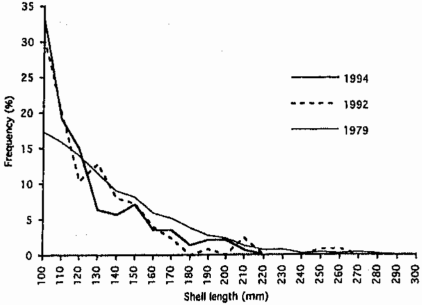

Fig. 3. Size distribution (%) of *T. maxima* larger than 100 mm SL landed at Vuna Wharf fish market in 1979, 1992 and 1994.

Fig 4 shows the size frequency distribution in percentage for natural stock of *T. maxima* larger than 100 mm SL for Tongatapu and Ha'apai Islands constructed from the data obtained in 1979 (Mckoy, 1980). This figure shows that

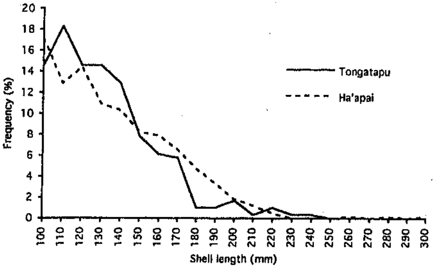

Fig. 4. Size distribution (%) of natural *T. maxima* larger than 100 mm SL observed in the sea off Tongatapu and Ha'apai in 1979.

the size distribution was a gentle downward slope to the right for Ha'apai whereas it was a reversed-J shape for Tongatapu. Therefore, the distribution was higher in Tongatapu than in Ha'apai for clams smaller than 150 mm SL, but higher in Ha'apai than in Tongatapu for clams larger than 150 mm SL. Such difference in the size frequency distribution can be explained by the levels of fishing pressure exerted on the giant clam resource between the two islands. In Tongatapu, where fishing pressure was high, large clams had been actively fished and eventually the stock of large clams became scarce. On the contrary, in Ha'apai, where fishing pressure was much lower than in Tongatapu, the stock of large clams was preserved.

Fig. 5 shows the size frequency distributions in percentages of *T. maxima* larger than 100 mm SL in both the natural stock and landings at the fish market. Both curves are constructed from the data obtained in Tongatapu in 1979

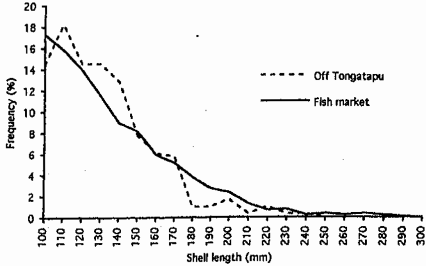

Fig. 5. Size distribution of *T. maxima* larger than 100 mm SL landed at Vuna Wharf fish market and observed in the sea off Tongatapu in 1979.

(Mckoy, 1980). The figure shows that the frequency of natural stock was higher for clams smaller than 150 mm SL and higher in the fish market landings for clams larger than 170 mm SL. This is an indication that the large clams were subjected to higher fishing pressure than the small clams and thus the frequency distribution tended to become reversed-J shape. Although the size frequency distribution of natural clam stock is not available in this study, it is believed that the size frequency distribution of the clams for 1992-94 became reversed-J shape with sharper angles than that for 1979 due to stronger fishing pressure as shown in Fig. 3.

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Fish. Res. Bull. Tonga, 3: 19-24 (1995).

A Tank Culture Trial of the Seaweed, *Gracilaria* sp.

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Abstract

A red algae, *Gracilaria* sp., was cultured in two 100 litre transparent plastic tanks with a conical shaped bottom and provided with a continuous supply of seawater and aeration. In one tank, Tank A, a culture was started with sea weed 200 g in wet weight, and in the other, Tank B, with 50 g in wet weight. After the seaweed had grown to about 450 g in wet weight, it started to grow faster with a constant daily growth rate of 114 g in Tank A and 93 g in Tank B. The growth then slowed down after it reached around 4,500 g and started to decrease after about 5,800 g. The stronger aeration in Tank A seems to be responsible for the larger daily growth rate than in Tank B.

Introduction

The red algae of genus *Gracilaria* is important as food for the green snail in its seed production and brood stock culture (Kikutani, 1994). The Ministry of Fisheries of Tonga presently maintains 73 green snails in a 4.5 m^3 concrete raceway tank with *Gracilaria* sp. as the main food. However, the collection of an adequate amount of the seaweed is time consuming work, particularly when the seaweed becomes scarce in the coastal waters in some seasons. In order to solve this problem, this study examined the possibility of culturing the sea weed, *Gracilaria* sp., in the plastic tank to ensure a constant supply.

Fish. Res. Bull. Tonga, 3: 19-24 (1995).

Materials and Method

Gracilaria sp. used in the examination was collected on November 5, 1994 in the shallow sea along the coast of Nukuleka on Tongatapu Island (Fig. 1). The collection location was close to a mangrove area, 80 cm deep at high tide and with the bottom deposits being a mixture of sand and mud. Two 100 litre transparent polycarbonate tanks were used for the sea weed culture. The tank (Earth Co. Ltd., Tokyo, Japan) was originally designed for the purpose of brine shrimp egg incubation and has a conical shaped bottom. Untreated seawater of 600 litres per hour and gentle aeration were supplied to each tank from the bottom (Fig. 2). The tanks were placed on an open concrete floor with a roof of translucent corrugated plastic panels. In one tank (Tank A) the seaweed of 200 g in wet weight (WW) was stocked on November 11, 1994. In another tank (Tank B) the seaweed of 50 g WW was stocked on November 23, 1994.

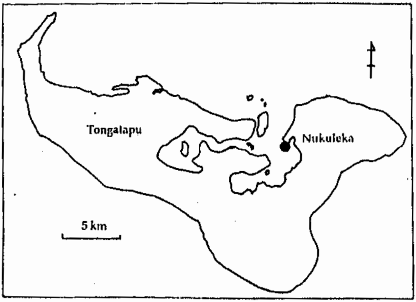

Fig. 1. Location of *Gracilaria* sp. collection.

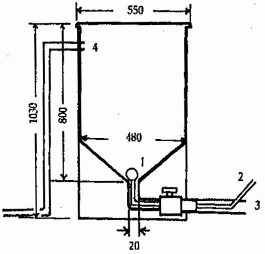

Fig. 2. Plastic tank used in the culture trial (dimensions in mm).
1: air-stone, 2: air supply pipe,
3: seawater supply pipe, 4: draining pipe.

Before the seaweed was weighed, as much water as possible was drained by putting the whole seaweed from each tank in a mesh bag and strongly swinging it around by hand.

Results

Fig. 3 shows the growth of the seaweed for both tanks. In Tank A, the seaweed grew from 200 g WW to 464.7 g WW in 6 days. Then the seaweed started to grow faster and constantly until 4,545 g WW on the 41st day. The linear regression line

$$y = 114.13x - 272.38 \qquad (R^2 = 0.995)$$

represents well the growth during this period. This indicates that the seaweed grew 114 g WW daily. After reaching 4,545 g WW, the seaweed continued to grow at a slower speed until the maximum of 5,789 g WW was reached on the 59th day. On the 62nd day, the wet weight of the seaweed dropped to 5,329 g and some parts of the seaweed were observed to be dead.

In Tank B the growth of the seaweed was slow until 492 g WW on the 14th day. Then the growth was faster and reached 3,864 g WW on the 50th day. The growth during the fast growing period is also described well by the linear regression line of

$$y = 92.64\,x - 738.54 \qquad (R^2 = 0.995),$$

which indicates that the seaweed grew 93 g WW everyday during the period.

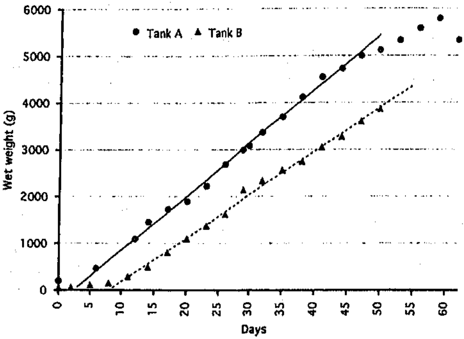

Fig. 3. Growth of *Gracilaria* sp. in the tanks.

The slopes of the regression lines are different at the 5% significance level between Tank A and Tank B. This indicates that the daily growth rate was significantly higher for Tank A than Tank B.

Discussion

The daily increase in weight of the seaweed was constant, namely 114 g WW for Tank A and 93 g WW for Tank B, after the total weight of the seaweed exceeded 460-490 g WW. Those daily increases are the daily sustainable crops from the tanks. At present, the brood stock of green snails consume seaweed at about 60 g per day, per one kg of total body weight. Therefore, the daily crops from Tank A and Tank B can maintain green snails of about 2 kg and 1.5 kg in total weight, respectively, or 26 and 20 individuals in number at the present body size, respectively.

Many factors affect the growth of the seaweed, namely, the seasons of the year, capacity of the tank, rate of water flow, intensity of aeration, intensity of illumination, growth of contaminating diatoms, concentrations of nutrient salts in the seawater etc. Among these factors, the intensity of aeration was stronger for Tank A than Tank B, while other factors were more or less the same. Therefore the difference in the daily growth between the two tanks can be explained by the difference in the aeration intensities. Further study should be conducted to clarify the relationship between the speed of growth and the intensity of aeration before the optimum intensity is determined.

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Fish. Res. Bull. Tonga, 3: 25-33 (1995).

Breeding Season of the Tongan Shellfish 3. Elongated Giant Clam (Kukukuku), *Tridacna maxima*

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Abstract

Monthly samples of *T. maxima* were taken at Vuna Wharf fish market in Tongatapu Island from April 1992 to March 1993. *T. maxima* at 40-59 mm SL were all male. The ratio of hermaphrodite shells gradually increased from 60 mm SL to 140 mm SL at which size all shells become hermaphrodite. The spawning of *T. maxima* seems to occur intermittently throughout the year as indicated by the wide range of gonad indices, from 0 or less than 10 to more than 30, in most of the months.

Introduction

The elongated giant clam, *T. maxima,* out of all the giant clams caught in the Kingdom of Tonga is the dominant species in terms of the amount of landings at the Tongatapu fish market. In spite of their commercial importance, there has been only one study on the biology of this species in Tonga (Mckoy 1980). This study deals with some of the basic biological features such as size at sexual maturity, sexual phases and the spawning season of *T. maxima*.

Materials and Method

Samples of *T. maxima* were taken at Vuna Wharf fish market once a month from April 1992 to March 1993. Most of *T. maxima*, except for a small number of large individuals, are displayed at the fish market after packaged in coconut leaf baskets which contain from 9 to 38 clams. One basket of giant clams was bought at each sampling time. The total number of sampled giant clams during the study period was 293. Measurements were taken on shell length (SL), total wet weight, wet soft body weight (FW) and wet gonad weight for all giant clams sampled. The gonad weight included weight of a part of the digestive mass since it is difficult to completely separate the digestive mass from the gonad. The weight of an almost empty gonad was recorded as 0 g. The gonad index (GI) was calculated as

$$GI = 100 \cdot \text{wet gonad weight (g)} \ / \ \text{wet soft body weight (g)}$$

Then the gonads were observed on all giant clams either by the naked eye or under a microscope to examine the occurrence of eggs in the gonads. Those clams which had eggs in the gonads were classified as hermaphrodite and those which had only sperms were classified as male.

Results

Table 1 shows the number of clams sampled each month and the fishing grounds where they were obtained. The fishermen of 'Afa village (situated on the northeastern coast of Tongatapu Island) caught all giant clam samples from the northeastern reef batches of Tongatapu Island, namely Tau, 'Ata, Motutapu and Fukave islands. Ha'atafu and Kolovai are both situated on the western most coast of Tongatapu Island (Fig. 1).

Table 1. Fishing grounds and sample number of monthly samples.

Month	Fishing ground	Number of clams sampled
April	'Ata	9
May	'Ata	22
June	Kolovai	24
July	Motutapu	24
August	Ha'atafu	38
September	'Ata	32
October	Tau	26
November	Motutapu	20
December	Tau	16
January	Tau	25
February	Fukave	41
March	Tau	16

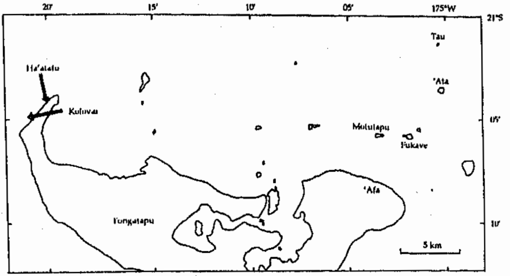

Fig. 1. Map showing fishing grounds of *T. maxima.*

Fig. 2 shows the shell length distribution for all *T. maxima* sampled during a one year period. The range of shell length was 55.9 mm to 194.5 mm (average 113.5 mm). The total weight ranged from 42.6 g to 1,304 g (average 264.2

g) whist the soft body weight ranged from 6.3 g to 177.4 g (average 41.6 g).

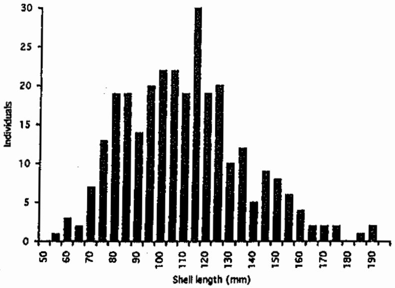

Fig. 2. Shell length distribution of *T. maxima* samples.

The relationship between shell length and soft body weight is shown in Fig. 3. The relationship is well represented by the curve:

$$FW = 0.0001219 \cdot SL^{2.665}$$

Table 2 shows the sexual phase composition of all samples against shell length. The smallest clams in the hermaphrodite phase were 60-70 mm in shell length. All clams larger than 140-150 mm in shell length were in the hermaphrodite phase. Fig. 4 shows the relationship between shell length and gonad index. The figure suggests

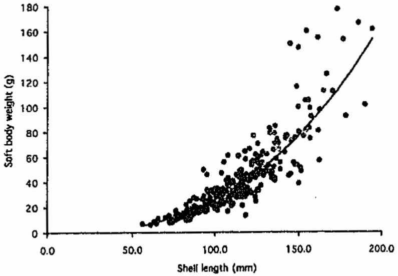

Fig. 3. Weight-length relationship of *T. maxima*.

Table 2. Composition of sexual phases of *T. maxima* by size group.

Size group (mm)	Unidentified	Male	Hermaphrodite Number	(%)
50-60		1		(0.0)
60-70		3	2	(40.0)
70-80	2	7	11	(55.0)
80-90	2	6	30	(78.9)
90-100		3	32	(91.4)
100-110		1	43	(97.7)
110-120		6	42	(87.5)
120-130		1	37	(97.4)
130-140		1	21	(95.5)
140-150			17	(100.0)
150-160			11	(100.0)
160-170			6	(100.0)
170-180			4	(100.0)
180-190			2	(100.0)
190-200			2	(100.0)

that the maximum GI increased as shell length increased until 110-120 mm SL as shown by the broken line. This in turn may mean that the clams smaller than 110-120 mm SL did not attain full maturity.

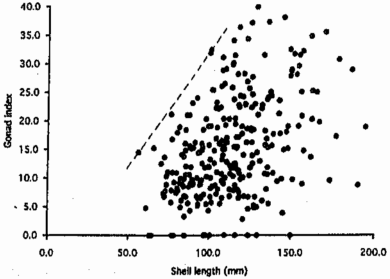

Fig. 4. Gonad index-shell length relationship of *T. maxima*.

Fig. 5 shows the maximum, average and minimum of the gonad index in each month. The monthly maximum gonad index was over 30 throughout the year except for May, December and February when the maximum gonad index was between 20 and 30, and January when the maximum gonad index was below 20. The average gonad index fluctuated around 15 with the highest of 21.1 recorded for October and the lowest of 10.2 recorded for January. The monthly minimum gonad index was 0 for seven sampling months and ranged between 2.8 and 6.7 for the remaining five sampling months. The wide ranges of the gonad index recorded each month, except January, indicate the occurrence of

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intermittent spawning events throughout the year. The relatively low gonad index recorded in January may indicate the occurrence of mass spawning just before the sampling date.

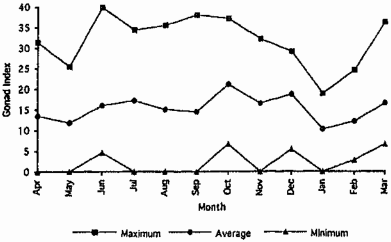

Fig. 5. Monthly maximum, average and minimum of gonad index of *T. maxima*.

Discussion

Mckoy (1979) shows that almost all of the *T. maxima* were male at 50-69 mm SL, 50% were hermaphrodite at between 100 and 109 mm SL and 100 % were hermaphrodite at over 140 mm SL. However, this study showed that the clams were male at below 59 mm SL and more than 50 % of the clams were hermaphrodite at 70-79 mm SL. The sizes that were 100% hermaphrodite were the same as Mckoy's (Fig. 6). This study did not find a reason for the discrepancy between the two results.

A gonad index or gonad weight ratio (=GI/(1-GI)) was used to examine the reproductive cycle of giant clams, *T. crocea* and *Hippopus hippopus* in Australia (Shelly and Southgate, 1988) and *T. crocea* in Japan (Murakoshi and Kawaguti, 1986). The Australian study showed that spawning events occurred in November for *H. hippopus* and

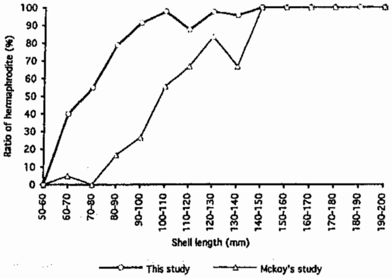

Fig. 6. A comparison of ratios of hermaphrodite of *T.maxima* by shell length range between results of this study and Mckoy's study.

October-November for *T. crocea*. The Japanese study showed that spawning events of *T. crocea* occurred from spring to summer. The Japanese study also showed that a complete release of gametes was ignited by a typhoon at the end of summer and this is indicated by the sudden drop in the gonad index. However, no clear seasonal tendency was observed in the changes of the gonad index for *T. maxima*. This, together with the wide range of gonad index observed in each month, suggests that there is no clear spawning season for *T. maxima* in Tonga.

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Short Report

Test Selling of Cultured Mullet at the Fish Market

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Mullet is the most highly appreciated fish by Tongan people, however, the mullet is constantly in short supply and cannot meet the strong demand. Therefore, a technical and economical feasibility study on the mullet culture has been taken up as one of the main objectives in the joint Tonga-Japan Aquaculture Research and Development Project. The project team has been conducting pen culture experiments on mullet, mostly *Liza macrolepis* with some *Mugil cephalus* and *Valamugil seheli*, in Fanga'uta Lagoon where salinity fluctuates in the range of 9-30‰ (Paongo, 1994). Although Tongans rank mullet caught in the open sea as the top grade fish in the market, it is not yet known whether they appreciate mullet which has been cultured in the brackish water of the lagoon with supplemental feeding. In this study, we sold on trial at Vuna Wharf fish market, the pen-cultured mullet of 100 g in average body weight, to examine the consumer's response to the cultured mullet. Those fish were cultured for about 7 months in the pen with supplemental feeds consisting of powdered pumpkin and copra.

251 mullets were harvested from the 20 m x 20 m pen with gill netting, on December 12-14, 1994. Staff members of

the Ministry of Fisheries tasted two fish each of *L. macrolepis* and *M. cephalus* and did not find the taste different from that of the natural mullet. On December 16, 1994, 237 mullets were placed in a seawater filled plastic tank with aeration and were transported to the fish market alive. The fish were scooped with a hand net and put in a plastic bag upon the order of a customer. Each bag containing 2.5 kg of fish was sold at T$ 10.00, that is T$ 4.00/kg. The price was almost the same as the average price of T$ 4.23/kg for the natural mullet sold at the market. Although it was raining heavily and the number of customers was much smaller than usual, all the mullet were completely sold within two hours. There were no comments from the customers on the taste of the fish later on. Therefore, we can conclude that the customers accepted the cultured mullet as equivalent to the natural mullet in taste. The consumers did not show any positive response to the live mullet and they seemed to feel that the number of fish was smaller when sold in a plastic bag than when sold in a string (the traditional way of selling fish in Tonga) even though the numbers were about the same. It may be better to sell cultured mullet in strings in future.

A large quantity of frozen mullet were imported from Australia and were sold at T$ 4.5/kg at Tu'imatamoana fish market in August 1994. The sale of the fish was poor so the price was lowered gradually until it reached T$ 2.0/kg in December 1994. The sale of the fish was still poor even at that price. The reason for the poor sales were: 1) Tongan people are not accustomed to consuming frozen mullet and 2) they have a preconception that fish caught in a river are tasteless. This experience shows that the import of frozen mullet from abroad does not seems to be a good solution to solve the short supply.

In conclusion, this study shows that mullet cultured in Fanga'uta Lagoon is readily accepted by the consumers, and if an economically feasible technique is developed, mullet culture is a promising solution to the problem of short supply.

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Short Report

Transport of Live Green Snails, *Turbo marmoratus*, from Japan to Tonga

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The green snail, *Turbo marmoratus*, was first introduced to Tonga from Vanuatu in 1993, to create a new fishery of this commercially valuable species. Fifty live green snails were transported by air on August 8, 1993. The flight from Vanuatu to Tonga took seventeen hours and twenty minutes and the survival rate of the snails was 100 % one week later (Fa'anunu and Sone, 1994).

To find another source of the green snail for transplantation, two transportation trials of live green snails were conducted from Japan. The first transportation of 28 snails was conducted on March 24, 1994. The journey took 48 hours from Narita airport, Japan, to the Ministry of Fisheries at Sopu, Tonga, via Nadi, Fiji. The survival rate of the green snails was 39 % one week after the transportation. It is thought that the low survival rate must have been due to the long transportation time. The second transportation was conducted using the much shorter air route via Auckland, New Zealand, and this report deals with the details of that second transportation.

A total of 292 green snails were placed in ten plastic cages with lids (52 cm x 35 cm x 27.2 cm) and hung in the sea at a depth of about 2.5 m at Boma Port, Tokunoshima Island (about 1,400 km south west from Tokyo). They were left there for ten days before being flown to Tokyo. Of the 292 snails, 278 were hatchery produced with 76 g being the average body weight (including the weight of the shell) and 14 were wild with 1 kg being the average body weight. The total weight of all the snails was 35 kg. During the ten day period, the green snails were fed every two days with seaweeds, *Gracilaria edulis*, *Coelothrix irregularis* and *Amansia glomerata*, and none of them died.

Five styrofoam boxes with lids (48 cm x 40 cm x 23 cm) were used for packing the snails. Newspapers soaked in seawater were spread over the bottom of each box. About 60 green snails, including two to three large ones, were placed in each box in the apex-up position. The spaces between snails were crammed with dry newspapers crumpled into balls. Snails were then covered with more seawater soaked newspapers and two packs of cooling agents also wrapped in newspaper were placed on top of the cover. Each box was covered with a lid and sealed with adhesive plastic tape.

The green snails were flown to Tokyo on July 28, 1994. They were then land transported from the airport to the Tokyo University of Fisheries. Upon arrival at the university at 10:00 pm they were placed in a 500 litre plastic tank filled with 100 litres of aerated seawater. The journey from Tokunoshima to the university took about 10 hours. The next morning, July 29, 1994, the green snails were packed in the styrofoam boxes in the same way and sent to Narita airport at 10:30 am. Water temperature in the plastic tank was 26.3-28.2 °C during the night. No mortality was observed at this stage.

The green snails were then flown from Narita airport to Fua'amotu airport, Tonga, via Auckland, New Zealand. Then they were land transported to the Ministry of Fisheries at Sopu. Upon arrival at the ministry, the snails were put into the 4.5 m^3 raceway tank supplied with running seawater. Two snails were found dead at this stage. Most of the snails found to be weak at the time of arrival died within five days. A total of 52 snails died during the first month, one large sized wild one and 51 small hatchery produced ones.

The survival rate was 92.9 % for the wild snails and 81.6% for the hatchery produced snails. Therefore, the survival rate was much improved by shortening the air-transportation time. The lower survival rate recorded for the hatchery produced snails may be explained by the fact that those reared under hatchery conditions have a lower resistance to a sudden change in the temperature and dried conditions. It may be given as a conclusion that the green snails can be transported live if transportation time does not exceed 24 hours and provided that the temperature inside the packing box is controlled by using some cooling agents.

Acknowledgment

The authors express special thanks to Nansei Togyo Co., Ltd, Japan for kindly donating the green snails produced in their hatchery. They also extend their heartfelt thanks to Dr. Hiroshi YAMAKAWA, associate professor at the Tokyo University of Fisheries, for allowing them to use the rearing facilities and giving them help in many ways.

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