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Ministry of Fisheries, the Kingdom of Tonga
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Growth of Fingerlings of Big-Belly Mullet, *Liza macrolepis*, Fed with Local Products

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Abstract

Effect on the growth of big-belly mullet, *Liza macrolepis*, was examined for three kinds of locally produced materials, namely, cassava, squash pumpkin and beer brewery residue, in a rearing experiment. All materials were processed to meal and mixed with formula feed for carp imported from Japan at 1:1 in weight before given to each batch of fish reared in separate tanks. For two other batches of fish, formula feed for carp and a test formula feed prepared by the senior author were given for the comparison. The fish of 2.6g in average body weight had grown to 4.4g, 4.5g and 4.2g in average body weight after 56 days of rearing for the batches fed with cassava, pumpkin and beer brewery residue mixed with formula feed, respectively. The fish fed with formula feed for carp and the test formula feed had grown to 5.4g and 5.6g in average body weight, respectively, in the same period. The difference in the growth between the fish fed with feed containing 50% of locally produced materials and those fed with formula feeds was statistically significant. Such difference seems to be caused by low protein content for cassava, pumpkin and beer brewery residue. The high fibre content of beer brewery residue might be another reason for the low growth rate.

Introduction

Big-belly mullet, *Liza macrolepis*, is the target fish of the fish-pen culture experiment conducted in the Aquaculture Research and Development Project, a technical cooperation project between Tongan Ministry of Fisheries and Japan International Cooperation Agency. One of the important problems to be solved in the experiment is the supply of appropriate supplemental feed for the mullet to enhance the growth of the fish. The main component of the supplemental feed should be inexpensive local products to secure the economic viability of the culture. The present report deals with the results of the feeding experiment to examine the possibility of using locally produced cassava, squash pumpkin and beer brewery residue as a major ingredient of the feed for the rearing of juvenile big belly mullet.

Materials and Methods

Juveniles of big-belly mullet were collected at sandy littoral of Navutoka situated off the north eastern coast of Tongatapu Island. Average body weight was 2.6g. Twenty fish were placed in each of five 500*l* circular plastic tanks (Tanks 1-5). Continuous seawater supply at a rate of about 2.0*l* per minute and gentle aeration were provided to each tank. The following five kinds of feed were used in the experiment.

Feed 1 : Cassava meal mixed with formula feed for carp at 1:1
Feed 2 : Formula feed for carp
Feed 3 : Squash pumpkin meal mixed with formula feed for carp at 1:1
Feed 4 : Beer brewery residue mixed with formula feed for carp at 1:1
Feed 5 : Experimental formula feed

Cassava, squash pumpkin and beer brewery residue were ground into fine meal after drying. The formula feed for carp was a product from Japan (Nippai Co., Ltd.) with the composition as shown in Table 1.

Table 1. Composition of formula feed for carp

Composition	%
Crude protein	>39.0
Crude fat	> 3.0
Crude fibre	< 5.0
Crude ash	<15.0
Calcium	> 1.5
Phosphorus	> 1.3

The formula feed was also ground into fine powder before being mixed with other ingredients. The quality of the formula feed seemed to have deteriorated to a certain extent since the feed had been stored under high temperature and high humidity conditions for more than two years. The experimental formula feed was prepared by the senior author during his training at Kinki University, Wakayama Japan. Ingredients and composition of the experimental formula feed are shown in Table 2.

Feeds 1-5 were supplied to Tanks 1-5, respectively. Daily amount of the feed supplied to each tank was 2.6g during the first 20 days of the experiment and 4.6g later on. Salinity, determined with a refractometer (Atago, Japan), ranged 33-42‰, water temperature 22-28° C and pH 7.9-8.5 during the experiment.

Table 2. Composition of experimental formula feed (Feed 5).

Ingredients (%)		Composition (%)	
Pumpkin meal	19.9	Crude protein	36.9
Sweet potato meal	53.1	Crude lipid	9.0
Fish meal	22.1	Crude carbohydrate	38.5
Pollack liver oil	1.1	Fibre	0.5
Vitamin mix	0.2	Crude ash	11.7
Mineral mix	2.2	Others	3.5
CMC*	1.3		

* Carboxymethyl cellulose sodium salt

Results

Table 3 shows the number of fish and their body weight measured on 56th day of the experiment, and Table 4 shows the results of analysis of variance conducted on the body weight data.

Table 3. Number and average body weight of big-belly mullet on 56th day of the rearing

Tank	Number of fish	Average body weight (g)
1	17	4.4
2	18	5.4
3	16	4.5
4	19	4.2
5	19	5.6

It can be said that the growth obtained by the feeds containing local products as a major ingredient was significantly smaller than that obtained by formula feed for carp and experimental formula feed. There is no significant difference in growth between formula feed for carp and the experimental formula feed, and among feeds containing local products.

Table 4. ANOVA table on the results of the feeding experiment

Source variation	d. f.	SS	MS	f
Between				
all Feeds	4	30.484	7.621	3.15*
Feeds (2,5) and (1,3,4)	1	29.465	29.465	12.18*
Feeds 2 and 5	1	0.324	0.324	0.13
Feeds 1, 3 and 4	2	0.695	0.348	0.14
Within Feed	84	203.152	2.418	
Total	88	233.636		

*: Significant at 5% level.

Discussion

Although the nutritional composition of local products used in this study has not been analyzed, crude protein content is estimated to be approximately 2.6% for cassava meal, 18.5% for pumpkin meal and 22.9% for beer brewery residue assuming moisture content being 12% (Agriculture , Forestry and Fisheries Research Council Secretariat, 1987). Applying these figures, the protein content is roughly estimated as 18.5% for Feed 1, 34.3% for Feed 2, 26.4% for Feed 3, 29.1% for Feed 4 and 32.4% for Feed 5. The smaller increase in body weight observed for Feeds 1, 3 and 4 seems to be explained by the low crude protein contents. Crude fibre content is as high as 14.4% for beer brewery residue and 13.8% for squash pumpkin meal (ditto), while it is lower than 5% for cassava meal and the formula feeds. This high content of crude fibre might also be responsible for the smaller body weight increase observed for Feeds 3 and 4.

The present experiment was conducted in the tanks placed in the laboratory and hence the condition was quite different from that of pen culture where many kinds of natural feeds are available for the fish other than the supplemental feed. An experiment conducted in India (Prasadam and Kadir, 1988) showed that the supplementary feeding of rice bran and groundnut oil cake mixture (1:1 in weight) given to the mixed culture of *L. macrolepis,, Mugil cephalus*, and some shrimps did not enhance growth of *L. macrolepis*. This may suggest that supplemental feed without appropriate nutritional composition is likely to have no growth enhancing effect. Further experiments should be conducted to establish an appropriate formula of supplemental feed before the establishment of the commercial pen culture technique of *L. macrolepis* .

Acknowledgement

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Water Quality of Fanga'uta Lagoon as the Site for Mullet Culture

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Abstract

Water samples were taken at the inner western part, entrance of the western part and entrance of the eastern part of Fanga'uta Lagoon as well as several locations along the northern coast of Tongatapu Island near the entrance of the lagoon. Analyses were made on each water sample to examine the water quality parameters, namely salinity, COD, NO_2-N, PO_4-P, NH_4-N, NO_3-N, Cr^{6+}, Cu, phenol and CN along with DO and pH. It has been shown that in the inner western part of the lagoon water is brackish and salinity changes widely from place to place under the strong influences of water inflows from the land and the water has been moderately eutrophicated. Eutrophication was also observed at the entrance of the western part of the lagoon and the location at Sopu where water inflows from inland marsh to the sea. No eutrophication was observed for the entrance of eastern part of the lagoon and locations facing to the open sea. No harmful substance has been detected at any locations studied. Since mullet is the species that often inhabits brackish and eutrophicated waters and has an ability to adapt to wide changes in salinity, the inner western part of the lagoon has been found to be suitable for the culture of mullet.

Introduction

Experiments on pen-culture of mullet have been conducted in Fanga'uta Lagoon, Tongatapu Island, since 1991 under the Aquaculture Research and Development Project, a technical cooperation project between Tongan Ministry of Fisheries and Japan International Cooperation Agency. There are various activities such as agriculture, industry and urbanization in the areas surrounding the lagoon, and therefore it has been feared that those activities might cause excessive eutrophication or pollution with harmful organic compounds and heavy metals entering the water in the lagoon, which might have adverse effects on the mullet culture. In the present study, water samples were taken inside and outside the lagoon and analyses were conducted on the selected parameters of water quality to examine whether the water of the lagoon is suitable for the culture of mullet or not.

Materials and Methods

Water samples were taken during the period from 13-26 October 1992 at 8 stations (Stations 1-8) shown in Fig. 1 and Table 1. At the inner western part of Fanga'uta Lagoon, namely Station 1 where experiments on pen-culture of mullet had been undertaken, sampling was conducted twice, on 13 and 26 October 1992. Samples were taken at nine points at each station inside the lagoon, namely Station 1, 2 and 3. Details of the sampling points of those stations are shown in Figs. 2, 3 and 4.

Water quality parameters that were analyzed in the present study were salinity, COD, NO_2-N, PO_4-P, NH_4-N, NO_3-N, Cr^{6+}, Cu, phenol and cyanide along with DO and pH. Sensitivities and accuracies of the analyses were not high since simple field analysis kits were used (Table 2).

Results

Table 3 shows the results of the water quality analyses for Station 1. Water depths were shallower on 12 October than on 26 October. Salinity ranged from 9-30‰. Salinity was

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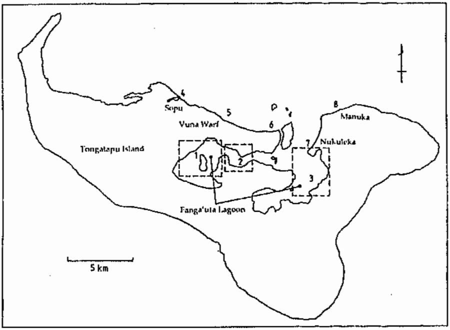

Fig. 1. Sampling stations.

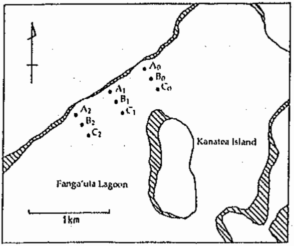

Fig. 2. Sampling points at Station 1.

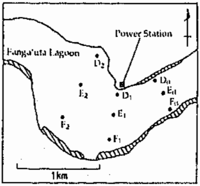

Fig. 2. Sampling points at Station 2.

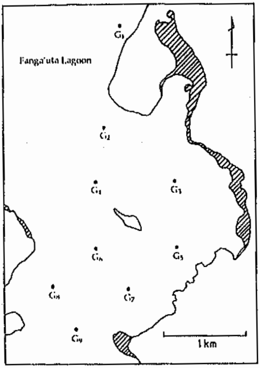

Fig. 3. Sampling points at Station 3.

Table 1. Sampling stations and dates for the water quality survey.

Station	Description of the site	Sampling date
1	Inner western part of Fanga'uta Lagoon. Mullet culture experimental site.	12 October 1992 26 October 1992
2	Entrance of western part of Fanga'uta Lagoon, in front of the power station	15 October 1992
3	Entrance of eastern part of Fanga'uta Lagoon.	23 October 1992
4	Sopu, near drainage gate for inland marsh.	16 October 1992
5	Vuna wharf	21 October 1992
6	Patangata	21 October 1992
7	Nukuleka	19 October 1992
8	Manuka	19 October 1992

Table 2. Analysis methods for the water quality parameters.

Parameter	Equipment	Readability
COD	WAK-COD	0, 2, 4, 6, 8, 10 mg/*l*
NO_2-N	WAK-NO_2	0.006, 0.015, 0.03, 0.06, 0.15, 0.3 mg/*l*
PO_4-P	WAK-PO_4	0.066, 0.165, 0.33, 0.66, 1.65, 3.3 mg/*l*
NH_4-N	WAK-NH_4	0.4, 0.8, 1.6, 4, 8 mg/*l*
NO_3-N	WAK-NO_3	0.23, 0.46, 1.15, 2.3, 4.6, 10 mg/*l*
Cr^{6+}	WAK-Cr	0.05, 0.1, 0.2, 0.5, 1, 2 mg/*l*
Cu	WAK-Cu	0.5, 1, 3, 5, 10 mg/*l*
Phenol	WAK-PNL	0.2, 0.5, 1, 2, 5, 10 mg/*l*
CN	WAK-CN	0.02, 0.05, 0.1, 0.2, 0.5, 1, 2 mg/*l*

WAK's are field analysis kits made by Kyoritsu Kagaku Kenkyusho, Japan.

low, from 9-18‰, along the coast line on 12 October. At the offshore points salinity was also low but did not drop to lower than 24 ‰. The highest salinity was 30 ‰ observed on 26 October for C_0 that was located about 300m offshore. COD was 2 mg/*l* at almost all points except for A_0 where COD was 4 mg/*l* on 26 October and B_1 where COD was lower than 2 mg/*l* on the same day. NO_2-N was 0.15 mg/*l* at A_1, A_2 and B_2 on 12 October while it was lower than 0.006 mg/*l* at other points on 12 October and at all points on 26 October. NO_3-N was 0.46 mg/*l* at A_1 and B_1, and 0.23 mg/*l* at A_0 and A_2 on 12 October. It was lower than 0.23 mg/*l* at other points on 12 October and at all points on 26 October. Concentrations of PO_4-P, NH_4-N, Cr^{6+}, Cu , phenol and cyanide were lower than the detection limits of the present methods at all points on both dates. DO ranged from 6.0-7.4 O_2 mg/*l* and pH from 8.1-8.4.

Table 4 shows the results of water quality analyses for Stations 2 and 3. Salinity ranged in much narrower range at Stations 2 and 3 than that for Station 1, namely from 30-32‰ and 35-38‰, respectively. COD was 2 mg/l for all points at Station 2 and lower than 2 mg/*l* at all points at

Table 3. The results of water quality analyses for Station 1.

Point	Salinity (‰)	COD (mg/l)	NO_2-N (mg/l)	PO_4-P (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	Cr^{6+} (mg/l)	Cu (mg/l)	Phenol (mg/l)	CN (mg/l)
A_0	18	2	<0.006	<0.066	<0.4	0.23	<0.05	<0.5	<0.2	<0.02
	24	4	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
B_0	27	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
	26	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
C_0	26	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
	30	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
A_1	9	2	0.015	<0.066	<0.4	0.46	<0.05	<0.5	<0.2	<0.02
	27	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
B_1	27	2	<0.006	<0.066	<0.4	0.46	<0.05	<0.5	<0.2	<0.02
	28	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
C_1	26	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
	28	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
A_2	11	2	0.015	<0.066	<0.4	0.23	<0.05	<0.5	<0.2	<0.02
	24	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
B_2	24	2	0.015	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
	25	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
C_2	25	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
	27	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02

Points	Water depth (m)	Water temperature (°C)	DO (O_2mg/l)	pH
All	0.5-0.8	25.0-27.2	6.0-7.3	8.1-8.4
	0.6-1.4	24.9-26.2	6.2-7.4	8.3-8.4

Upper figures: 12 October 1992 Lower figures: 26 October 1992

Table 4. The results of water quality analysis for Stations 2 (D_0-F_2) and 3 (G_1-G_9).

Point	Salinity (‰)	COD (mg/l)	NO_2-N (mg/l)	PO_4-P (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	Cr^{6+} (mg/l)	Cu (mg/l)	Phenol (mg/l)	CN (mg/l)
D_0	31	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
E_0	32	2	<0.006	<0.066	0.8	<0.23	<0.05	<0.5	<0.2	<0.02
F_0	32	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
D_1	31	2	<0.006	<0.066	0.6	<0.23	<0.05	<0.5	<0.2	<0.02
E_1	32	2	<0.006	<0.066	0.4	<0.23	<0.05	<0.5	<0.2	<0.02
F_1	30	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
D_2	31	2	<0.006	<0.066	0.6	<0.23	<0.05	<0.5	<0.2	<0.02
E_2	31	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
F_2	32	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_1	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_2	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_3	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_4	37	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_5	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_6	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_7	38	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_8	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G_9	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02

Station	Water depth (m)	Water temperature (°C)	DO (O_2mg/l)	pH
2	0.7-3.2	25.8-26.8	5.7-7.8	No data
3	0.7-5.2	25.5-27.0	6.4-7.7	8.2-8.3

Station 3. NH_4-N was high at some of the points at Station 2, namely 0.8 mg/*l* at E_0, 0.6 mg/*l* at D_1 and D_2, and 0.4 mg/l at E_1, while it was lower than 0.4 mg/*l* at the rest of the points of Station 2. It was lower than 0.4 mg/*l* at all points of Station 3. Other parameters were lower than the detection limit of the present analyses methods for all points of Stations 2 and 3. DO ranged from 5.7-7.8 O_2 mg/*l* at Station 2 and 6.4-7.7 O_2mg/*l* at Station 3. pH ranged 8.2-8.3 at Station 3.

Table 5 shows the results of water quality analyses for Stations 4-8. Salinity was 14‰ at Station 4 where land water flows into the sea from inland marsh areas. Salinities were 34-37‰ at the rest of the stations. COD was high, 8 mg/*l*, at Station 4 and was 2 mg/*l* at Station 8 whereas it was lower than 2 mg/*l* at the rest of the stations. Other parameters were lower than the detection limits of the present analysis methods at all stations. DO was low, 5.5 O_2mg/*l* for Station 4, while it ranged from 6.0-7.5 O_2mg/*l* at Stations 5-8. pH ranged from 8.2-8.3 at Stations 4-8.

Discussions

Low salinity recorded for Station 1 has shown that the inner western part of Fanga'uta Lagoon has been strongly influenced by land water inflows. Furthermore, the water exchange between the open sea seems to be poor. That area is eutrophicated to some extent as shown by the COD value of 2 mg/*l* or higher recorded for almost all points (Table 6). The level of the eutrophication seems to be higher along the coast line than offshore areas as indicated by higher concentrations of NO_2-N and NO_3-N. Also it is suggested that the influences of the land water inflow is stronger at low tide time than at high tide time. However,

Table 5. The results of water quality analysis for Stations 4-8.

Points	Salinity (‰)	COD (mg/l)	NO_2-N (mg/l)	PO_4-P (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	Cr^{6+} (mg/l)	Cu (mg/l)	Phenol (mg/l)	CN (mg/l)
4	14	8	<0.006	<0.066	<0.5	<0.23	<0.05	<0.5	<0.2	<0.02
5	34	<2	<0.006	<0.066	<0.5	<0.23	<0.05	<0.5	<0.2	<0.02
6	34	<2	<0.006	<0.066	<0.5	<0.23	<0.05	<0.5	<0.2	<0.02
7	37	<2	<0.006	<0.066	<0.5	<0.23	<0.05	<0.5	<0.2	<0.02
8	35	2	<0.006	<0.066	<0.5	<0.23	<0.05	<0.5	<0.2	<0.02

Station	Water depth (m)	Water temperature (°C)	DO (O_2mg/l)	pH
4	0.5	24.0	5.5	8.3
5	4.0	25.0	6.0	8.3
6	0.5	28.5	7.2	8.3
7	0.5	27.5	7.0	8.2
8	0.3	30.5	7.5	8.3

Table 6. Classification of water quality (modified from Yoshida, 1973).

Parameter	Rotten	Highly eutrophic	Eutrophic	Oligotrophic
COD (mg/l)	>10	3-10	1-3	<1
Inorganic N (mg/l)	>100	10-100	2-10	<2
Inorganic P (mg/l)	>10	1-10	0.2-1.0	<0.2

the eutrophication is still not such a high level to cause any adverse effect on the aquatic lives and human activities.

At the entrance of western part of Fanga'uta Lagoon, Station 2, salinity of water is lower than that of open seawater suggesting the influence of low salinity water from the inner part of the lagoon. The water of the area has been eutrophicated to some extent as indicated by COD of 2 mg/l for all points. At the entrance of the eastern part of the Fanga'uta Lagoon, Stations 3 and 7, salinity was higher than that of open seawater. To clarify the reason for the high salinity, further survey should be carried out to cover the whole area of the eastern part of the lagoon.

Station 4 is strongly affected by the inflow from the inland marsh as indicated by the low salinity. The water at the station has been highly eutrophicated as indicated by the high COD (Table 6). The salinity recorded for Stations 5, 6 and 8 are the same level as that of the open seawater.

The concentrations of harmful substances to human health or aquatic organisms, such as Cr, Cu, phenol and cyanide, were lower than the detection limits of the present analysis methods at all stations suggesting that there still is no serious problem of water pollution originated from industrialization and urbanization both inside and outside Fanga'uta Lagoon. It can be said that the lagoon is still in healthy condition (Anon. 1992). Since mullet is the fish often inhabiting eutrophic waters, and is an indicator fish of eutrophic to highly eutrophic water areas (Sumikawa, 1992), the area seems to be suitable for the culture of mullet. However, recent intensive use of agricultural pesticide, particularly for the cultivation of squash pumpkin, might be a potential source of water pollution particularly in the inner part of the lagoon. Therefore, it is hoped that a system that enables the analysis of organic compounds at high sensitivity and high accuracy will be established in Tonga in the near future.

Acknowledgement

The author wishes to express his thanks to Mr. Hiroshi SUMIKAWA, a short term expert of water quality survey dispatched by Japan International Cooperation Agency to Tonga in 1992, for his guidance during the survey.

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Breeding Season of Tongan Shellfish 2. Ark Clams (Kaloa'a), *Anadara* spp.

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Abstract

By examination of sex ratio of *A. antiquata* and *A. maculosa* of various size groups, it has been shown that the former species performs sex inversion from male to female at the size range between 45mm and 60mm in shell length. The latter species does not seem to perform such sex inversion. Monthly examination of the gonad condition of the both species from April 1992 to March 1993 showed that the spawning of the both species takes place from November to March while gonad of the both species remain inactive from April to October.

Introduction

Ark clam, genus *Anadara*, is the most important mollusc in Tonga in terms of quantity of consumption. Tulua and Udagawa (1994) reports that ark clam accounts for 33% of total molluscan sale in the fish markets on Tongatapu Island. Two species of ark clams are commonly found on the sea grass beds around Tongatapu Island. Both species are called Kaloa'a in Tongan and are not distinguished from each other in the market. The habitats of the two species are closely overlapping, however one species is more abundant than the other. Women collect ark clams by hand on the intertidal flat of Tongatapu Island and surrounding small islands. Some of the collected shells are sold at the fish market and the rest are consumed by their family. A sizable amount of ark clam are caught by divers in Ha'apai and Tongatapu island groups for the shipment to Vuna fish market on Tongatapu Island. In spite of the importance of ark clam in the diet of Tongan people, fisheries biology of this shell has not yet been fully studied. The present study aims at revealing the relationship between sex ratio and shell length, as well as the spawning season of ark clams around Tongatapu Island. The species names of ark clams are somewhat confusing. In this report, the names given by Yamaguchi (1992) are used, namely *Anadara antiquata* for the commonest species and *A. maculosa* for the less common species.

Materials and method

200 individuals of *A. antiquata* were collected during the period from November 1991 to March 1992 by irregular random sampling at Vuna fish market. Standard shell length (SL; Fig. 1) was measured and sex was identified for each of those individuals. Monthly sampling of *A. antiquata* and *A. maculosa* was conducted from April 1992 to March 1993 at the same fish market. Samples were taken twice, before and after the full moon, in April 1992 and March 1993. Information on the fishing ground of the shell was obtained at the time of each sampling. The largest ten shells and the smallest ten shells were selected from each sample for *A. antiquata*. However, only the largest ten shells could be taken for *A. maculosa* as the number of shells in each sample was not sufficient to take the smallest ten shells. Standard shell length was measured and sex was identified for each of the selected shells. Then gonad of each shell was examined and classified according to the following three types.

Type 1 : Neither gamete nor trace of spawning is seen in the gonad.

Type 2 : Gametes are present but do not fill the gonad. In some cases trace of spawning is observed in the gonad.

Type 3 : Gametes fill the swollen gonad.

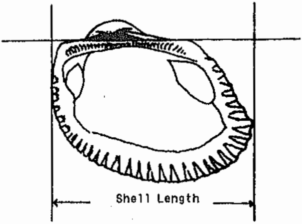

Fig. 1. Measurement of standard shell length.

Results

Fishing grounds of *A. antiquata* were Popua, Polo'a, Sopu, Pátangata, Pangaimotu, Nukuleka and Velitoa, all of which are situated on the northern coast of Tongatapu Island (Fig. 2).

Fig. 3 shows the relationship between number of male and female shells and standard shell length for 200 randomly sampled individuals of *A. antiquata*. The majority of the shells smaller than 30 mm SL could not be sexed as they were still immature, and the rest are male. In the 30-50 mm SL range, males outnumber females. The ratio of females to males increases as shell length becomes larger until 80 mm SL. However, in the shell length larger than 80 mm, no increase in the ratio of females is observed indicating that some individuals remain male. Fig. 4. shows the relationship between the number of female and male shells for a total of 280 individuals of the largest ten and smallest ten shells taken from the monthly samples. A similar pattern of changes in sex ratio is observed in Figs 3 and 4. Those changes in sex ratio suggest that for *A. antiquata* some of the males change sex to female in the size range of 50-70 mm SL. Fig. 5 shows the relationship between number of female and male shells and shell length for all *A. maculosa* obtained by the monthly sampling. No clear tendency of change in the sex ratio is observed for this species.

Monthly changes in composition of gonad types of *A. antiquata* for the largest ten shells (size range; 42.7-104.2mm SL) are shown in Fig. 6. In the beginning of April all shells have gonads of Type 2 while in the end of the month majority of the shells have gonads of Type 1. All shells have gonads of Type 1 from May to July. The majority of the shells have gonad of Type 1 from the beginning of August to the beginning of September while some of the shells have gonads of Type 2. In October most of the shells have gonads of Type 2, while some of the shells have gonads of Type 1 or Type 3. From November to March all of the shells have gonads of Type 2 or Type 3. From those changes, it can be said that the gonad of *A. antiquata* starts to develop in October and spawning occurs during the summer months from November to March. From the beginning of April gonad of the shell start to shrink and during autumn and winter, namely from the end of April to September the gonad stay in inactive phase. It is suspected that a massive spawning occurred just before 8 January as gonad of all shells were spent on the day. Fig. 7 shows monthly changes in gonad maturation condition for the smallest ten shells (20.7-49.1 mm SL) of *A. antiquata*. The pattern of the changes are

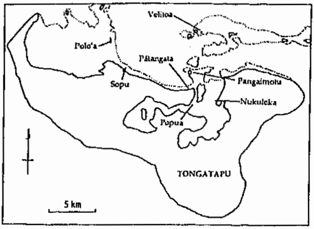

Fig. 2. Fishing grounds of ark clams on Tongatapu Island.

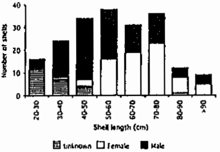

Fig. 3. Sex composition of *A. antiquata* from November 1991-March 1992.

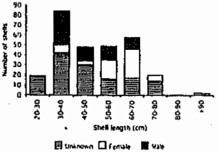

Fig. 4. Sex composition of *A. antiquata* from April 1992-March 1993.

Fig. 5. Sex composition of *A. maculosa* from April 1992-March 1993.

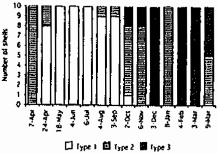

Fig. 6. Composition of gonad types for largest ten shells of *A. antiquata* from April 1992-March 1993.

Fig.7. Composition of gonad types for smallest ten shells of *A. antiquata* from April 1992-March 1993.

Fig. 8. Composition of gonad types for largest ten shells of *A. maculosa* from April 1992-March 1993.

similar to that for the largest ten shells. However, some of the shells remain inactive even from November to January.

The fishing grounds for *A. maculosa* are the same as those for *A. antiquata*, except for Nukuleka where no sample of *A. maculosa* was obtained (Fig. 2). No sample of *A. maculosa* could be obtained at the fish market in July, January and beginning of April. Monthly changes in gonad maturation condition for the largest ten shells of *A. maculosa* are shown in Fig. 8. In April, Type 1 and Type 2 co-exist and in May all of the shells have gonads of Type 1. In June and August, the majority of the shells have gonads of Type 1 but some of them have gonads of Type 2. Again, all of the shells have gonads of Type 1 in September. In October, most of the shells have gonads of Type 2 and from November until March most of the shells have gonads of Type 2 and Type 3. This pattern of changes in gonad type composition shows that for *A. maculosa* spawning takes place also in summer months while gonads of the shells becomes active in winter months.

Discussion

Baron (1992) mentions that for *A. scapha* (or *A. antiquata*) in New Caledonia, males significantly outnumber females at

34-42 mm SL and female significantly outnumber males at 46-54 mm SL and thus the species shows a sex inversion. The pattern of sex inversion observed in the present study for *A. antiquata* of Tonga seemed to be almost same except for the range in which females outnumber males. A taxonomical examination should be made on the New Caledonian ark calm and the Tongan ark clam before any comparison on sex inversion pattern can be made.

A. antiquata and *A. maculosa* in Tonga spawn in the months of high temperature and high precipitation (Thompson, 1986). It is likely, therefore, that the main trigger for the gonadal maturation and spawning activity of ark shells is the change in temperature and sudden changes in the salinity cause by the heavy rain.

It is believed that ark shell is still plentiful in certain areas, even though the average sizes of individuals seems to be getting smaller (Bell, Fa'anunu and Koloa) due to strong fishing pressure. It might be still pre-mature to apply any regulation on the ark shell fishing. A minimum size limit and closed season should be considered in future, if fishing pressure causes further decrease in the size of the shell or depletion of the resource. For the formulation of any such regulation, size limits should be larger than the size at which many of the ark clams complete sex inversion from male to female and the closed season should include the months of spawning of the ark shells.

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The Present Situation of Fisheries in the Tongatapu Island Group

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Abstract

There are three types of fisheries in the Tongatapu island group, namely export oriented fisheries, small scale commercial fisheries and subsistence fisheries. Export oriented fisheries consist of the tuna long line fishery and deep sea bottom line fishery. The small scale commercial fishery consists of the diving fishery, net fishery, fish fence fishery, hand line fishery, trolling fishery and shellfish collecting. Among them, night-time diving is the most important in the Tongatapu island group in term of quantity of fish landed. Subsistence fisheries are performed as part time work and are closely related to Tongan people's life style. In the Inshore Fisheries Statistics Program, annual fisheries landing in Tongatapu Island have been estimated to be about 580 tons in total with 420 tons of fish and 160 tons of shellfish.

Introduction

The Tongatapu island group consists of 24 islands of which 10 are inhabited. Those inhabited islands are Tongatapu, 'Eua, Atata, 'Euaiki, Nukunukumotu, Fafa, 'Onevai, Pangaimotu, Ata, and 'Oneata (Fig. 1). Although agriculture is the main economic activity in the Tongatapu island group, fisheries play an important role in both supply of high quality animal protein to the people and earning foreign exchange through export of fisheries products. Therefore, rational utilization of fisheries resources through fisheries management is essentially important for the

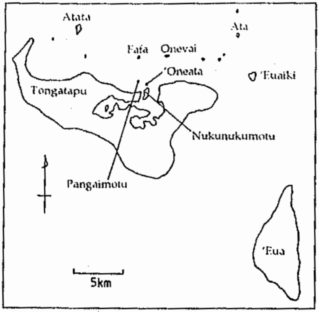

Fig. 1. Inhabited islands in the Tongatapu island group.

development of the country. The present report describes the fisheries activities in the Tongatapu island group mainly based on the information obtained under the Inshore Fisheries Statistics Program undertaken during the first two years of the five-year Aquaculture Research and Development Project. This project commenced in October 1991 as a technical cooperation project between the Tongan Ministry of Fisheries and the Japan International Cooperation Agency.

Data Collection

The authors went to Vuna wharf fish market and Faua road side market every day from Monday to Saturday from 6:00 to 12:00 a.m. and from 3:30 to 5:00 p.m. to collect data on catches, fishing method, fishing effort and fishing ground as well as miscellaneous information on fisheries in Tongatapu and surrounding islands. Information was also collected by interviewing fishermen, government officers and persons related to the fisheries at their home villages. Literature concerning the Tongan fisheries were also sought extensively.

Fisheries in Tongatapu Island Group

1. Export oriented fisheries

The export oriented fisheries include a tuna long line fishery operated mainly by the quasi government "Sea Star Company" and the UNDP/FAO/JICA supported deep sea bottom line fishing operation.

The Sea Star tuna longline fishery fleet consists of one 188 gross ton boat "Lofa", one 50 foot boat "Sea Star 1" and one 73 foot boat "'Otumu'omu'a". Lofa's annual catch in 1990 was 231 tons, of which 217 tons were exported (Ministry of Fisheries, 1991). The main species caught by this fishery are albacore (*Thunnus alalunga*) and yellow-fin tuna (*T. albacares*).

The deep sea bottom line fishery was initiated by a UNDP/ FAO/JICA "Artisanal Fisheries Development Project". This project provided diesel powered wooden boats to fishermen at half price. By September 1993, 46 boats were built and among them 16 boats are based in Tongatapu. Most of these boats are said to be at break-even point due to the decline of catch rate (King, 1992). Recently, larger and more powerful boats with a higher fishing efficiency have been introduced from overseas. The total annual catch from this fishery was 256 tons in 1991, and 141 tons was exported. The main species caught by this fishery is long-tail snapper (*Etelis coruscans*). There are three fish exporting companies buying fish from these fishing boats. One company also produces fillets for supply to local restaurants.

2. Small scale commercial fisheries

There are six main small scale fishing methods in the Tongatapu island group. They are the diving fishery (*uku*), net fishery (*kupenga*), fish fence fishery (*paa*), hand line fishery (*taumata'u*), trolling (*fakatele*) and shellfish collecting (*fangota*). Observation during February-April 1993 discovered that 43 boats were landing their catch at Faua road side and Vuna wharf market on and off.

2.1. Diving fishery

The diving fishery can be further divided into the night-time diving spear fishery (*amauku*), day-time diving spear fishery (*uku'aho*) and day-time diving shellfish fishery (*uku fingota*). The night-time diving fishery is the most significant fishery in Tonga which catches 49.4% of the total marketed fish in Tongatapu during the period from March to December 1993. The main species caught by night divers are: parrotfishes (Scaridae), surgeonfishes (Acanthuridae), groupers (Serranidae), and goatfishes (Mullidae). Night divers also spear spiny lobsters (Palinuridae), slipper lobsters (Scyllaridae), octopus (Octopoda) and sea turtles (Chelonidae). Kawaguchi (personal communication) mentions that the night diving fishery developed extensively after the under-water torch was introduced to Tonga in the early 1980s. Before the under-water torch was introduced, the fishermen used an ordinary battery operated torch wrapped with a plastic sheet.

Halapua (1982) mentions that most of the night diving fishermen were from the Ha'apai island group and they did not have land or any other property in Tongatapu. Felfoldy-Ferguson (1990) showed that there were 53 people engaged in the night diving fishery. The present survey shows that there are 9 boats and 63 fishermen landing their catch in Nuku'alofa. They land their catch at Faua road side between 4:00 a.m. to 7:00 a.m., and the average catch per fisherman in one week is about 113.2 kg with an income of T$ 292 including cost of operation. When the demand looks high, some of the fishermen go to catch lobsters, especially when the sea is calm. Good fishing grounds for lobster are located on the *liku* side, namely southern side, of islands where rough water prevents an easy approach for fishermen.

Day-time spear divers catch surgeonfishes (Acanthuridae), squirrelfishes (Holocentridae), and octopus. Day-time shellfish diving usually has a specific target such as giant clam (Tridacnidae) diving, *uku vasuva*, octopus diving, *uku feke*, ark shell (*Anadara* spp.) diving, *uku kaloa'a*, and sea cucumber (Holothurioidea) diving, *uku mokohunu*. Giant clam fishermen dive with fellow fishermen in order to take a huge clam out of the ocean (Kava and Udagawa, 1994). There is only one fishing boat for the day-time diving fishery regularly landing its catch now. However, there were 341 day-time spear divers identified during a 1988 survey (Felfoldy-Ferguson, 1988). In 1992, hookah diving gear was introduced to Tonga by American businessmen whereupon collection of sea cucumber and tropical aquarium fish commenced. There are 11 sets of hookah gear currently used and the target species has expanded to deeper water fish, giant clams and corals.

2.2 Net fishery

The net fishery may be classified into the gillnet fishery, surrounding net fishery and cast net fishery. The total number of fishermen involved in the net fishery was 164 in 1988 (Felfoldy-Ferguson, 1988). The present survey revealed that there were 8 units of net fishing operators including fish fence operators.

The gill net fishery could be further divided into *tapo, tali*, *ha'o* and *taa taa*. *Tapo* and *tali* are the gill nets which are set to cover a water passage in a reef. Tapo is used at night time. *Tali* is set during high tide to catch fish when the tide becomes low and fish try to swim out from the reef. *Tapo* catches emperors (Lethrinidae) and groupers, and *tali* targets parrotfishes and goatfishes. *Ha'o* net is another type of removable set net that is set inside as well as outside of the reef and targets trevallies (*Caranx* spp.) and mullet (Mugillidae). *Taa taa* is a fishing method used outside of the reef. First, a group of fishermen swim around the fishing ground and locate a school of fish. Then a net is dropped in front of the fish school from the boat, fishermen beat the water to chase the fish into the gill net. Goatfishes and parrotfishes are usually targeted in this fishing.

Surrounding net type fishing (*uloa, fakamamaha*) usually targets horse mackerel (*Selar* spp.), emperors (Lethrinidae) and mullet. When a school of fish is found, the net is dropped to surround the fish. Then the fishermen spear the fish in the net.

Cast net type fishing (*sili*) is used inside the reef. A fisherman throws the net to capture sardine, mullet and horse mackerel.

2.3 Fish fence fishery

A fish fence or weir (*paa*) is constructed with stick and chicken wire mesh. Fish fences are built on sea grass beds and/or shallow inner reef zones. The length of a fish fence may reach up to 30 m and some fish fences are built from the end of a first fence extending further out toward the ocean. In the mid-1960s the building of fish fence was a boom and the fence nets covered all the strategic locations including inside of Fanga'uta Lagoon. The target species for the fence fishery was mainly mullets which migrate to inshore areas for spawning. In 1975 use of fish fences and commercial fishing activities in the lagoon were made illegal in order to protect mullet and other fishery resources. Nevertheless, Zann (1984) reported that in spite of the regulation, 50% of the lagoon entrance was covered by fence nets which intercepts the entry of the fish to the lagoon. Due to the decline of the catch, the number of fence nets currently under operation has decreased to 24 (Felfoldy-Ferguson, 1988).

2.4 Hand line fishery

The hand line fishery is operated during day or night. There are 8 boats and more than 30 fishermen currently landing their catch at Vuna wharf. Previous studies suggest that there were 702 hand line fishermen as a whole in Tongatapu (Felfoldy-Ferguson, 1988). Commercial hand line fishing is usually done by boat with 3 to 6 fishermen on board. The boat may anchor at suitable fishing points or the boat drifts above the sea mount where demersal species are abundant. The target species are horse mackerel and emperors.

2.5 Trolling fishery

The trolling fishery is seasonally operated when migrating fish come closer to the Tongatapu island group. Trolling is also performed by hand line fishermen on their way to and back from the fishing ground. 'Atata and 'Eua fishermen usually engage in this fishery. Yellowfin tuna, skipjack (*Katsuwonus pelamis*), and dolphin fish (*Coryphaena hippurus*) are specific target fishes. Sharks are also caught by this method.

2.6 Shellfish collecting

Shellfish collection for commercial purpose is widely exercised in Tongatapu by women as well as men. Shellfish collection is done during low tide in day time. Fishing grounds are situated near the lagoon or shallow sea grass beds for ark clams (*Anadara* spp.), venus clams (*Gafrarium* spp.), mussels (Mytilidae), lucia clams (Lucinidae) and spider conch (*Lambis lambis*). Some women collect sea cucumber in the inner reef zone. Other women collect jellyfish and venus clams in Fanga'uta Lagoon. Seagrapes (*Caulerpa* spp.) are also collected in the inner reef zone or the lagoon, wrapped in coconut leaves and then sold at the fish market. There are some boats taking groups of women to the sea grass beds of the outer islands such as Oneata, 'Onevai and Fukuva. On the reef flat and reef crest, turban shells (Turbinidae) and giant clams are collected, though, commercial activities are usually limited to outer islands where shallow water diving fishermen operate often using canoes.

3. Subsistence fisheries

The subsistence fishery is part time work usually performed by individuals using very simple fishing gears. However, there are no clear differences in fishing method between small scale commercial fishery and the subsistence fishery. Subsistence fishermen may sell their catch if the catch is more than enough for their family consumption.

The traditional, subsistence fishery is closely related to the Tongan people's life style and eating habits. Women collect shellfish in front of their village while they are chatting with their friends. They sometimes sit in the sun heated water and enjoy taking a bath. Men and children use a line with hook and stand in the inner reef or reef edge to catch reef fish. Some people have a canoe to do some hand lining and shell collecting. Fish traps made of roots of plant or/and chicken wire mesh are also used. There used to be a poisoning fishery (*'Aukava*) using roots of plants such as *masi* and *kavafisi*. Luring octopus by a rat shaped lure (*makafeke*) used to be popular, but has now been replaced by the diving fishery and is rarely seen in Tongatapu, although it is still exercised in Ha'apai. Village people used to gather and make a huge beach seine type gear such as *silita* and *pola*. Instead of using nets they used coconut leaves attached to rope. This kind of fishery is done when there is a big ceremony such as weddings, funerals or church activities.

4. Other fishing activities

Aquarium fish have been exported mainly to the United States. There are three exporters in Tongatapu. They export coral rocks and sea anemone as well as aquarium fish.

Although the possession and usage of explosives is strictly limited in Tonga, there are some fishermen still using dynamite to catch schools of fish. This fishing method not only kills juvenile fish but also destroys the live coral which supplies food and provides a hiding place for fish and other marine animals. Fish are usually damaged in their gut and their bones are fractured. The fish caught by explosives do not have fishing gear marks on the body surface, such as gill net marks or spear marks. The fish are sold cheaply so that they can be sold at once. The fishermen do not want to stay at the market for a long time to avoid the risk of being caught by fisheries staff and / or police. The fish which are caught by dynamiting are not usually caught in large quantities by ordinary fishing methods, i.e. bulls eye (Priacanthidae), small barracuda (*Sphyraena* spp.), top sail drummer fish (*Kyphosus cinerascens*), fusilier (Caecioninae) and mullets.

5. Fish processing

There is not much fish processing activity in Tonga. Salted and dried fish as well as smoked octopus are the only processed and preserved products. Fish is usually sold fresh without icing or cooling except for the fish for export purpose. However, there is some frozen fish sent from Ha'apai and Vava'u to the market in Nuku'alofa by ferry boats. These fish are usually sold at Tu'imatamoana market while other fish caught in Tongatapu are sold at Vuna wharf and Faua road side market.

There are some sea cucumber processors which cook and smoke dry the animal for the export market. Main species used are sand fish, black teeth, and white teeth. There are 13 exporters of dried sea cucumber in Tongatapu. Recently, hookah diving gear was introduced to Tonga which rapidly depleted the sea cucumber resources, even in deeper areas.

Inshore Fisheries Landing

In Nuku'alofa, fish and shellfish are sold every day except for Sunday. Monday morning is a small market day as nobody goes fishing on Sunday night. The largest amount of fish and shellfish are landed on Saturday followed by Friday. Observation of the Nuku'alofa fish markets showed that 10,000 kg of fish and 3,500 kg of shellfish were sold in a week (Tulua and Udagawa, 1994).

In the rural area of Tongatapu, fishermen with a small boat or without a boat go fishing in nearby fishing grounds and often sell the catch solely in their villages. During the recent fishermen interview survey, 21 out of 28 fishermen 75%) answered that they sold their fish and shellfish in Nuku'alofa. The remaining 7 fishermen replied that they sold in their home village. The share of the fish for sale to the total catch ranged from 66% to 98% with the average of 86%. Their catch ranged from 12 kg to 200 kg per week for fish and 5 kg to 250 kg per week for shellfish.

Fig . 2 shows the weekly average of daily catch per person for the trolling fishery from 31 May to 31 December 1993. Daily catch of the trolling fishery fluctuated in the wide range between 13.6 kg and 114.3 kg during the period. There seems to be no particular seasonal fluctuation except for an increase in catch just before Christmas and a sudden increase in the middle of September. The increase in daily catch before Christmas may be explained by the increase in demand for fish as well as fishermen's intention to secure cash income before Christmas. The reason for the increase in the middle of September might be due to a combination of favorable weather, oceanic and fish biological conditions.

Figs. 3, 4 and 5 show the weekly average of daily catch per person for the hand line fishery, day-time diving fishery and night-time diving fishery from 31 May to 31 December 1993, respectively. The catch fluctuated around 20 kg in the hand line fishery, 15 kg in the day-time diving fishery and 20 kg in the night-time diving fishery until the middle of October and then showed upward trends in all of

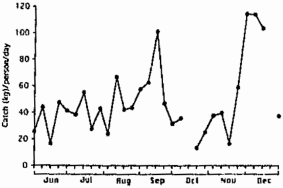

Fig. 2. Weekly average of daily catch per person for trolling.

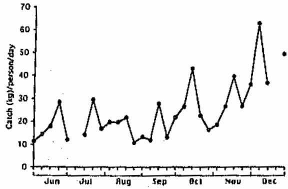

Fig. 3. Weekly average of daily catch per person for hand line fishery.

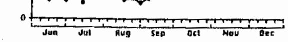

Fig. 4. Weekly average of daily catch per person for day-time diving fishery.

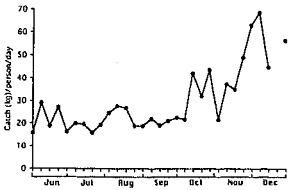

Fig. 5. Weekly average of daily catch per person for night-time diving fishery.

the three fisheries. These trends indicate that activities of those fisheries are low during the period when both air and seawater temperatures are low and they gradually become higher as the temperatures become higher.

Fig. 6 and 7 show estimates of monthly fish and shellfish landings from March to December 1993 for Faua road side

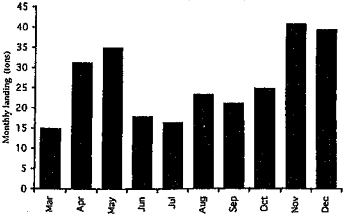

Fig. 6. Monthly fish landing for Faua road side market and Vuna wharf market.

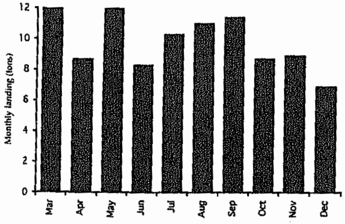

Fig. 7. Monthly shellfish landing for Faua road side market and Vuna wharf market.

market and Vuna wharf market combined, respectively. If the landings in January and February are assumed to be equal to the average landings of the 10 months from March to December, namely 26.5 tons for fish and 9.8 tons for shellfish, then the annual landings are estimated to be 318 tons for fish and 118 tons for shellfish. Further, assuming that those figures represents 75% of the total landings, the total annual landing of fish and shellfish combined in Tongatapu is estimated to be 581 tons. Tulua and Udagawa (1994) reported that Total landing in Tongatapu was estimated to be 902.7 tons based on their week-long survey at the fish markets in early April 1992. There is an estimation of 1,757 tons for the catch in entire area of Tonga's shallow reefs and lagoons (Sixth Development Plan, 1991). Kawaguchi (1991) reported that 1,300 tons of fish, excluding shellfish, was caught from the same area. More reliable estimation on the total fisheries landing in tongatapu will be possible in the future as the result of the Inshore fisheries Statistics Program.

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Short Report

Giant Clam Fishing off Tongatapu Island

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Introduction

It has long been said that resource management measures should be introduced to prevent depletion of giant clam resources caused by over fishing (Mckoy, 1980; Munro, 1993). However, scientifically justifiable management measures have not been established yet. The purpose of the present study is to observe the detail of the traditional diving fisheries for giant clam in an attempt to establish a determination method of the magnitude of fishing effort and catch per unit effort (CPUE) which are the most basic indicators for fishing pressure and stock size, respectively.

Fishing Operation

The diving fishery for giant clam by fishermen of Afa, situated northeast coast of Tongatapu Island, was observed on 21 and 22 October 1992. Fishing grounds were the patched coral reef zone to the north of Fukave Island and to the west of Ata Island on the first day and outer coral reef zone of Tau Island on the second day (Fig. 1). The depth of the water was 10m to 12m. Fishermen wore T-shirt, short or long pants, goggles, snorkel and a pair of fins. They swam as fast as

1m/sec. while towing tire tube floats tied to their waist with ropes as long as 5m. The tire float can carry collected giant clams and some tools of the fisherman with a hemp cloth spread inside of it.

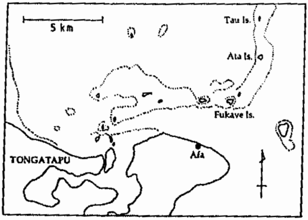

Fig. 1. Giant clam fishing grounds around Tongatapu Island.

When they found a giant clam from the surface, they dived half way down to the bottom in order to confirm if it was truly a giant clam or not. When the fishermen confirmed a large giant clam, as large as 30cm shell length or larger, he called fellow fishermen for assistance. When fellow fishermen gathered, he dived half way down and pulled down a spear like weight (Fig. 2), which is also tied to the tire, carefully near the clam (Fig. 3, a). After he came up to the surface for breathing and untied the rope from his waist, he dived close to the bottom and put the weight inside the opening of the clam (Fig. 3, b). When the clam closed the shells pinching firmly the weight, fellow fishermen started to pull up the clam. The fisherman once came up to the surface for breathing and dived again in order to support the clam from dropping off. There sometimes was another weight with rope dropped close to the clam. The fisherman held the rope in order to get extra force to lift up the heavy giant clam (Fig. 3, c). When the clam was small, 30cm shell length or smaller; the fisherman dropped the weight close to the clam and dived down to the bottom to pick up the clam alone and bring up the clam using the rope as a guide to the tire float. *Tridacna derasa* were caught on the outside edge of patch reefs while *T. squamosa* were caught slightly inside of the reef edge. T. maxima was not the target species here although some of them were found inside of the patch reefs.

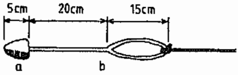

Fig. 2. Spear like weight used for giant clam fishing.
a. Lead head b. Steel shaft

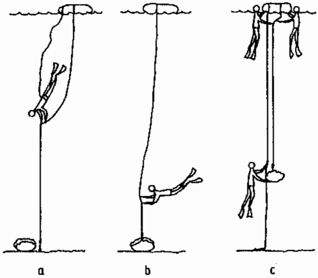

Fig. 3. Method of giant clam fishing.

Fishing Effort, Standardized Catch and CPUE

Three operations were observed in the two days. Kind and size of giant clams caught in each operation are shown in Table 1. It seems to be appropriate to construct fishing effort, standardized catch and CPUE in the following way. Fishing effort can be expressed by the number of fishermen engaged in a operation multiplied by the duration of the operation. The catches of clams of different sizes can be standardized by taking one clam of less than 30cm shell length to be one unit, one clam of between 30cm and 40cm to be 1.5 units and one clam larger than 40cm to be 2 units. From these fishing efforts and standardized catches, CPUE (pieces of clam caught per hour per fisherman) has been calculated for each operation as 1.3, 3.1 and 3.3, respectively.

Table 1. Species and size (shell length in cm) of giant clams caught.

Species	1st operation	2nd operation	3rd operation
T. derasa	42, 41, 45	21	35, 50
T. squamosa		20, 23, 24, 24 27, 29, 31, 31 41	18, 32, 32, 45 45, 50
T. maxima			26, 28

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