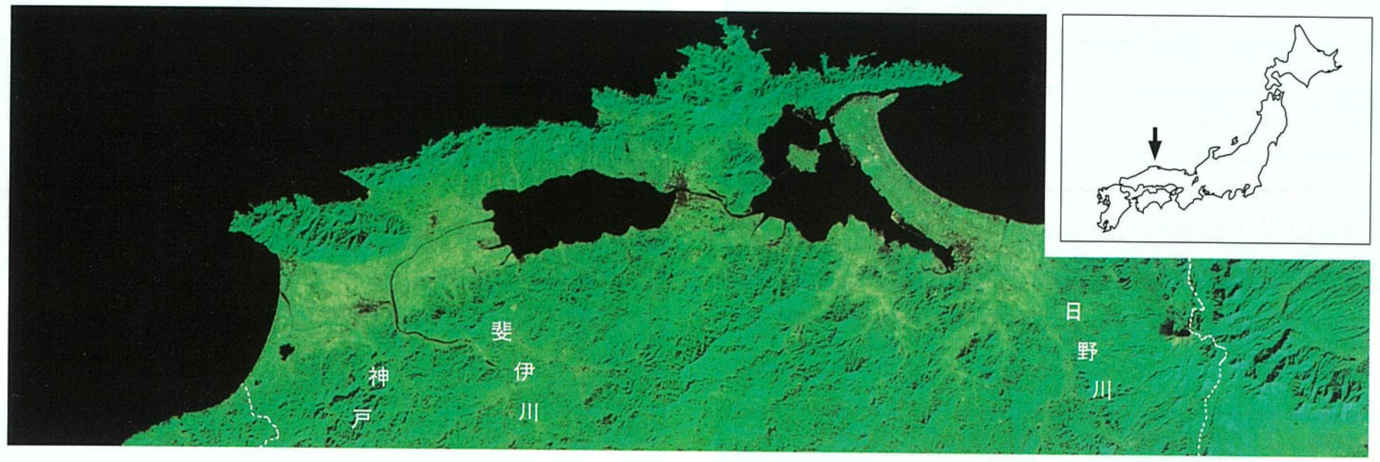
IMPROVING LAGOONAL ENVIRONMENTS FOR FUTURE GENERATIONS

– A CASE STUDY OF LAKES NAKAUMI AND SHINJI, JAPAN – *

T. Tokuoka**, K. Takayasu**, H. Kunii**, F. Takehiro** and Y. Sampei***



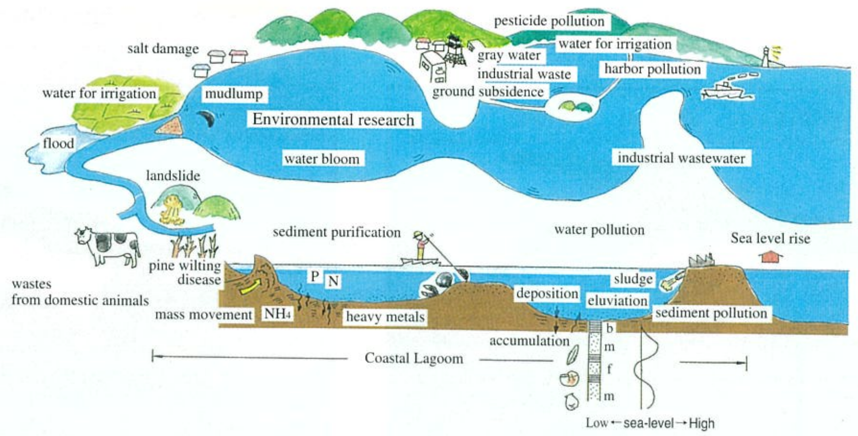
The purpose of the Research Center for Coastal Lagoon Environments

The Center of Shimane University was established in 1992, and mainly studies the history of natural, cultural, and social environments of Lakes Nakaumi and Shinji, and their surrounding areas, to develop new ideas for the wise use of natural resources while maintaining a sound ecological balance. The main topics are (1) Natural environmental changes and sea-level changes in coastal lagoon areas, (2) Biodiversity and environmental changes in coastal lagoon area, and (3) synthetic studies on geographical, cultural, and social environments of lagoons and their hinterlands.

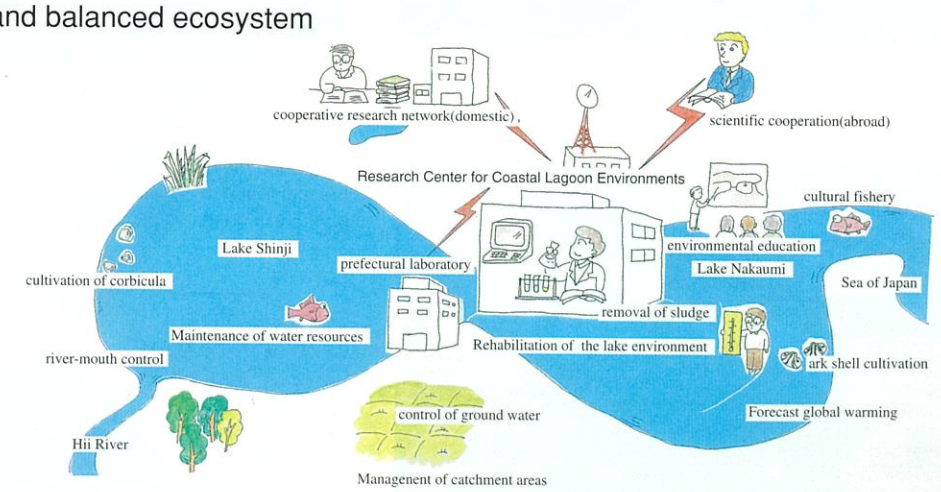
Study of the past → II III → **Collate and analyse all present data** → IV V → **Aims and outcome**

Forecast global warming and develop countermeasures to limit environmental changes VI VII
Promote wise use of natural resources and the creation of a balanced ecosystem VIII

Facing problems



Programs for wise use and balanced ecosystem

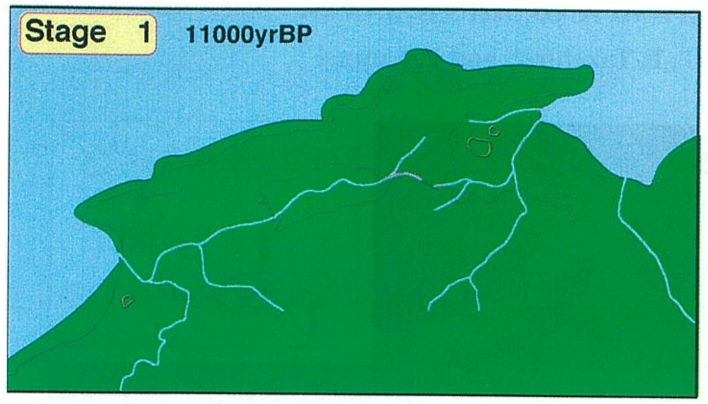


*Presented originally at the poster session of THE IGBP-LOICZ OPEN SCIENCE MEETING, October 10-13, 1997, held in the Netherlands, and revised.

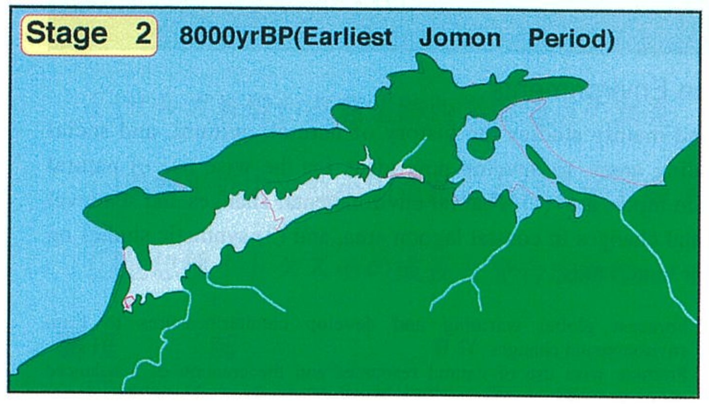
**Research Center for Coastal Lagoon Environments, Shimane University, Matsue 690-8504, Japan
***Department of Geoscience, Faculty of Science & Technology, Shimane University, Matsue, 690-8504, Japan

STUDY OF THE PAST

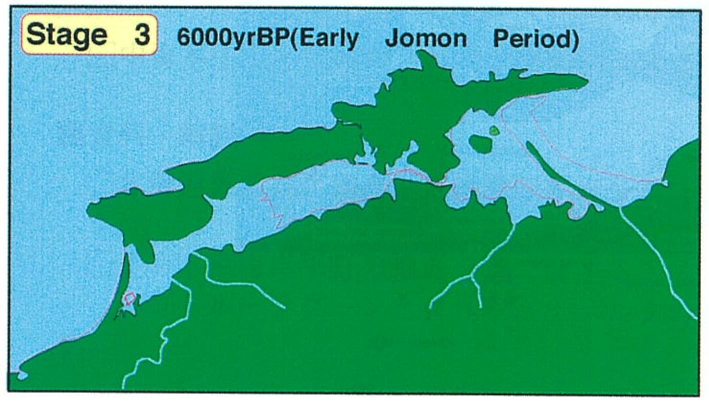
Coastal lagoons are very sensitive to sea level changes. Their environment can easily be changed by falling or rising sea level. Such changes are recorded in the bottom sediments, and the paleogeography is reconstructed in Stages 1 to 7.



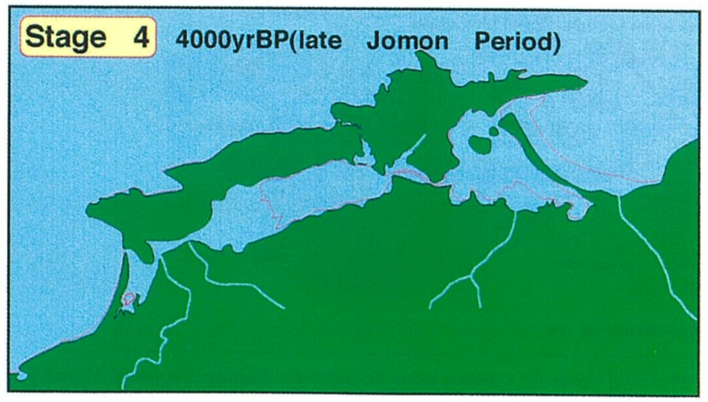
The sea level ascended gradually, reaching a level about -45m lower than present day.



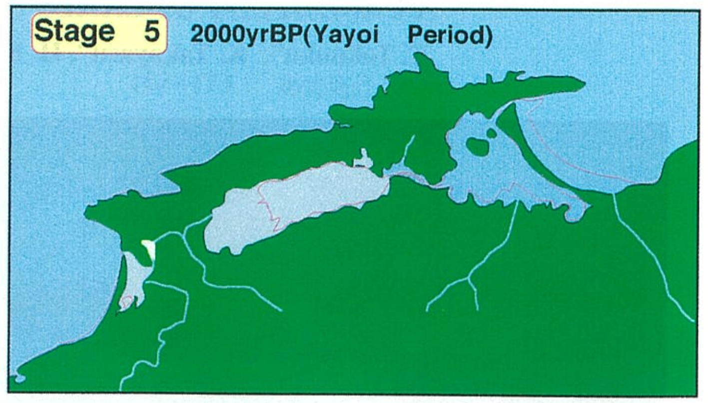
Worldwide transgression (Jomon Transgression in Japan) occurred, and the sea level ascended rapidly. The valley was invaded by the sea to yield the Paleo-Shinji Inlet in the west and the Paleo-Nakaumi Inlet in the east. They were separated from each other by a N-S barrier.



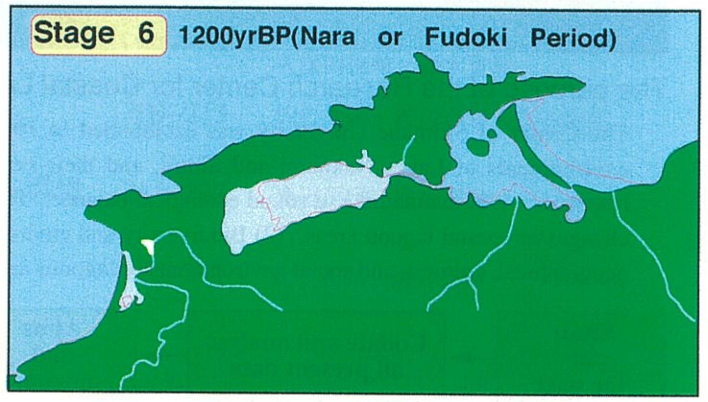
The sea level reached a maximum height, about 1.5m higher than present. Both inlets were connected and ideal conditions for fisheries prevailed. Sand bars began to develop on the seaward side of the inlets.



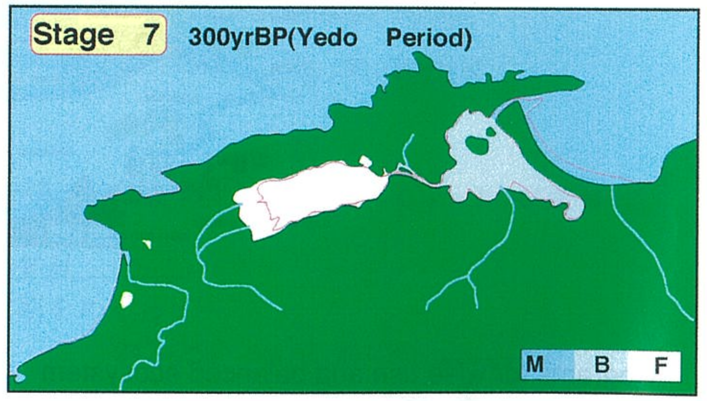
Sand bars continued to develop, but exchage of water with the open sea was maintained.



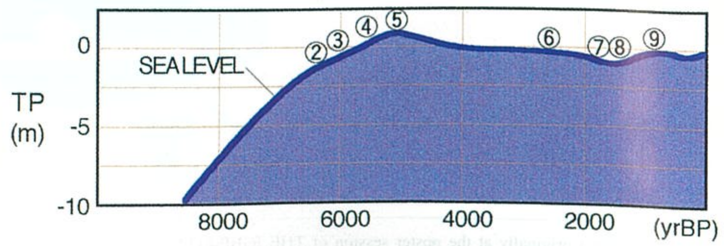
Sea level fell about 2 or 3 meters, and the western inlet was separated into two lagoons by a transgressive delta of the Hii River. Brackish conditions in Lake Shinji appeared for the first time, and a connection to Lake Nakaumi was maintained by a channel.



The sea level ascended slightly to no more than one meter above present, and exchange of brackish water between Lakes Shinji and Nakaumi became stronger than in the previous stage.



Iron production activities, especially 16th and 17th Century onward, have strongly affected the lake environment. Lake Shinji was changed to a freshwater lake in the middle of the 17th Century, and the Hii River changed its course eastward, flowing into Lake Shinji. At the same time the delta fan prograded rapidly eastwards, forming the eastern part of the Izumo Plain. The present brackish conditions of both lakes was formed artificially mainly, for the purpose of preventing flooding by the Hii River.



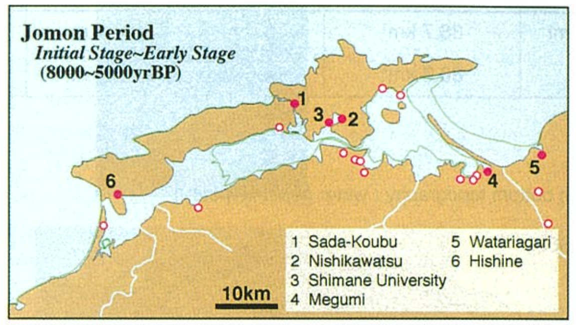
Holocene sea level changes in Lakes Nakaumi and Shinji area
The numerals with circle indicate direct evidences of sea level at the historic sites.

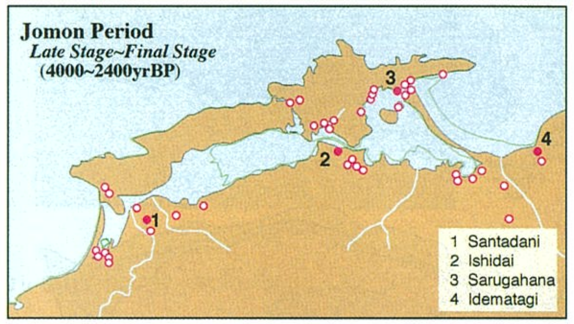
Diversified human activities around the coastal lagoons during the Holocene Period

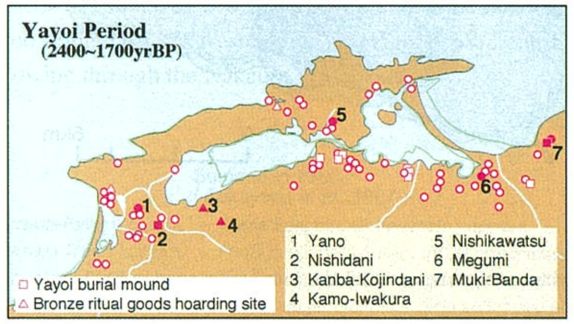
In the areas around Lakes Nakaumi and Shinji, many archaeological sites since the Holocene (Jomon Transgression in Japan) have been discovered. The activities of our ancestors are recognized as multi-sided usings of the lakes as fishery grounds, fishery ports and transportation bases. The surrounding lowland areas had provided convenient conditions for human activities especially for rice cultivation. These had made possible the prosperity of Paleo-Izumo, one of the most famous archaeologic sites in Japan.

Oars and handle of fish spear of the Jomon Period (5000-5500 yr. B. P.) excavated at the Shimane University campus

Dugout canoe of the Jomon Period (5500-6000 yr. B. P.) excavated at the Shimane University campus

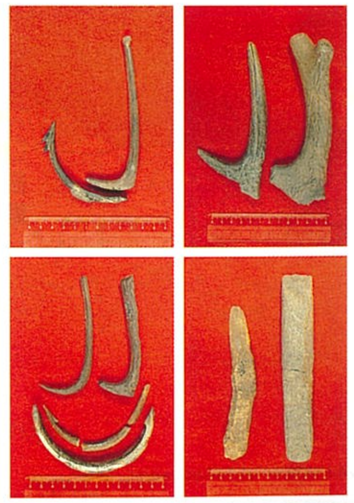






Shell stratum of the Jomon Period (ca. 5,500 yr.B.P.) excavated at the Sada-Koubu Shellmound site

Fishing gears of the Yayoi Period excavated at the Nisikawatsu site



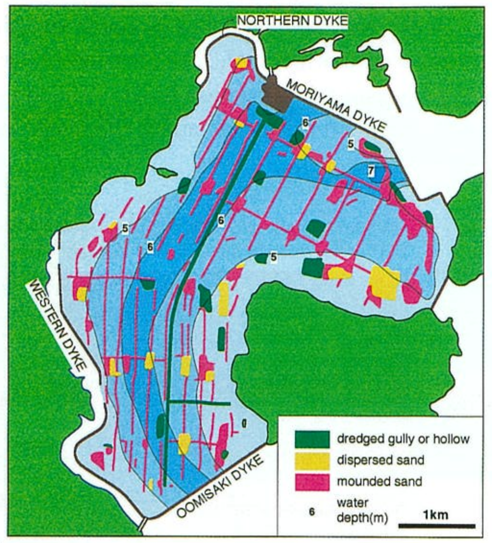
Hand net (56cm in length)

Stone net sinker

STUDY OF THE PRESENT

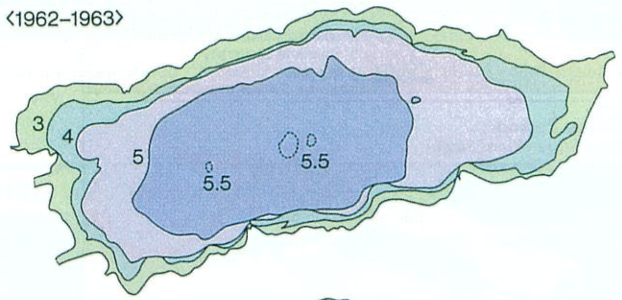
The Lakes Nakaumi and Shinji have been surveyed by various methods of echo-sounding. Lake bottom sediments have been sampled systematically and analysed sedimentologically and geochemically. Organic remains of mollusc, pollen, diatom, ostracod, foraminifer, etc. have also been studied.

	Water surface area	Mean depth	Max.depth	Average water level (TP)
L.Nakaumi	88.7 km²	5.4 m	8.4 m	+0.20m
L.Shinji	80.3 km²	4.5 m	6.4 m	+0.30m

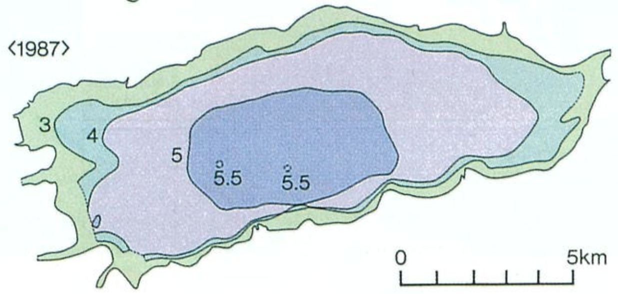


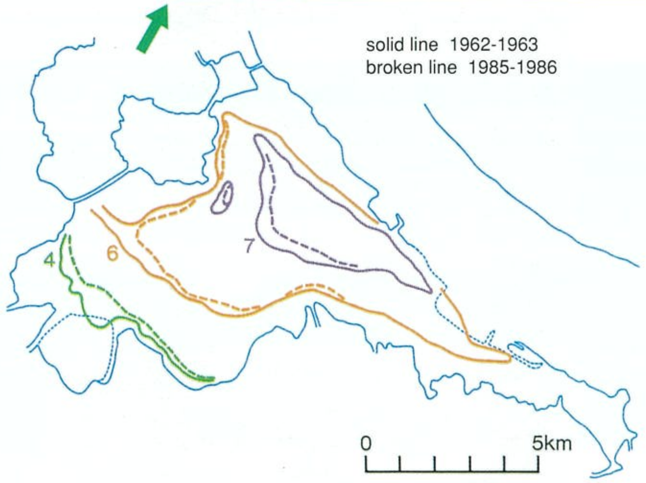
Change in bottom topography (water depth in meter)

‹1962–1963›



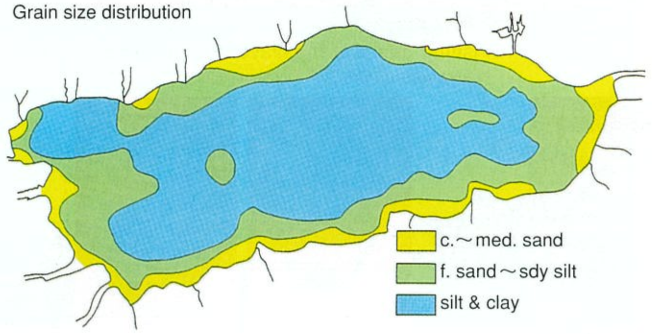
‹1987›



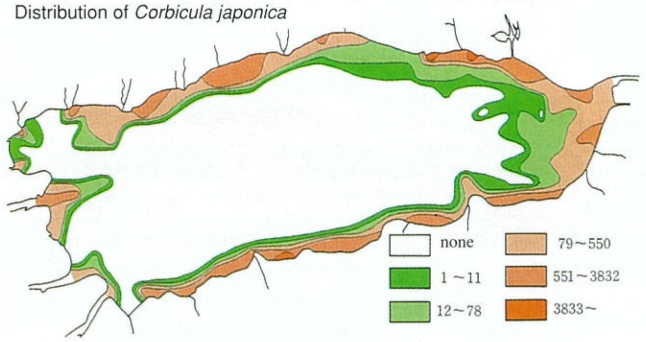


Present bottom characteristics of Lake Shinji (surveyed in 1982)

Grain size distribution

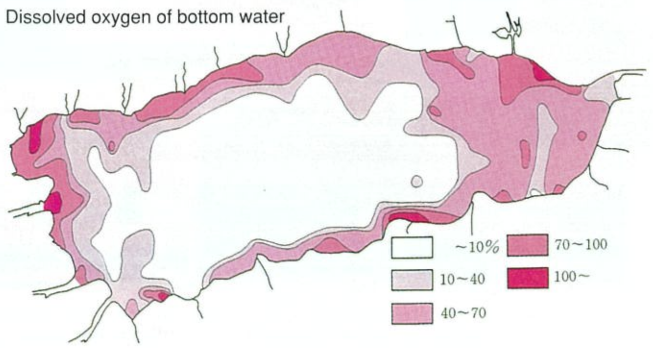


Distribution of *Corbicula japonica*

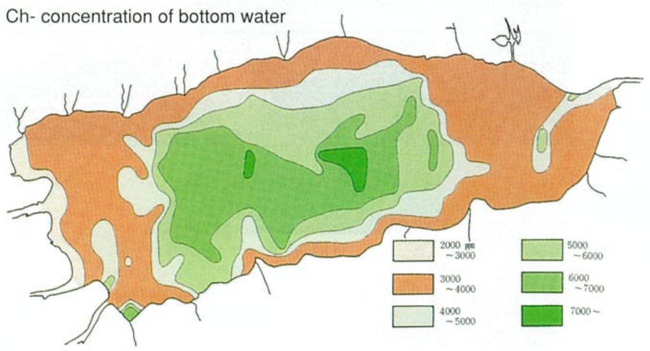


Corbicula japonica is a dominant molluscan species in brackish lakes. Lake Shinji accounts for about 60% of the production (30 billion Yen, 25million US$) in Japan. The scene of fishermen working Lake Shinji early iu the morning is one of the beautiful scenes in Matsue, a famous sightseeing place.

Dissolved oxygen of bottom water



Ch- concentration of bottom water

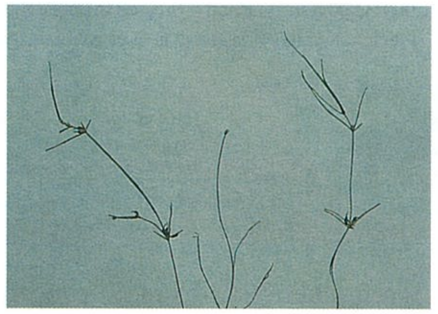


As a part of the studies on the biological diversity of estuaries and coasts, studies on several endangered aquatic macrophytes are ongoing from the viewpoint of ecological conservation.

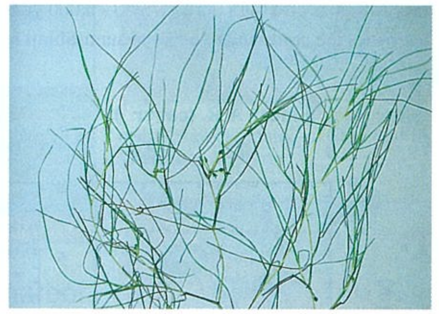
Sparganium sp.

Monochoria korsakowii

Zannichellia palustris

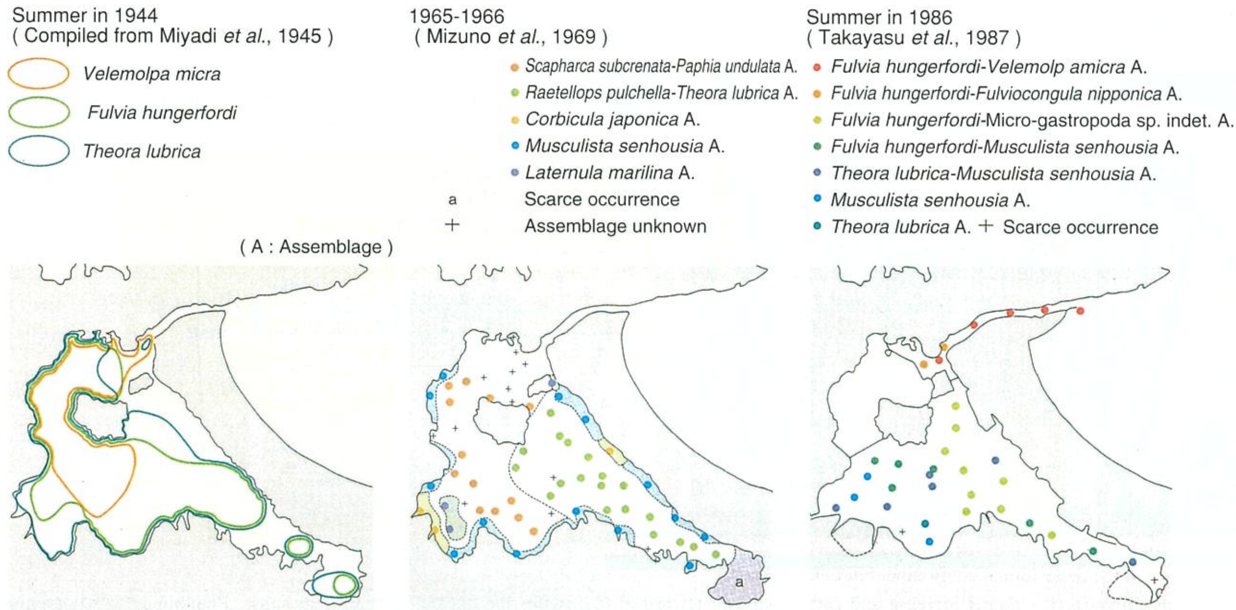


Ruppia maritima



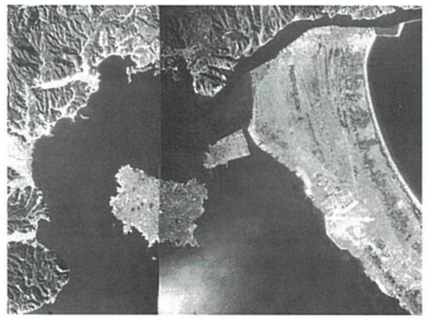
Change of the molluscan assemblages in Lake Nakaumi caused by reclamation project

Before the closing of the northwest area, distribution of the molluscan assemblages was controlled by the anticlockwise invasion of high saline water. After the closing, the assemblages distributed in the north to west area of the lagoon were entirely extinct and the other assemblages have been subjected only to the water flowing through the Nakaura Water Gate.



Artificial changes of the northern part of Lake Nakaumi by reclamation project

1947



1975

1988

TOWARD THE FUTURE

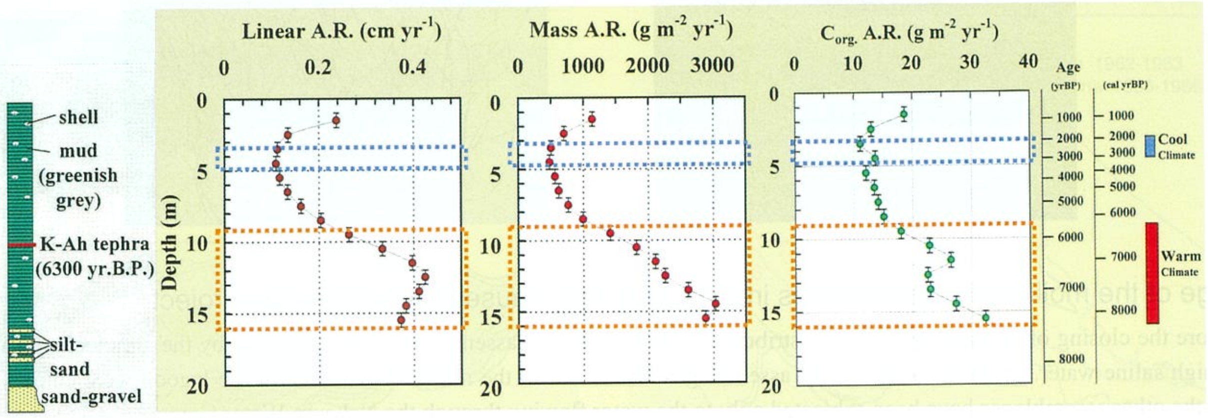
Sea-level rise due to global warming has great impact on coastal zones, especially on coastal lagoon areas. Inundation and displacement of lowlands and wetlands, increase in salinity of coastal lagoons, salt water intrusion into freshwater aquifers, etc. are predicted. Geochemical study on sediment core and observation system of halocline behaviour at Lake Nakaumi are introduced.

Depositional environment during the Holocene climatic optimum and projections of the environment in future global warming

Based on analyses of a sediment core NU9007 (central portion of Lake Nakaumi) for organic carbon accumulation rate (C_{org}.A.R.), organic nitrogen accumulation rate, sedimentation rate (S.R.), total mass accumulation rate (mass A.R.), ^{14}C dating, C_{org}.·S contents and stable carbon·oxygen isotopes ratio, the following characteristics of the depositional environment during the Holocene climatic optimum have been established. The results will offer basic informations for projections of lagoonal environments in future global warming.

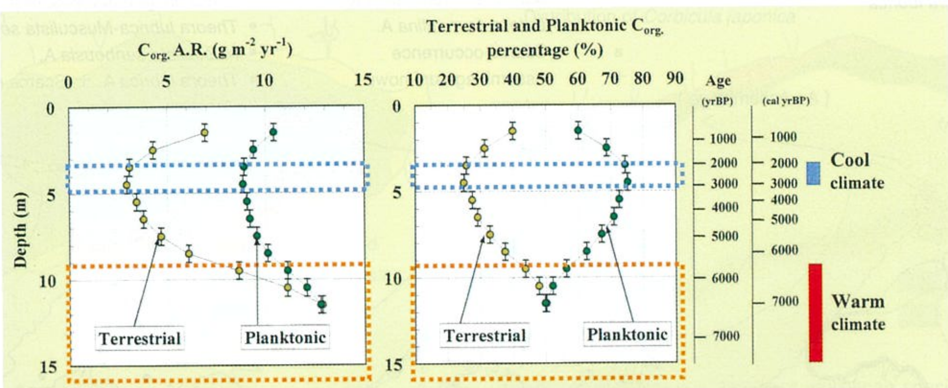
(1) Precipitation

Considering S.R. (Linear A.R.) and mass A.R. changes, precipitation appears to have increased during the Holocene climatic optimum in Lake Nakaumi. The S.R. was significantly higher (range 0.20 - 0.42 cm yr^{-1}) in the 7,500 - 5,500 yr B.P interval (warm climate) than in the 2,000 - 3,000 yr BP (cool climate; 0.11 cm yr^{-1}). Mass A.R. was also high during 7,200 - 6,000 yr B.P. at about 1,000-3,000 g m^{-2} yr^{-1}, and decreased to about 500 g m^{-2} yr^{-1} at 3,000-2,000 yr BP. These characteristics are representative of Nakaumi-Shinji lagoonal area. Precipitation in the lagoonal area possibly increase in future global warming.



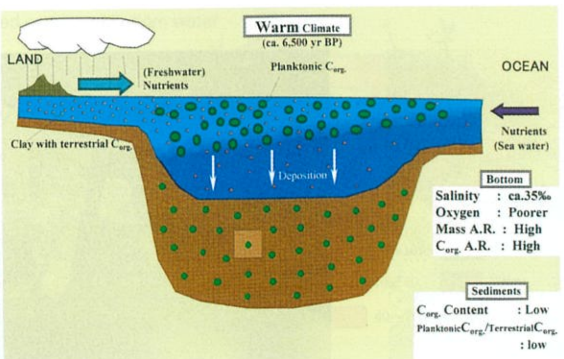
(2) Primary production

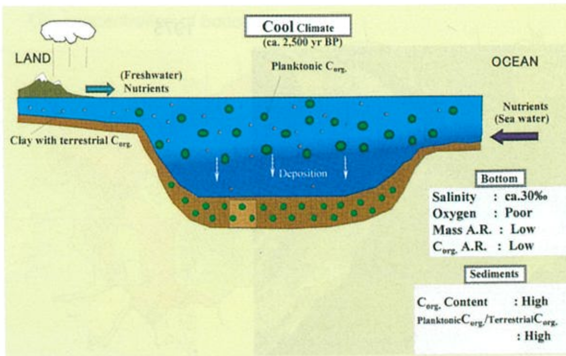
From the results of the relationships between C_{org}.A.R. and mass A.R., and between C_{org}. contents and mass A.R., the terrestrial C_{org}. content of clayish sediment is approximately constant at 0.61 %, and the relationship between planktonic C_{org}.A.R. and mass A.R. is expressed by the equation: planktonic C_{org}.A.R. (g m^{-2} yr^{-1}) = 0.0024 mass A.R. + 7.70. According to this relationship, the planktonic C_{org}.A.R. was relatively high (about 11 - 13 g m^{-2} yr^{-1}) in the warm climate of 7,200 - 5,500 yr BP, and decreased to about 9 g m^{-2} yr^{-1} in the cool climate of 3,000-2,000 yr BP. Primary production was thus at most 1.4 times higher in the warm climate during the Holocene than in the cool climate. During the warm climate interval, the river runoff would increase due to large precipitation and carry abundant nutrient salts (mainly nitrogen and phosphorous) for high primary production.



(3) Schematics of the depositional environment in Lake Nakaumi

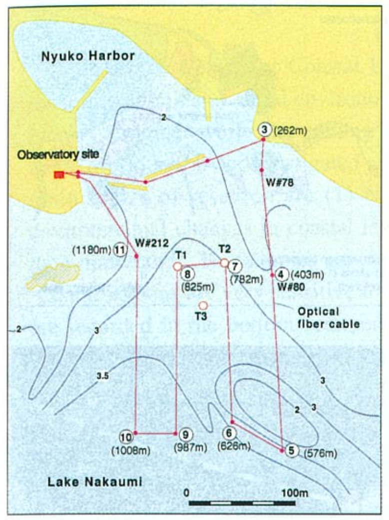
During warm climate, river runoff increase and carry abundant terrestrial C_{org}. with fine clastics and nutrient salts. Planktonic C_{org}. contents of the sediments are diluted by the clastics to low levels, although primary productivity is high. The proportion of terrestrial C_{org}. to planktonic C_{org}. in sediments is high. Lake bottom is poorer in oxygen by high primary production.



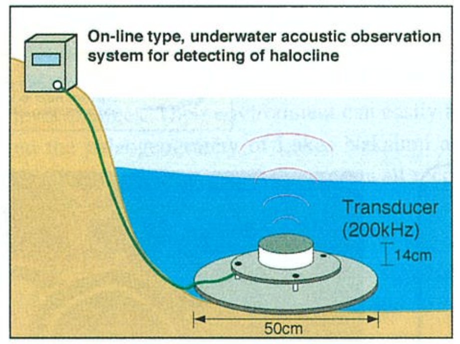


Development of a long-term observation system for the study of Halocline behaviour in brackish lakes and estuaries

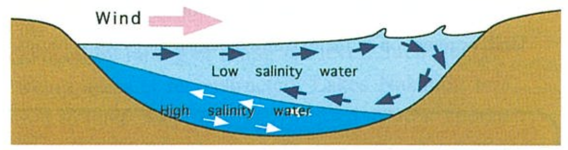
Brackish lakes are characterized by the existence of halocline. If heavy more saline water lie constantly in lower part in lakes in summer season, it become oxygen-free to dissolve P from bottom sediment, causing water pollution. It is important to know the behaviour of halocline.



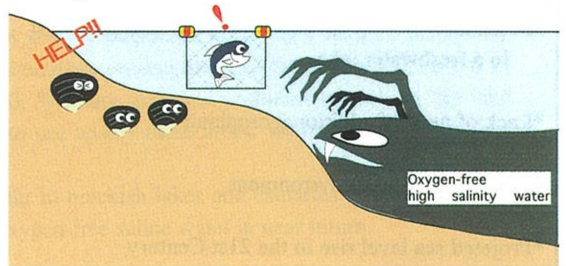
The system consists of an acoustic observation system and a lake bottom thermometry system using an optical fiber distributed sensor. The acoustic observation system measures acoustic reflection caused by the rapid change of acoustic impedance at the boundary of the halocline in water. The lake bottom thermometry system detects movement of the lower part of the lake water by means of temperature change. Long-term observations using this system were successfully carried out in Lake Nakaumi.



Halocline behaviour by wind

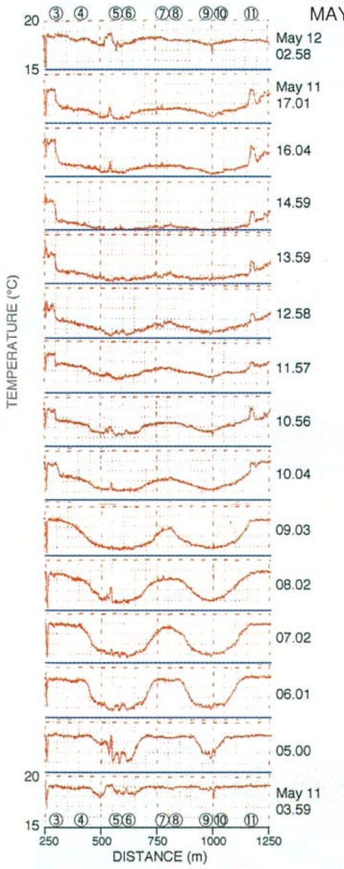


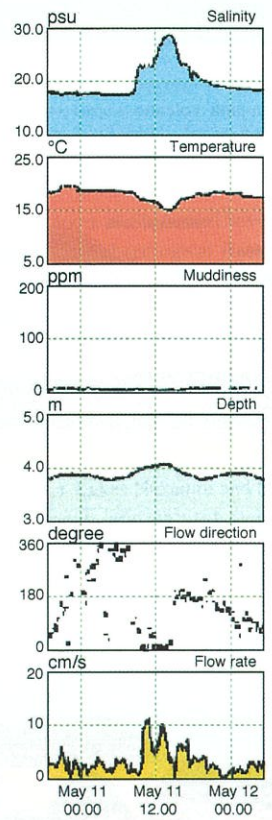
Invasion of stagnated oxygen-free high saline water to shelf area to damage fish-farm



The observation at the margin of Lake Nakaumi (Nyuko harbor, Daikon-jima Island)

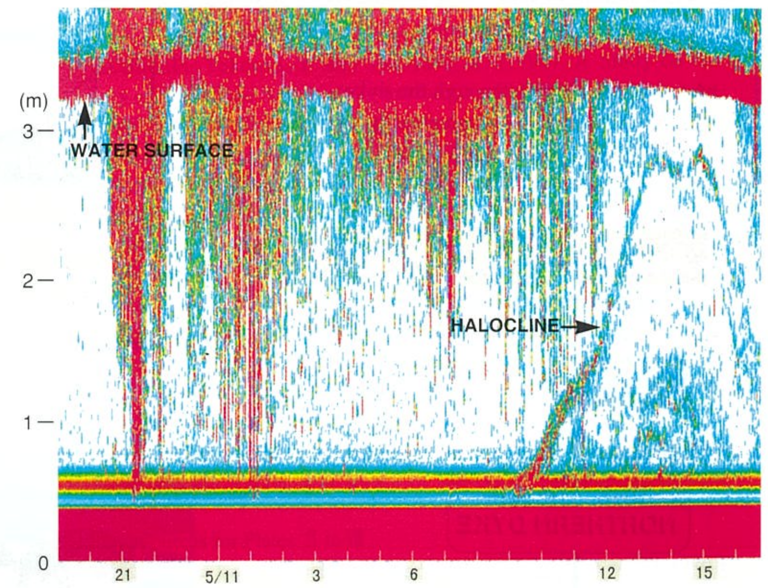
DISTRIBUTED TEMPERATURE ON LAKE BOTTOM
MAY 11,03-MAY 12,02.58





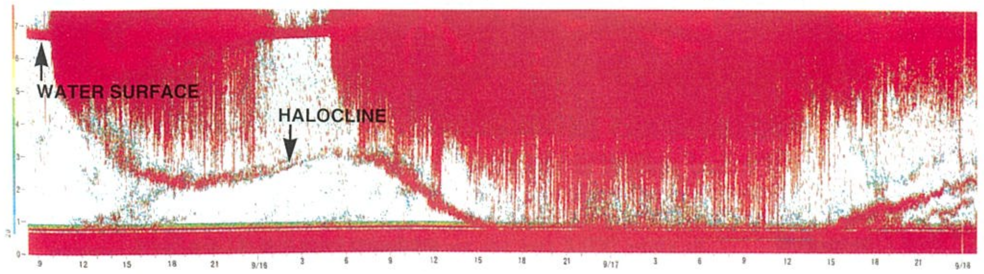
The time series data of the lake bottom water at T-3

The time series acoustic profile at T-3, May 10-11, 1995, showing the invasion of high salinity water after strong wind(> 12cm/s)

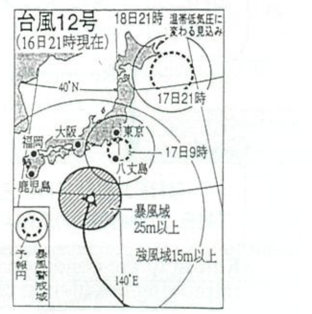


The observation at the center of Lake Nakaumi, September 15-17, 1995

The time series acoustic profile at the center of Lake Nakaumi, Sept.15-17, 1995. Strong windy days were caused by Typhoon No.12. The halocline was moved by strong wind (max.15.7cm/s) , approaching to the lake bottom.



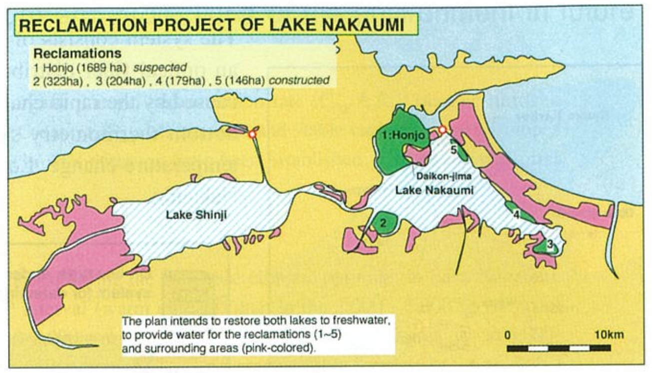
Weather chart at the time of Typhoon No.12 (21:00, sept. 16,1995)



A PROBLEM AWAITING SOLUTION

LAND RECLAMATION PROBLEM - PRO OR CON ? -

The Lake Nakaumi Reclamation Project by the Ministry of Agriculture was started in 1963, and has been suspected due to opposition by citizens since 1988, although more than 80 billion yen (about 67 million US$) has already been spent. In the background there is a national policy to decrease rice production in Japan and a tacit aknowledgement of the lack of need to develop additional cropland through reclamation. However, from a financial viewpoint, the local government of Shimane Prefecture asked the Ministry of Agriculture to resume the project in 1995, notwithstanding the local opposition. Recently the Ministry of Agriculture has decided to carry out a 2-year study to decide the best use; either reclamation for farm land, or retention of the existing brackish lakes for fisheries.



Main objections against the Nakaumi Reclamation Project

*Potential water bloom of *Microcystis* and pollution in a freshwater lake

*Lack of need of additional cropland

*Protection of lake environment

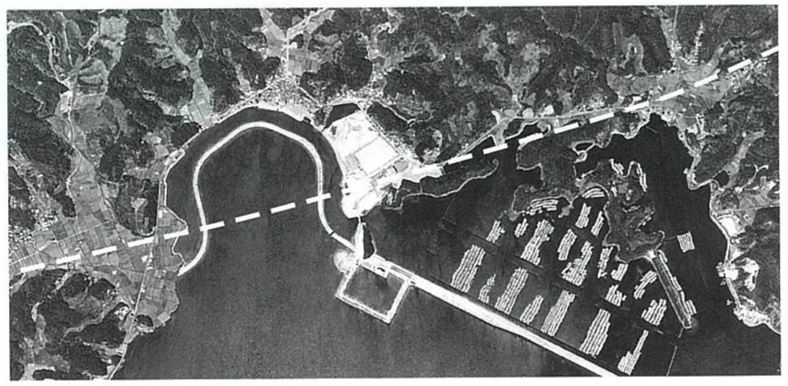
*Projeted sea level rise in the 21st Century

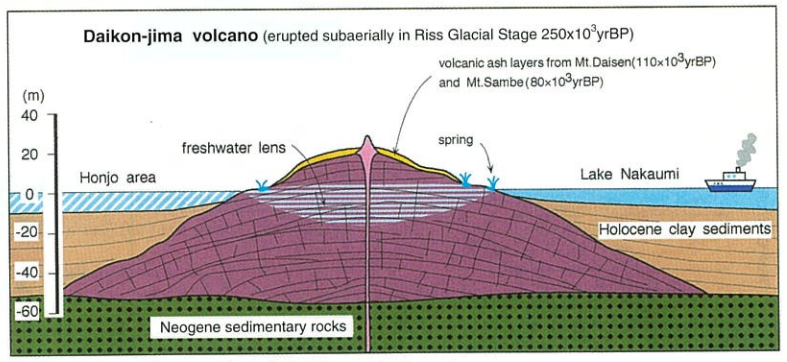
*Technical problems of making dry land below sea level

•Honjo area is too deep for reclamation(deeper than -5m)

•Daikon-jima Island in Lake Nakaumi is a porous Quaternary volcano and water could easily leak through it. Prevention would be extremely costly.

•An active fault runs through the dykes. It is inappropriate and potentially dangerous to create sub-sealevel land in this situation.





A proposal of future land-use

" To use brackish lakes wisely, we must learn from their histories."

PRESENT

1st step

BREACH THE NORTHERN DYKE

Restore the condition of 8 years ago.

2nd step

BREACH THE MAIN DYKES OF MORIYAMA AND OOMISAKI

Restore the condition of 30 years ago.

Goal

BREACH THE BASE OF THE YUMIGAHAMA SAND BAR

Return to the condition of 1000 years ago, improving circulation of sea water.

An image of the future use

Lake Shinji is used primarily as a shellfish fishery, which yields more than 30 billion Yen per year, and also for sightseeing and recreation.

Lake Nakaumi has been extensively polluted, and is less used by fishermen. It had a prosperous fishery 30years ago, producing twice that of Lake Shinji.

LOICZ OPEN SCIENCE MEETING 1997 (10-13 October, 1997) *Poster Presentation* (Abstract)

IMPROVING LAGOONAL ENVIRONMENTS FOR FUTURE GENERATIONS — A CASE STUDY OF LAKES NAKAUMI AND SHINJI, JAPAN —

T. Tokuoka, K. Takayasu, F. Takehiro and Y. Sampei

The Research Center for Coastal Lagoon Environments, Shimane University was established in 1992, and mainly studies the history of natural, cultural, and social environments of Lakes Nakaumi and Shinji, and their surrounding areas, to develop new ideas for the wise use of natural resources while maintaining a sound ecological balance. In general, coastal lagoon areas of Japan and other similar areas elsewhere in the world are to be investigated at the center in comparative studies aimed at contributing to solving global environmental problems. The main topics of research are (1) Natural environmental changes and sea-level changes in coatal lagoon areas, (2)Biodiversity and environmental changes in coastal lagoon areas, and (3) synthetic studies on geographical, cultural, and social environments of lagoon and their hinterlands. These topics are closely related to the aims of the IGBP-LOICZ Programs.

Coatal lagoons are very sensitive to sea level changes. Their environment can easily be changed by falling or rising sea level. Such changes are recorded in the bottom sediments, and the paleogeography of Lakes Nakaumi and Shinji areas is reconstructed. Lakes Nakaumi and Shinji are surrounded by many historic sites from the Holocene Period, are well recognized to have been used as fisthery grounds, fishery ports and transportation bases by the ancestors.

The Lake Nakaumi Reclamation Project to make the farm land below sea-level and to restore both lakes to freshwater to provide water for the reclamations and surrounding areas was started in 1963, and has been suspended due to opposition by citizens since 1998. In the background there is a national policy to decrease rice production in Japan, and a tacit acknowledgement of the lack of need to develop additional cropland through reclamation. Main objections against the Nakaumi reclamation project are 1) Potential water bloom of Microcystis and pollution in a freshwater lake, 2) Lack of need for additional cropland, 3) Many technical problems of making dry land below sea level. The effects due to sea-level rise should also be considered. In order to use wisely these areas, we must learn from their individual histories.

We have developed a long-term observation system for the study of Halocline behaviour in brackish lakes and estuaries. This system was successfully carried out in Lake Nakaumi, and would contribute to control the move of oxygen-free saline water in near future.

References (*in Japanese, **in Japanese with English abstract, ***in English)

Akazawa, H., Takehiro, F., Uchiyama, J. (1994) Sada-Koubu Shellmound Site Excavation Report, Part 2. Kashima Town Board of Education, Kashima, 32p.*

Ege, K.(1997, ed) The First Excavation Report of Shimane University Sites (Location Hashinawate No.1). Center for Archaeological Research, Shimane University, Matsue, 138p.*

Ege, K.(1998, ed.) The Third Excavation Report of Shimane University Sites (Location Fukamachi No.1). Center foe Archaeological Research,, Shimane University , Matsue, 96p.*

Matsumoto, I..and Adachi, K.(1996, eds.) Izumo Kanba-Kojindani Site Excavation Report, Part 1. Shimane Prefectural Board of Education, Matsue, 515p.*

Mitsunashi, T. and Tokuoka, T. (1988, eds.) Lakes Nakaumi and Shinji - Atlas for geomorphology, bottom sediments and natural history-. Research Center for the San'in Region, Special Pub., Shimane University, 115p.**

Miyadi, D., Habe, T., Kaeguchi, M. and Yamane, K. (1945) Benthic biocoenoses and thanatocoenoses of the Naka-no-umi. Rep. Physiol. Ecol., Kyoto Imp. Univ., 31, 1-24.*

Mizuno, A.,Sekine, S. Nakazawa, J.Takaku, A.Onodera K. and Ono, M. (1969) Uranium concentration in bottoms of the Lake Shinji-ko and Lake Naka-umi, with the special reference to its genetic relationship with sedimentary environment. Rep. Geol. Surv. Japan, 232, 317-352.*

Nakamura ,T., Tokuoka, T., Onishi, I., Sampei, Y., Takayasu, K., Takehiro, F., Ege, K., Nishio, K. and Watanabe, M.(1996) Holocene environmental changes and lowland historic sites in eastern part of the Shimane Prefecure. LAGUNA, 3, 9-11 with plates Ⅰ－Ⅷ.*

Nishimura, K., Anma, K., Tuchiya, Y., Matsuda, S., Tokuoka, T. and Inouchi, Y. (1994) Development of an underwater acoustic profiler for survey of wedge-like saline layer. LAGUNA, 1, 1-9.**

Sampei, Y., Matsumoto, Tokuoka, T. and Inoue, D. (1996) Organic carbon accumulation rate during the last 8000 years in Lake Nakaumi, Southwest Japan: Coastal lagoon sediments as carbon sink. The Quaternary Research (Japanese Association for Quaternary Research), 35, 113-124.**

Sampei, Y., Matsumoto, Tokuoka, T. and Inoue, D. (1997) Changes in accumulation rate of organic carbon during the last 8,000 years in sediments of Nakaumi Lagoon, Japan. Marine Chem., 58, 39-50.***

Takayasu, K., Ono, T. and Sumita, K. (1989) Natural history of the Nakano-umi and Shinji Lakes -X. Molluscan thanatocoenoses from the bottom deposits of Lake Nakano-umi and their historical distribution-. Geol. Rept. Shimane Univ., 8, 33-50. *

Takayasu, K. and Tokuoka, T. (1993) Lakes Nakaumi and Shinji. In URBAN KUBOTA, 32, 38-47.*

Takehiro,F., Tokuoka, T. and Takayasu, K. (1997) A Study on the History of the Human Activities around the Coastal Lakes. In Abstracts of International Conference on Ancient Lakes- their biological and cultural diversities-, Organizing Committee of ICAL'97, Kusatsu, 194p.***

Tokuoka, T., Onishi, I., Takayasu, K. and Mitsunashi, T.(1990) Natural history and environmental changes of Laakes Nakaumi and Shinji. Mem. Geol. Soc. Japan, 36,15-34.**

Tokuoka, T., Sampei, Y., Kamei, T., Tamari, K., Nishimura, K., Matsuda, S. and Suzaki, S. (1996) Long-term observation of the halocline in Nakaumi Lagoon. LAGUNA, 3, 73-90.**

Tokuoka, T. and Takayasu, K. (1992, eds.) Atlas for the Northern part of Lake Nakaumi (Honjo reclamation-planned area). Research Center for the San'in Region, Special Pub., Shimane University, 92p.*

Uchida, R.(1988,1989, ed.) Nishikawatsu Site Excavation Report, Part Ⅳ&Ⅴ. Shimane Prefectural Board of Education, Matsue, 274p. and 340p.*

Data sources for Plates Ⅱ to Ⅷ

Ⅱ. Modified from Tokuoka *et al.* (1990) and Nakamura *et al.* (1996) by T. Nakamura.

Ⅲ. Uchida (1988,1989, ed.); Akazawa *et al.* (1994); Ege (1997, ed.); Ege (1997, ed.); Takehiro *et al.* (1997) . Photos were offered by Archaeologocal Res.Center,Shimane Univ. and Shimane Pref. Board of Education.

Ⅳ.Takayasu and Tokuoka (1993) ; Tokuoka and Takayasu (1992, eds.) ,

Ⅴ. Airphoto(1947) by U.S. Army (published by Geographic Survey of Japan) ; Topographic map (published in 1977 by Geographic Survey of Japan, scale 1/25,000)

Ⅵ . Sampei *et al.* (1996, 1997)

Ⅶ. Tokuoka *et al.* (1996) ; Nishimura *et al* (1994)

Ⅷ. Airphoto (scale 1: 40,000) taken in 1983 by Geographic survey of Japan.

MAIN COASTAL LAGOONS IN JAPAN

No.	Name	Type	Alt. (m)	Depth(m) Max.	Depth(m) Ave.	Area (km²)	Source
1	Onuma	D	1	2.2	1.6	4.86	●
2	Kucharoko	E	0	2.5	1	14.02	●
3	Komukenuma			1.83		7.77	+
		M	0.4	2.5		4.20	×
			3	2.5		5.03	○
		E	2.5	3.8	1.2	5.81	●
4	Jibunonnaiko			5.87		3.41	+
			3	6.0		2.98	○
		E	2.5	3.0		2.76	●
5	Saromako			18.29		151.18	+
		M	0	19.5		150.53	×
			0	19.5		149.2	○
		E	0	20.5	8.7	150.29	●
6	Notoroko			21.95		59.34	+
		M	0	22.0		58.49	×
			0	21.2		58.0	○
		E	1	21.2	8.6	58.51	●
7	Abashiriko			16.46		34.25	+
		E	0.6	17.6		34.04	×
			5	16.0		32.8	○
		E	0	16.8	6.1	32.87	●
8	Touhutsuko	E	1	2.5	1.1	9.01	●
9	Huurenko			10.97		53.43	+
		M	0	11.0		52.13	×
			0	11.0		52.0	○
		O	1	11.0		56.38	●
10	Onneto			4.57		4.99	+
		E	0	6.7		5.06	×
			0	7.0		4.93	○
		O	1	6.7	1.2	5.51	●
11	Akkeshiko			6.87		34.15	+
		M	0	6.9		31.99	×
			0	6.9		31.7	○
		M	0			31.80	●
12	Touroko			4.0		5.90	+
		E	8	7.0		6.32	×
			8	7.0		6.53	○
		E	8	7.0	3.1	6.37	●
13	Harutoriko		1.8	10.90			+
			5	8.5		0.38	○
		E	5	9.0	3.4	0.37	●
14	Yuutounuma	D	5	3.5	1.3	3.49	●
15	Obuchiko			4.95		3.93	+
			5	6.0		3.68	○
		M	3	4.7	2.1	3.71	●
16	Takahokonuma	E	1	7.0	2.7	5.83	●
17	Ogawarako		4	5.5		107.96	+
		O	1.5	25.0		62.26	×
			1	25.0		64.8	○
		M	0	24.0	10.5	62.69	●
18	Juusannko			2.3		48.43	+
		M/D	0	7.0		20.80	×
			0	3.0		20.8	○
		M	0	3.0		18.07	●
19	Hachirogata			4.6		286.36	+
		E	0	4.7		223.29	×
			0	4.7		220.4	○
		E	0	12.0		27.64	●
20	Kamoko			8.2			+
		E	0	9.0		4.86	×
			0	9.0		4.83	○
		E	0	9.0	5.2	4.95	●
21	Hossyouzuko			2.7		4.71	+
22	Kahokugata		6.5	2.7			+
		E	0.8	2.1		23.10	×
			0.8	2.0		26.0	○
		E	0	6.5	2.0	8.17	●
23	Imaegata			2.8		3.20	+
			0.8	1.9		2.38	○
24	Shibayamagata			4.6		5.40	+
		E	1	2.8		5.13	×
			1	2.8		5.0	○
		E	2	4.9	2.2	1.71	●
25	Kitagatako			2.7		2.60	+
			5	3.0		2.0	○
		E	0	3.6	2.1	2.14	●
26	Kugushiko		1?	2.5		1.40	+
			0	2.5		1.38	○
		E	0	2.5	1.8	1.40	●
27	Hirugako		1?	43.0		1.10	+
			0	38.0		0.9	○
		O	0	38.5	14.3	0.92	●
28	Asokai	M	0	14.0	8.4	5.01	●
29	Kumihamawan	M	0	20.0		7.26	●
30	Koyamaike		2	5.0		6.66	+
		E	1	8.9		7.25	×
			2	8.9		6.93	○
		E	0	7.0	2.8	6.88	●
31	Togoike			1.8		6.27	+
			4	7.5		4.1	○
		E	0	4.6	2.1	4.06	●
32	Nakaumi			7.8		108.80	+
			0	9.0		104.0	○
		E	0	8.4	5.4	88.69	●
33	Shinjiko		2.5	6.9		84.00	+
		E	1	6.4		83.13	×
			0.7	6.4		80.0	○
		E	0	6.4	4.5	80.3	●
34	Jinzaiko		3	2.2		1.35	○
		E	0			1.35	●
35	Mangokuura	E	0			3.72	●
36	Matsukawaura	E	0	5.5		6.33	●
37	Hinuma		1.5	3.0		1.93	+
		E	0.6	3.6		12.20	×
			3	3.5		12.0	○
		E	0	6.5	2.1	9.35	●
38	Kasumigaura		2	7.58		187.7	+
		E	2	7.6		189.17	×
			1	7.0		178.0	○
		E	0	7.0	3.4	168.18	●
39	Kitaura		0.5	3.5		52.75	+
		E	1	10.0		39.85	×
			1	10.0		78.8	○
		E	0	10.0	4.5	34.39	●
40	Sotonakasakaura		1	9.0			+
		E	1	8.9		6.60	×
			1	8.9		6.13	○
		E	0	8.9		6.01	●
41	Teganuma	E	3	2.9	0.9	6.5	●
42	Inbanuma	E	1	1.8	1.7	11.6	●
43	Sanaruka			3.90		1.07	+
			5	3.9		1.23	○
		E	3	3.3	1.5	1.21	●
44	Inohanako			12.12		5.36	+
			0	12.1		5.43	○
		M	0	7.0	4.6	5.48	●
45	Hamanako			13.0		66.92	+
		E	0	15.8		72.04	×
			0	15.8		73.5	○
		M	0	16.6	4.8	66.05	●

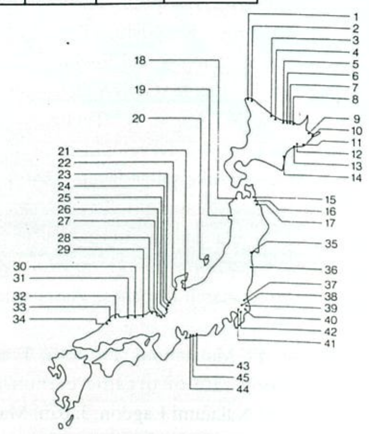
E:Eutrophic Lake

M:Mesotrophic Lake

O:Oligotrophic Lake

D:Dystrophic Lake

+ A.Tanaka,1911
× S.Yoshimura,1937
○ S.Horie,1956
● Environment Agency,1989



LAGUNA（汽水域研究）5，1～13 頁（1998 年 2 月）
LAGUNA **5**, p.1－13 (1998)

コアＳＪ96の概要と宍道湖の古環境変遷

高安克己[1]・出雲古代景観復元チーム[2]

Holocene environmental change of a coastal lagoon, Shinji-ko, southwest Japan, based on the analyses of the Core SJ96

Katsumi Takayasu[1] and the Team for Reconstruction of Ancient Environment in Izumo Province[2]

Abstract: For clearing the Holocene environmental change, a core sample, SJ96, drilled in the coastal lagoon, Shinji-ko, southwest Japan, is examined by soft X-ray photo observation, and analysed for water content, loss of ignition, total nitrogen content, total organic carbon content and total sulphur content. The Holocene deposit of the core, Nakaumi Formation, is 14.83m in thickness and is divided into 5 units, I, II, III, IV and V in ascending order. The unit IV is divided into 3 subnunits, IV-L, IV-M and IV-U from the lower to the upper. The unit I and II show a brackish water environment with much terrigeneous material. The unit III has the highest saline environment in the core and some species of molluscs are present indicating a bay environment. The organic matter of planktonic origin is dominant, indicating high primary productivity. The unit IV, characterised by the occurrence of many juvenile shells of *Potamocorbula* sp., is a closed lagoon environment with rather low primary productivity. The K-Ah tephra（about 6300yr.B.P.）is intercalated in the lower part of the unit IV-L. The average ratio of sedimentation is smaller in the upper part of the K-Ah tephra than in the lower part of it. The unit V is deposited after the Hii River flowed directly into the Shinji-ko. The average sedimentation ratio of this unit is more than twice of the previous unit. Plenty of nutrients have been transported by Hii River, due to which the primary productivity in Shinji-ko becomes high and the organic matter of planktonic origin become predominant in the bottom sediments.

Key words: Holocene environmental change, coastal lagoon, C-N-S analyses, Shinji-ko, Jomon transgression

は　じ　め　に

これまでに宍道湖で行われた調査ボーリングのうち，完新統の基盤にまで達するコアで古環境復元を目的に分析されたものには，1960 年代に工業技術院地質調査所が掘削した SB1 と SB2，および 1987 年に建設省出雲工事事務所が掘削した BP1 がある（図 1）．SB1 と SB2 については水野ほか（1972）が層序学的な記載と対比について検討し，三梨・徳岡編（1988）の「中海・宍道湖　地形・底質・自然史アトラス」の中で，水野が肉眼的記載の詳細と間隙水の塩素イオンおよび炭酸イオン濃度の分析結果について公表している．また，大西（1977），大西ほか（1990）は同じコアで花粉分析を，紺田・水野

[1] 島根大学汽水域研究センター
Research Center for Coastal Lagoon Environments, Shimane University, Matsue 690-8504, JAPAN
[2] 井川浩子，立見博俊，船来桂子　（以上，島根大学），松本岩雄，佐伯徳哉，野々村安浩（以上，島根県古代文化センター）
Hiroko Igawa, Hirotoshi Tatsumi, Keiko Funaki; Shimane University.
Iwao Matsumoto, Noriya Saeki and Yasuhiro Nonomura; Center for Studies of the Ancient Culture, Shimane Prefecture