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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, NO₂-N, PO₄-P, NH₄-N, NO₃-N, Cr⁶⁺, 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, $\text{NO}_2\text{-N}$, $\text{PO}_4\text{-P}$, $\text{NH}_4\text{-N}$, $\text{NO}_3\text{-N}$, 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

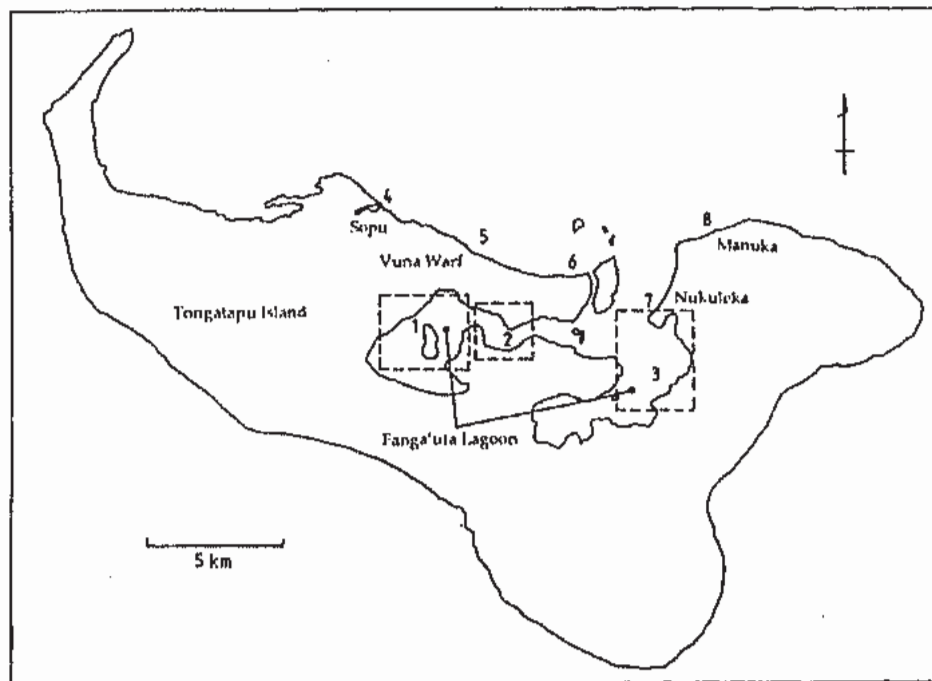


Fig. 1. Sampling stations.

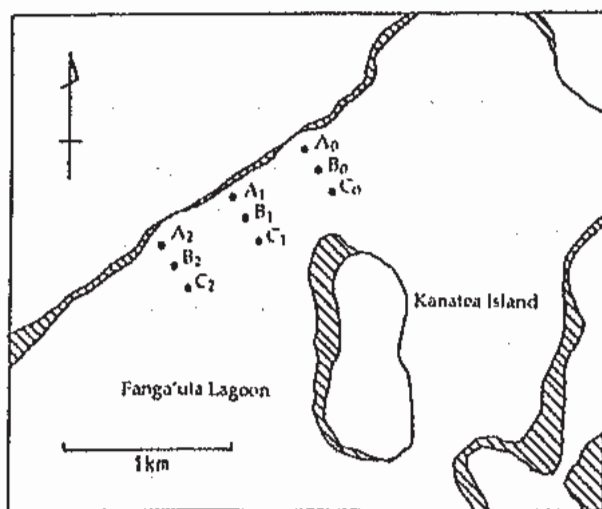


Fig. 2. Sampling points at Station 1.

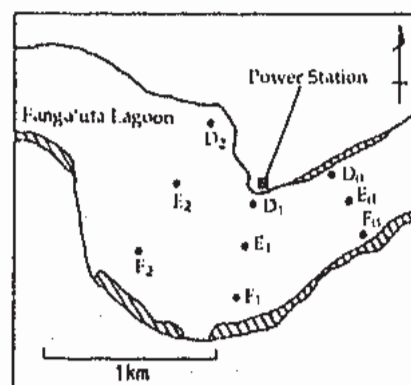


Fig. 2. Sampling points at Station 2.

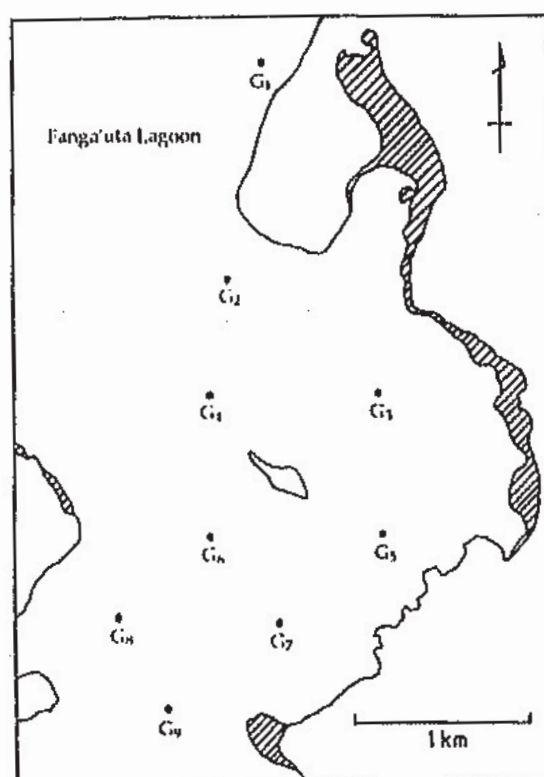


Fig. 3. Sampling points at Station 3.

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 C₀ that was located about 300m offshore. COD was 2 mg/l at almost all points except for A₀ where COD was 4 mg/l on 26 October and B₁ where COD was lower than 2 mg/l on the same day. NO₂-N was 0.15 mg/l at A₁, A₂ and B₂ 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. NO₃-N was 0.46 mg/l at A₁ and B₁, and 0.23 mg/l at A₀ and A₂ 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 PO₄-P, NH₄-N, Cr⁶⁺, 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 O₂ 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	NO ₂ -N	PO ₄ -P	NH ₄ -N	NO ₃ -N	Cr ⁶⁺	Cu	Phenol	CN
	(‰)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
A0	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
B0	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
C0	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
A1	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
B1	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
C1	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
A2	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
B2	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
C2	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 ₂ mg/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 (D0-F2) and 3 (G1-G9).

Point	Salinity	COD	NO ₂ -N	PO ₄ -P	NH ₄ -N	NO ₃ -N	Cr6+	Cu	Phenol	CN
(‰)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)
D0	31	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
E0	32	2	<0.006	<0.066	0.8	<0.23	<0.05	<0.5	<0.2	<0.02
F0	32	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
D1	31	2	<0.006	<0.066	0.6	<0.23	<0.05	<0.5	<0.2	<0.02
E1	32	2	<0.006	<0.066	0.4	<0.23	<0.05	<0.5	<0.2	<0.02
F1	30	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
D2	31	2	<0.006	<0.066	0.6	<0.23	<0.05	<0.5	<0.2	<0.02
E2	31	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
F2	32	2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G1	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G2	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G3	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G4	37	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G5	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G6	36	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G7	38	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G8	35	<2	<0.006	<0.066	<0.4	<0.23	<0.05	<0.5	<0.2	<0.02
G9	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 ₂ mg/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. $\text{NH}_4\text{-N}$ 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_2 mg/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_2 mg/l for Station 4, while it ranged from 6.0-7.5 O_2 mg/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 $\text{NO}_2\text{-N}$ and $\text{NO}_3\text{-N}$. 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 ₂ mg/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.

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