STUDIES ON YOSA-NAIKAI

3. ANALYTICAL INVESTIGATIONS ON THE INFLUENCE OF THE RIVER NODA AND THE BENTHONIC COMMUNITIES*

By

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As mentioned already in my previous report, the water of Yosa-Naikai is divided into the following five water layers: the brackish layer, upper layer, chemocline, layer, stagnant layer and Miyazu Bay water layer. In that report, I refered to the boundaries of these water layers and the out-line of the relation between the living organisms and each water layer. The benthonic fauna was, however, very poor in that time; animals else than the empty shells of *Theora* were extremely scarce. Consequently, I was not able to discuss fully on the relation between the benthonic communities and each water layer, but only give a glimpse on the total number of dead shell valves in each area covered with respective water layer. In order to clarify the above-mentioned relationships, I was engaged in the observations during the period from Sept. 30 to Oct. 1, 1950. Examining the data carefully, I have been aware of the fact that the composition of the benthonic communities, including thanatocoenosis, is closely related with the division of the lagoon water according to the chlorinity which is hardly affected by the environmental factors.

Before going further, I must express my hearty thanks to Prof. Dr. D. MIYADI (Zoological Institute, Kyôto University) for his kind guidance and crticism given to me on this study. I must also record here my sincere thanks to Prof. Dr. M. ISHIBASHI (Institute of Chemistry, Kyôto University) and Dr. T. TOKIOKA (Seto Marine Biological Laboratory, Kyôto University), who gave me many valuable advices, to Mr. Y. KUSAKA and Mr. T. HARA, who aided me extensively in the observations and to Mr. T. HABE who taught me kindly names of numerous benthos.

METHOD AND RESULTS OBTAINED

The observations were made during the period from Sept. 30 to Oct. 1, 1950, at the stations shown in Fig. 1, by the same methods as described in my previous reports. The results obtained are shown in tables 1 and 2. The water of the lagoon shows the following feature:——

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Table 1. Oceanographical conditions of Yosa-Naikai (Sept. 30-Oct. 1, 1950)

Station number	Depth of station (m)	Depth of sampling (m)	Water temp. (°C)	Chlorinity (‰)	Satur. percentage of dissol. O_2	pH	Silicate-Si (γ/L)	Phosphate-P (γ/L)	Bottom character	Mud temp. (°C)
I	7.0	0	21.8	12.85	109	7.9	300	7	Black ooze	23.8
		7	26.0	16.58	37	7.8	175	200		
II	11.0	0	22.0	13.63		8.1	110	50	Black ooze	22.6
		11	24.0	17.21				284		
III		0	21.8	13.00		8.0	350	37		
IV	14.0	0	23.0	13.47	101	8.1	250	95	Black ooze	21.6
		3	25.4	16.44	108	7.9		125		
		14	22.6	17.02	0		110	154		
V	13.0	0	22.8	13.31	108	8.0		110	Black ooze	
		13	25.4	16.43	67	8.0		200		
VI	5.5	0	22.5	14.40	110	7.8	125	171	s. M.	
		5.5	25.2	16.00	83	7.9	175	171		
VII	13.0	0	21.3	12.58	106	7.6	185	35	Black ooze	
		13		17.17	0	7.8	3025	600		
VIII	14.5	0	22.0	13.37	103	8.2	536	85	Black ooze	21.3
		2	24.6							
		3	26.4	16.43	87	8.0	420	101		
		6	25.6	17.05	12	7.9	1430	278		
		9	24.4	17.11	0	8.0	1800	360		
		12	23.0	17.08	0			353		
IX	3.0	0	22.1	12.67	100	8.0	150	53	Sand	
		3	23.2	14.95	84	8.2	425	91		
X	2.0	0	21.3	12.43	105	7.6	175	25	Gravel	
		2	23.2	14.56	101	7.8	175	35		
XI	13.5	0	21.6	12.73	98	7.8	300	19		22.4
		13.5	23.2	16.73	0		850	540		
XII		0	21.8			8.0			Sand	
XIII	8.5	0	23.4	13.59		8.2	125	15	Black ooze	23.7
XIV	7.0	0	23.9	12.29		8.0	881	22	Black ooze	
		7	26.2	16.55	75	7.9	357	78		
XV	7.5	0	23.4	13.80	101	8.2	484	85	Black ooze	23.6
		3	26.4	16.09	86	8.2	170	164		
		5	25.8	16.61	57	8.2	241	209		
		7.5	25.4	16.65	0			582		
XVI	0.4	0		0.55		7.3	4760	65	Sand	
		0.4		8.21			3710	175		
XVII	5.5	0	21.4	12.44	105	8.0	875	46		24.7
		5.5	26.4	16.49	61	8.1	105	99		

Table 2. Composition of benthonic communities in Yosa-Naikai. (Sept. 30—Oct. 1, 1950)

Classification of benthonic communities	Estuary region		Polychaeta region		L. region	L.-G. region	Theora region								Other
Station	XIV	XVI	IX	X	VI	XI	I	IV	V	VII	VIII	XIII	XV	XVII	III
ANNELIDA															
Polychaeta															
Spirorbis for inosus MOORE et BUSH			⊦	⊦		⊦									
Spirobranchus giganteus (PALLAS)				⊦											
Serpula ver icularis LINNE			⊦	⊦											
Prionospio pinnata EHLERS	13	21	3												
MOLLUSCA															
Amphineura															
Liolophura japonica (LISCHKE)				⊦											
Lamellibranchia															
Brachidontes senhousia (BENSON)	⊦	1													
Loripes pisidium (DUNKER)					(4)	(1)									
Fulvia hungerfordi (SOWERBY)					3										
F. mutica (REEVE)					(⊦)										
Venerupis semidecussata (REEVE)		(8)	(2)			(1)									
Tellina juvenilis HANLEY	6					1									
Theora lubrica GOULD					(26)	(163)	(24)	(6)	(12)	(70)	(53)	(46)	(18)	(22)	
Mya japonica JAY			(⊦)		(1)	(2)									
Laternula kamakurana PILSBRY			(⊦)												
Gastropoda															
Assiminea japonica V. MARTENS		(1)													
Contumax dialeucus (PHILIPPI)						(⊦)									
Liola semisulcata (DUNKCR)						(1)									
PROCHORDATA															
Urochorda															
Styela plicata LESUEUR															⊦

Notes

L. region : Lamellibranchia-region.

L.-G region : Lamellibranchia-Gastropoda-region.

This table shows the individual number in $0.02m^2$.

The bracketed number shows the dead shell valves in $0.02m^2$.

The sign " ⊦ " indicates the existence of animals which are clinging to rocks or gravels and can not be caught quantitatively by the bottom sampler.

The sign "(⊦)" indicates the existence of the shell fragments, the accurate number of which can not be counted.

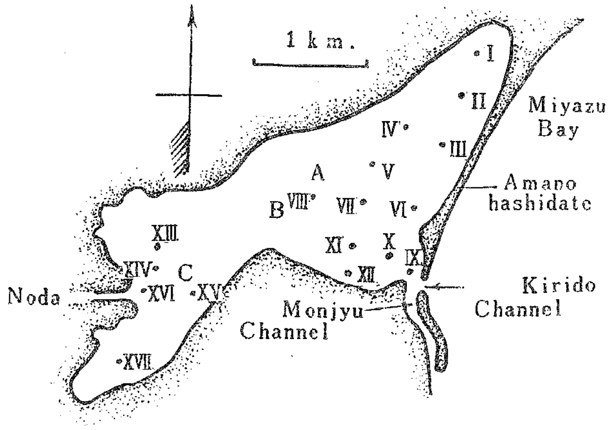

Fig. 1. The sketch map of Yosa-Naikai.
Roman numbers indicate the position of stations.
Capital letters, A, B and C indicate the position of tidal rips across which water samples were taken.

Temperature of water is highest at the middle layer and decreases towards both shallower and deeper layers. The surface temperature is 18.4–24.2° C and shows a wide deviation according to stations. The temperature of mud is a little lower than that of the water covering directly the bottom.

Chlorinity of the surface water shows a wide range of deviation from 0.55 to 14.73‰, although the lagoon water as a whole may be considered in the chlorinity from 12 to 14‰. This wide deviation according to stations is surely due to the strong effect of the river. Chlorinity increases suddenly in the surface layer, and below this layer it increases very slowly with depth.

Dissolved oxygen is over-saturated in the surface layer, but decreases with depth; it is quite absent near the bottom.

Silicate is rich in the estuary and near the bottom.

Phosphate increases with depth.

Tidal rips : There were found three tidal rips in the lagoon during the observations : the tidal rip A appeared between the brackish water areas No.3 and No.4 in the central part of the lagoon (the number of the brackish water area is described in the following chapter), the tidal rip B between the brackish water

Table 3. Oceanographical conditions at each side of respective tidal rip.

Position		Water temp. (°C)	Chlorinity (‰)	Silicate-Si (γ/L)	Phosphate-P (γ/L)
A	north side south side	24.2 22.8	14.73 13.72	174 333	20 24
B	north side sonth side	20.0 18.4	12.37 10.12	375 2000	30 18
C	north side south side	22.0 23.2	4.30 13.77	5000 200	115 550

areas No.1 and No.3 and the tidal rip C between the brackish water areas No.1 and No.3 near the estuary of the river Noda. I made some observations at both sides of these tidal rips and got the following results that the temperature was differing from 1.2 to 3.6°C, the chlorinity 9.74–1.01‰, the silicate 400–139 γ/L and the phosphate 4–435 γ/L between the surface waters of each side of respective tidal rip.

GENERAL CONSIDERATIONS

1. Influence of river.

High chlorinity is a characteristic of the sea water, and rich silicate is that of the river water. In the surface layer, the chlorinity and the concentration of silicate are safely considered to be negatively correlated with each other. Therefore, the degree of the influence of the river or the sea can be estimated theoretically by analysing one of these two factors. This time, I used the chlorinity as an indicator for this purpose, because the much accuracy is retained in the titration of the chlorinity than in the colorimetry of the silicate.

Table 4. Division of surface water.

Order of treatment	Maximum permissible value of chlorinity (‰)	Minimum permissible value of chlorinity (‰)	Rejected station		Name
			Station number	Chlorinity (‰)	
1	18.44	5.72	St. XVI North side of tidal rip C	0.55 4.03	Brackish water No.1
2	15.00	11.12	South side of tidal rip B	10,12	
3	14.50	11.94	North side of tidal rip A	14.73	Brackish water No.4
4	14.29	11.98	St. VI	14.40	
5	14.11	12.01	None		

Brackish water No.2 : St.I, St.VII, St.IX, St.X, St.XI, St.XII, St.XIV, St.XVII and the north side of tidal rip B.

Brackish water No.3 : St.II, St.III, St.IV, St.V, St.VIII, St.XIII, St.XV, the south side of tidal rip A and the south side of tidal rip C.

In order to divide the water mass affected strongly by the river water into several groups, I applied THOMPSON's method for rejecting the data of the chlorinity of the surface samples at 0.05 level of significance, on the assumption that the distribution of the chlorinity of the proper surface water of the lagoon follows the normal distribution. The rejection was repeated till no more sample was able to be rejected. The group of samples remained after the last rejection may be considered as the proper surface water of the lagoon, the group of samples

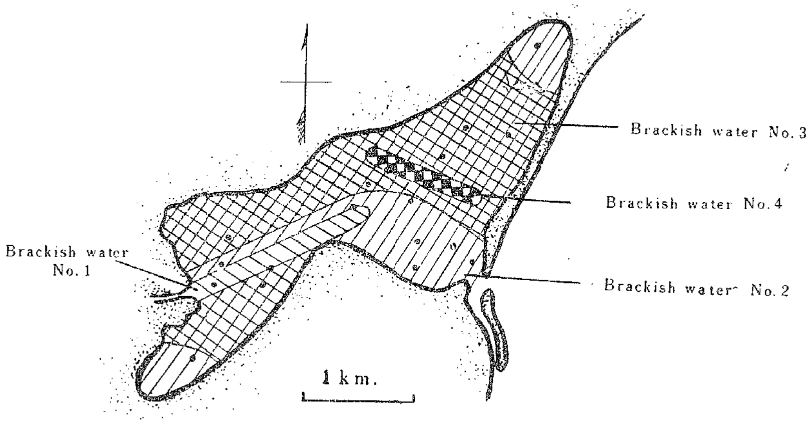

Fig. 2. Division of surface water.

rejected by their lower values is called the brackish water No.1, and the group of samples rejected by their higher values is the brackish water No.4. The stations along the line connecting the estuary to the openings of the channels are regarded as being in the course of the river water flowing into the lagoon; samples from these stations, as well as those from stations in the northeastern and southwestern parts of the lagoon, show the lower chlorinity than that of samples from other stations in the proper surface water area at 0.01 level of significance. The group of stations showing lower values is called the brackish water No.2, and that of stations showing higher values is numbered as No.3. It may be safely said that the influence of the river Noda is strongest at the brackish water No.1 (St. XVI, north side of tidal rip C and south side of tidal rip B), and decreases gradually in the order of No. 2 (St.I, St.VII, St.IX, St.X, St.XI, St.XII, St.XIV, St.XVII and north side of tidal rip B), No.3 (St.II, St.III, St.IV, St.V, St.VIII, St.XIII, St.XV, south side of tidal rip A and south side of tidal rip C) and No.4 (St.VI and north side of tidal rip A).

2. Division of the bottom water.

It is necessary to refer to all present environmental factors of the bottom water, useful or injurious to living organisms, when we discuss the relation between the benthonic communities and the character of the surrounding water. Moreover, the environmental factors in the past must be considered, if we deal with the benthonic communities including thanatocoenosis. Many factors of the environmental water are easily changeable secondarily, and consequently they can not be used as indicators showing the origin of the water mass stricly to us. When the origin of the water mass is pursued, some factors unchangeable secondarily must be chosen among environmental factors as indicators, even if they have some lesser biological meaning. Thus, the chlorinity was taken up as an indicator and treated with the same method as in the case of the surface water. The group of samples

Table 5. Division of bottom water.

Order of treatment	Maximum permissible value of chlorinity (‰)	Minimum permissible value of chlorinity (‰)	Rejected station		Name
			Station number	Chlorinity (‰)	
1	20.15	11.51	St.XVI	8.21	Bottom water No.1 (Brackish layer)
2	17.79	15.07	St.IX St.X	14.95 14.56	Bottom water No.2
3	17.30	16.14	St..XI	16.00	Bottom water No.3
4	17.43	16.16	None		Bottom water No.4 (Stagnant layer)

The remainders at the third treatment belong to the bottom water No.4.

rejected at first on account of their lower values is called the bottom water No.1 (St.XVI), the group of samples rejected next is No.2 (St.IX and St.X) and that of samples rejected thirdly is No.3 (St.XI). There is no sample to be rejected at the fourth treatment; the remainder is called the bottom water No.4 (St.I, St.IV, St. V, St.VI, St.VII, St.VIII, St.XV and St.XVII). The bottom water No.1 may be considered as corresponding to the brackish layer described in my previous report (1953) and No.4 to the deeper stagnant layer. If some samples were rejected on account of their higher values, the group of those samples should be called the bottom water No. 5 and considered as corresponding to the Miyazu Bay water layer mentioned in my previous report.

3. Classifcation of the benthonic communities.

The benthonic communities in this report comprise not only living organisms but also the thanatocoenosis. The benthonic communities in this lagoon are

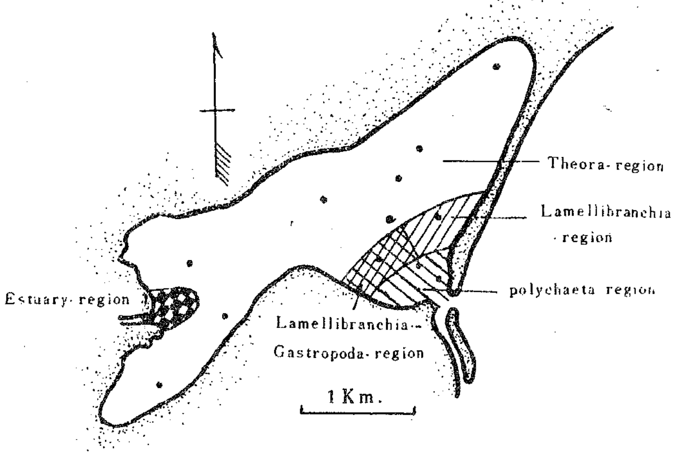

Fig. 3. Classification of Benthonic communities.

classified into the following three groups: 1) *Theora*-region, the benthonic communities composed of only *Theora;* 2) estuary-region, the region near the estuary and with rich benthonic fauna; and 3) channel-region, the region near the openings of the channels and also with rich benthonic fauna.

Prionospio pinnata, Brachidontes senhousia, Venerupis semidecussata Tellina juvenilis and *Assiminea japonica* were found at St.XIV and St.XVI near the estuary. The region near the openings of the channels is divided into two parts; one may be called as Polychaeta-region, because the fauna is composed mainly of polychaets and holds no *Theora,* while the other may be called as Mollusca-region, because the fauna is rich in molluscs including *Theora.* The latter is then divided into Lamellibranchia-region where the benthonic fauna is composed of four species of Lamellibranchia including *Theora* (St.XI), and Lamellibranchia-Gastropoda-region where the benthonic fauna adds *Fulvia hungerfordi* and *F. mutica* of Lamellibranchia and *Contmax dialeucus* and *Liola semisulcata* of Gastropoda to that found at St.XI.

4. Relation between the division of the bottom water and the composition of the benthonic communities.

The composition of benthonic communities is closely related with the division of the bottom water classified by chlorinity as shown in table 6. The *Theora*-region correlates with the bottom water No.4 (stagnant layer), the estuary-region is covered with the bottom water No.1 (brackish layer) and the water near the boundary between the bottom water No.4 and the bottom water No.1, the bottom water No.2 covers the Polychaeta-region, the bottom water No.3 correlates with the Lamellibranchia-Gastropoda-region and the water near the boundary between the bottom water No.3 and the bottom wator No.4 covers the Lamellibranchia-region.

Table 6. The relation between the composition of benthonic communities and the division of the bottom water

Estuay-region			Bottom water No.1 and the water near the boundary between Bottom water No. 1 and No.4 (St.XIV, St. XVI)
Channel-region	Polychaeta-region		Bottom water No.2 (St.IX, and St.X)
	Mollusca-region	Lamellibranchia-region	The water near the boundary between bottom water No.3 and No.4 (St.VI)
		Lamellibranchia-Gastropoda-region	Bottom water No.3 (St.XI)
Theora-region			Bottom water No.4 (St.I. St.IV, St.V, St.VII, St.VIII. St.XIII, St.XV and St.XVII)

The fact, mentioned above, does not mean that the benthonic communities are controled solely by chlorinity of the environmental water. Preferably, I think that water masses differing in chlorinity differ, or might be differed, in other biologically important factors, and that the composition of the benthonic communities is controled by these biologically important factors.

SUMMARY

1. Results of the observations during the period from Sept. 30 to Oct. 1, 1950 are shown in Tables 1 and 2.

2. The degree of the influence of the river water was analysed, using the chlorinity of the surface water as an indicator. The influence of the river Noda is strongest at St. XVI, north side of tidal rip C and south side of tidal rip B, and decreases gradually in the order of (St.I, St.VII, St.IX, St.X, St.XI, St.XII, St.XIV and the north side of tidal rip B), (St.II, St.III, St.IV, St.V, St.VIII,St.XIII, St.XV, the south side of tidal rip A and the south side of tidal rip C) and (St.VI and the north side of tidal rip A).

3. The bottom water are classified into the four groups, the bottom water No.1—No.4, by the similar method as in the case of the surface water.

4. The benthonic communities, including thanatocoenosis, are classified into five groups: estuary-region, polychaeta-region, Lamellibranchia-region, Lamellibranchia-Gastropoda-region and *Theora*-region.

5. The composition of benthonic communities is closely related with the division of the water as shown in Table 6.

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