P3-1

WATER QUALITY ASSESMENT IN THE DIYAWANNA LAKE, SRI LANKA

U. Y. I. L. Dharmoasma[1], Ranjana U. K. Piyadasa[2]

[1]Sri Lanka Land Reclamation and Development Cooperation, Colombo, Sri Lanka,
[2]Department of Geography, University of Colombo, Colombo, Sri Lanka.

Keywords: algae, dissolved oxygen, electrical conductivity, pH, turbidity

ABSTRACT

Water in Diyawanna Lake, Sri Jayawardenapura, Sri Lanka indicated many water quality degradation due to human activities and interconnected stream discharge. Diyawanna Lake located in the centre of the administrative capital of Sri Lanka. Diyawanna Lake is an important water retention area which is to be completely dredged, de-silted and fully rehabilitated resent past years. In present the lake environment is become deteriorated by human and natural phenomena. The Lake catchment surrounding urban areas are influenced by various industrial zones and homestead. The study was done with the objective of determining the status and trends in water quality assessment in Diyawanna Lake. The results reveled that for the period of 2006-2010; the pH values of varied from 5.2 to 7.4. The electrical conductivity values varied from 0.07 mS/cm to 0.30 mS/cm and from 0.11mS/cm to 0.23 mS/cm respectively. The turbidity values of Location 1 and Location 2 are varied from 4.15 NTU to 33.50 NTU and from 4.00 NTU to 27.90 NTU respectively. The Dissolved Oxygen concentrations chnaged ranged from 3.02 mg/l to 6.88 mg/l and 2.17 mg/l to 6.84 mg/l respectively. The Nitrate (V)-N values of are varied from 0.01 mg/l to 0.70 mg/l and from 0.01 mg/l to 0.80 mg/l respectively.

1. INTRODUCTION

two-thirds of the Earth is covered by water. Among many water bodies, lakes are the most fertile, diversified and productive of all the ecosystems in the world. A variety of environmental goods and services are bestowed upon us by lakes which makes them vulnerable to human exploitation. The water quality of receiving water bodies such as rivers and lakes is critically important because it is one of the most essential resources for human existence and settlement. However, the rapid growth of population and increase of urban activities significantly influence the water quality of receiving water bodies [1]. water quality of urban water bodies are being changed over the time due to various reasons. Lakes are subject to various natural processes taking place in the environment, such as hydrologic cycle. With enormous developmental activities, human beings are responsible for the severe deterioration of several lakes.

The canal system which is in and around Colombo-Sri Jayewardenepura area is currently in such an environmentally deteriorated condition due to rapid development and urbanization of the area. The quality of water and habitat in most of the areas are influenced by industrial and public effluent discharge to the canal system [2]

In the recent past, water of Diyawanna Lake indicated many water quality problems such as bloom formation, fish kills etc. The maintenance of good water quality in Diyawanna Lake is fundamental to the long term future of the lake as a multi-user resource. Good water quality, with low levels of micro organisms, pesticides and other contaminants, is vital to maintain the lake's current social and scenic value. Any future development of recreation in the lake is likewise dependent on maintaining good water quality in the lake now.

However there is no recent scientific water quality analysis conducted for the inlets of the lake to determine its' status and to identify the potential pollution sources. The lack of such scientific information is a constraint to develop proper management criteria to protect the lake and to maximize its' uses to the community. Therefore it has become a needy requirement to identify level and trends of the deterioration of the water quality of the lake by analysing the inlets' water.

The objective of this research study was to determine the status and trends in water quality changes of two inlets of Diyawanna Lake.

2. METHODOLOGY

2.1. Study Area

The study area is confined to two water inlets to the Diyawanna Lake and surroundings (Figure 1). In this study, the water samples collected at two locations namely: Kimbulawala Madiwela (Location 1) and Battaramulla South-Pelawatte (Location 2) were analyzed.

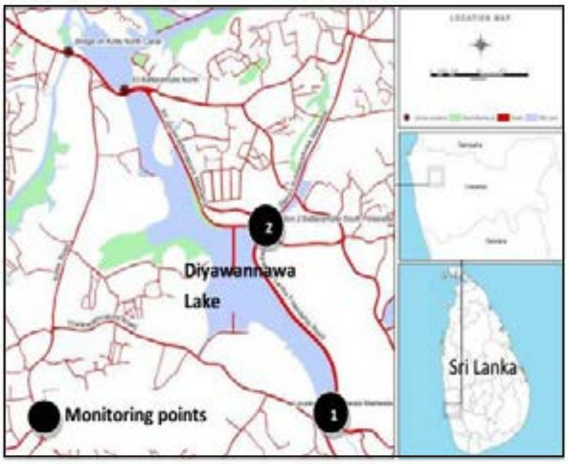


Figure 1: Study area including two water inlets to the Diyawanna Lake and surroundings

The GPS coordinates of Location 1 and Location 2 are 6°52'43.93"N; 79°55'36.58"E and 6°53'31.48"N; 79°55'17.08"E respectively.

2.2 Data Collection and Analysis

The monthly water quality data for a period of five years from 2006-2010 available at Sri Lanka Land Reclamation and Development Corporation were used for the study. The water quality parameters considered for the study are pH, Turbidity, Electrical Conductivity, Dissolved Oxygen and Nitrate (V)-N. In addition,

In addition, rainfall data, land use maps of the study area and primary data gathered through field visits were used in the study. Field visits were made along two identified canals and around the lake in order to ground verify the existing land use pattern of the area. In addition, identification of potential point and non-point pollution sources of the area, which will directly or indirectly impact on the water quality of the canals were done through transect walks.

The primary and secondary data collected through field observations and secondary sources were analyzed using MS Excel and SPSS packages.

3. RESULTS

According to the results obtained for the period of 2006-2010; the variation of the selected water quality parameters of Location 1 and Location 2 are given in Table 1 and Table 2.

Table 1: Variation of water quality parameters of Location 2 during the period of 2006-2010

Parameter	Unit	Min	Max
pH	-	5.4	7.4
Electrical Conductivity	mS/cm	0.07	0.30
Turbidity	NTU	4.15	33.50
Dissolved Oxygen	mg/l	3.02	6.88
Nitrate (V)-N	mg/l	0.01	0.70

Table 2: Variation of water quality parameters of Location 2 during the period of 2006-2010

Parameter	Unit	Min	Max
pH		5.2	7.2
Electrical Conductivity	mS/cm	0.11	0.23
Turbidity	NTU	4.00	27.90
Dissolved Oxygen	mg/l	2.17	6.84
Nitrate (V)-N	mg/l	0.01	0.80

In all the instances, except in 2006 where the mean pH is 6.7, the mean pH values of both locations are less than 6.5, which indicate the water is more acidic.

The average electrical conductivity value of Location 1 and Location 2 over the five years varies from 0.14 mS/cm to 0.17 mS/cm and 0.15 mS/cm to 0.18 mS/cm respectively. When comparing the electrical conductivity variation of 2 locations over the period of five years, the highest electrical conductivity is in year 2009 for both locations and the electrical conductivity of Location 2 is comparatively higher than the electrical conductivity of Location 1.

In Location 1, the lowest mean turbidity was recorded in 2008 (9.01 NTU) and the highest mean turbidity was recorded in 2007 (14.90 NTU). In Location 2, the highest mean turbidity was recorded in 2006 (12.21 NTU) and the lowest mean turbidity was recorded in 2010 (10.18 NTU). Except for the mean turbidity of 2009, the mean turbidity values of other four years show a decreasing trend. Except in few cases, the turbidity values of both locations are higher than the maximum permissible limits (max. 2 NTU according to SLS 614:2013; max. 5 NTU according to proposed water quality standards for Sri Lanka by CEA).

The mean Dissolved Oxygen concentration in the Location 1 over the five years is ranged from 4.69 mg/l-5.86 mg/l. The Dissolved Oxygen values over the period indicate an increasing trend. The mean Dissolved Oxygen values of Location 2 during the period of 2006-2010 are varied from 4.15mg/l to 5.29mg/l. In all five years, mean Dissolved Oxygen values in Location 1 is higher than the mean Dissolved Oxygen values in Location 2. Except in few cases, the Dissolved Oxygen levels recorded for two locations for the period of 2006-2010 are higher than 3 mg/l which indicating acceptable levels during the sampling occasions according to the proposed water quality standards for Sri Lanka by CEA for fish and aquatic life.

The mean levels of Nitrate (V)-N in Location 1 are varied from 0.14 mg/l to 0.27 mg/l where the lowest mean value is in 2006 and the highest mean value is in 2010. The mean levels of Nitrate (V)-N in Location 2 is varied from 0.12 mg/l to 0.27 mg/l whereas the variation of the mean Nitrate (V)-N value in 2010 is similar to the mean Nitrate (V)-N recorded in 2010 in Location 1. In both locations, Nitrate (V)-N levels are within the standard limits (max. 5 mg/l Nitrate (V)-N is threshold for fish and aquatic life as indicated in proposed water quality standards for Sri Lanka by CEA).

4. CONCLUSION

The study revealed that the water quality of two inlets have deteriorated over the period of 2006-2010. The quality of water in most of the areas along these two canals are influenced by both point and non-point sources. It has been severely affected on well being of the community live around these canals. Therefore it is important to conduct further studies on the current status of water quality of inlets, outlets and also the Lake and implement effective policy implications to avoid polluting the Diyawanna Lake.

Acknowledgment: Authors wish to express their sincere thanks to Sri Lanka Land Reclamation and Development Corporation.

REFERENCES

[1] Goonetilleke, A., Thomas, E., Ginn, S. and Gilbert, D., Understanding the role of land use in urban storm water quality management. *Journal of Environmental Management*, 74 (01), pp. 31-42, 2005.

[2] Perera, L. G. R. Y., Wattavidanage, J. and Nilakarawasam N., Development of a Macroinvertebrate–based Index of Biotic Integrity (MIBI) for Colombo-Sri Jayewardenepura Canal System, Journal of Tropical Forestry and Environment, 2 (01), pp.10-19, 2012.

[3] Lebrun J.P, Water environmental issue in Greater Colombo. In: *Colombo Environmental Issues at Stake.* Colombo: CMC, pp 58-74, 2007.

[4] Perera, R. , Problems and prospects of utilizing canal banks to enhance the built-environment in Colombo, Built-Environment, 03(02), 2003.

[5] Sri Lanka Land Reclamation and Development Cooperation, *Proposed remedial measures for floods in the city of Colombo.* Colombo: SLLRDC, p2, 2011.

P3-2

Abundance and Distribution of Ciliated Protozoans in Marantao's Littoral and Pelagic Zones of Lake Lanao, Philippines

Fema Abamo[1,2], Camar Ameril[1], Hanifah Diacatra[1], Morsidah Ampa[1]
[1]Biology Department, Mindanao State University, Marawi City, Philippines
[2]Office of the Research Director, MSRTC, MSU, Marwi City

Keywords: ciliates, protozoa, bio-indicators, Lake Lanao, freshwater

ABSTRACT

Ciliated protozoans are one-celled organisms known as bio-indicators of organic pollution in freshwater ecosystem. The study intended to determine the presence, distribution and abundance of ciliates in Lake Lanao at the littoral and pelagic zones of Marantao, Lanao del Sur during summer season of 2016. It also aimed to determine the trophic state of the waters in sampling stations. Ten (10) morphologically distinct ciliate species belonging to 6 genera, were observed in littoral zone while 11 species belonging to 7 genera in pelagic zone. In both zones the abundances of ciliates were quite low except for station 3 in the littoral zone and it was significantly different from rest of the stations in both zones. The said station was readily accessible for human activities thus probably had higher organic load during sampling which may account for its higher abundance. Although the average abundance of ciliates in the littoral zone (201.56 cells/m^3) was higher than the pelagic zone (29.19 cells/m^3), but the difference was not statistically significant. Interestingly, the ciliate abundance data when compared to a trophic state classification standard for lakes, the results implied that the water quality in both zones are still categorized as ultraoligothrophic, that is, the water was still pristine and fit for drinking. Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were commonly distributed in both zones which is reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp., *Opercularia* sp. *and Euplotes* sp. in pelagic zone only.

1. INTRODUCTION

Ciliated protozoans are one-celled animal-like organisms characterized by the presence of hair-like structures called cilia. They play a very significant link in the food chain as algal grazers and bacterial feeders. Ciliates gained popularity because they are bio-indicators of organic pollution [1,2,3] and in monitoring the health of aquatic ecosystems. They have been utilized as model organisms for microbial, cell and molecular biology studies, toxicity bioassays of pollutants, chemosensory responses, lysosomal studies and others. They have ubiquitous distribution, high reproductive rate, and they can easily be cultured in hay infusion.

Little has been known about ciliates in Lake Lanao thus this study was conducted as part of a big project on preliminary inventory of ciliated protozoan in Lake Lanao, situated in Lanao del Sur, Mindanao, Philippines. Moreover, alarming reports on lake's deterioration triggered the conduct of this study as human activities are prevailing in the lake such as throwing of garbage and sewage directly into the lake, making lake as receptacle of human wastes. Since ciliates can be tapped as bio-indicators of organic pollution, ciliate profile of the lake such as ciliate inventory, distribution and abundance is seen as important component of establishing base line data to monitor the health ecosystem of Lake Lanao. The study therefore aimed to determine the spatial variation of ciliates in terms of abundance and distribution between the littoral and pelagic zones of Lake Lanao bordered by Barangay Inudaran, Municipality of Marantao, Lanao del Sur. It also intended to determine the trophic status of the Lake by ciliate abundance. Results of the data can serve as basis for proper management, conservation, and sustainability of the lake's resources.

2. METHOD

Sampling Sites, Sample Collection and Fixation

The study was conducted in the littoral and pelagic water zones of Lake Lanao bordered by Barangay Inudaran, municipality of Marantao, Lanao del Sur. Three sampling stations (Fig 1) with 20-m intervals were established in each zone. Water temperature, pH level, and turbidity (improvised secchi disk in pelagic zone only) were also recorded. Sampling collection was conducted in April 2016, a summer season in the Philippines.

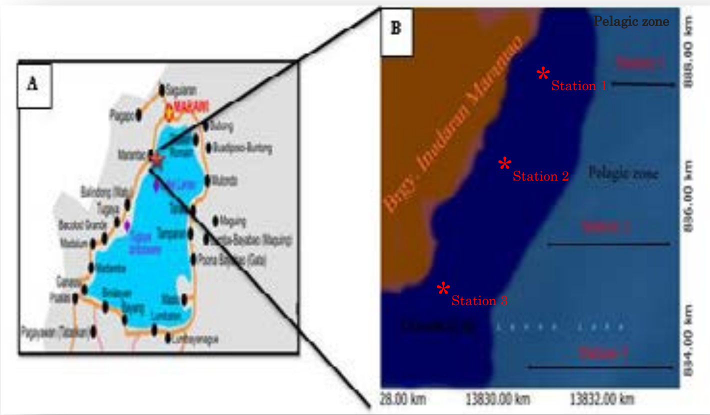


Fig 1. Map of Lake Lanao (A) showing sampling stations (B)

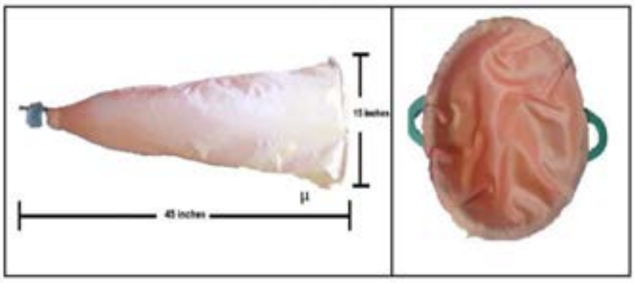


Fig 2. The improvised plankton net (left) and sieve (right)

Microscopic Observation and Documentation

Ken-A Vision and an ordinary compound microscope (at 100x and 400x magnifications) were used to observe and count ciliates. Ciliates from the fixed samples were identified primarily by the presence of a hair-like structure called cilia, ciliatures, body size, shape and nuclei [4]. The counts of each replicate were recorded for calculation of ciliate abundance as shown below.

Abundance: (cells/m^3) = (n x k) / V

Where, n= the number of counts for a particular ciliate
k= the proportion of subsample volume/ total volume sampled
V= mouth area of plankton net x distance towed diameter = 0.381m

Data Analysis

In determining whether ciliate abundance between sampling stations and between zones had significant difference, Analysis of Variance (ANOVA), Duncan's Multiple Range Test (DMRT) and Mann-Whitney U test were utilized.

3. RESULTS

Ten (10) morphological distinct ciliate species were identified in the littoral zone distributed across six (6) genera, namely: *Paramecium*, *Vorticella*, *Podophrya*, *Tetrahymena*, *Oxytricha*, and *Loxodes*; while 11 species in pelagic zones, under seven (7) genera, namely, *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella and Euplotes.* Selected photomicrographs of these ciliates are shown in Figs 3-7. Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were commonly distributed in both zones which is actually reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp., *Opercularia* sp. *and Euplotes* sp. in pelagic zone only.

Fig 8 shows the abundance of ciliates in three different sampling stations from both the littoral and pelagic zones. In the deeper pelagic zone, no significant difference in the abundance of ciliates observed in three different stations by ANOVA; however in the shallower littoral zone, the mean abundance of ciliates in station 3 (536.11 cells/m^3) was far higher than the rest of the sampling stations and the difference was highly significant by ANOVA and DMRT. All stations in littoral zone were shallow at 1-1.5m depth but the water in station 3 was relatively turbid compared to other 2 stations. Moreover, stations 1 and 2 were rarely frequented by people due to the nearly inaccessible path towards that part of the Lake. Station 3, on the other hand, was readily accessible and frequently disturbed by human activities like bathing and washing clothes. The organic load of the said station could be higher during the sampling which probably accounted for higher ciliate counts.

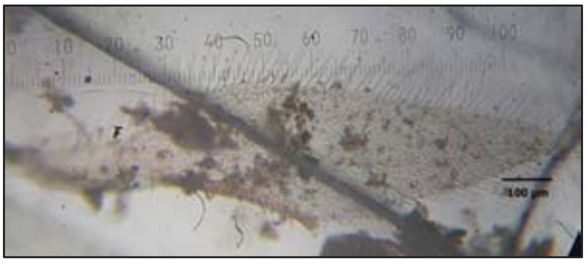


Fig 3. *Loxodes sp.*

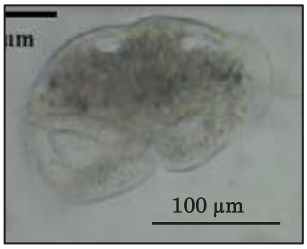


Fig 4. *Euplotes* sp.

Fig 5. *Vorticella* sp.

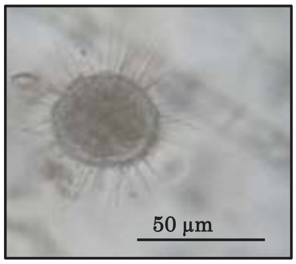


Fig 6. *Podophrya* sp.

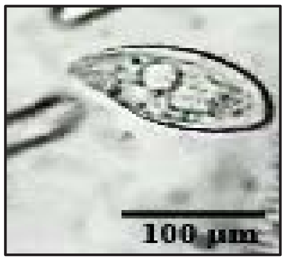


Fig 7. *Tetrahymena* sp.

The average abundance of ciliates in each zone is compared in Fig 9. The figure seemingly demonstrates that ciliate abundance in the littoral zone outweighed the pelagic zone but interestingly the difference between zones was not statistically significant when compared using Mann-Whitney U test. This could probably be due to the fact that all stations in both zones had similar lower ciliate counts except for station 3 in the littoral zone; but the abundance of the said station 3 somehow did not affect the abundance of the whole zone consequently the average abundances between zones were not statistically different when compared.

Although the sampling station 3 in the littoral zone so far had the highest ciliate abundance but in terms of ciliate composition, but only 3 genera were observed and it was dominated by *Vorticella* species (Fig 10) comprising 92% of ciliates in the site. This is not surprising though since *Vorticella* spp. have been identified as typical indicator of pollution as early as 1952 from moderately to heavily polluted [5]. It is possible that this ciliate group indicated higher organic nurients in that particular station.

The ciliate abundance data can be utilized to determine the trophic condtion of the lake. Table 1 shows the trophic classification of the lakes set by Beaver & Crisman in 1989 [3]. Based on the gathered data on ciliate abundance, the results implied that both zones of Marantao lake waters was still under ultraoligotrophic state, that is, the lake is highly pristine, the waters are of high-drinking quality, well-oxygenated and low in nutrients [6] during sampling.

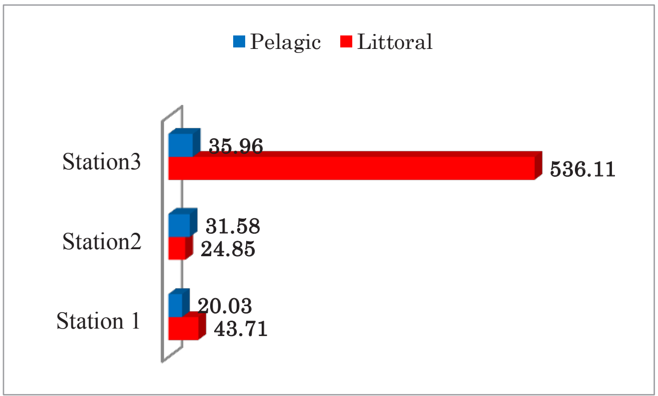


Fig 8. Mean abundance of ciliates in 3 stations (cells/m^3) of littoral and pelagic zones

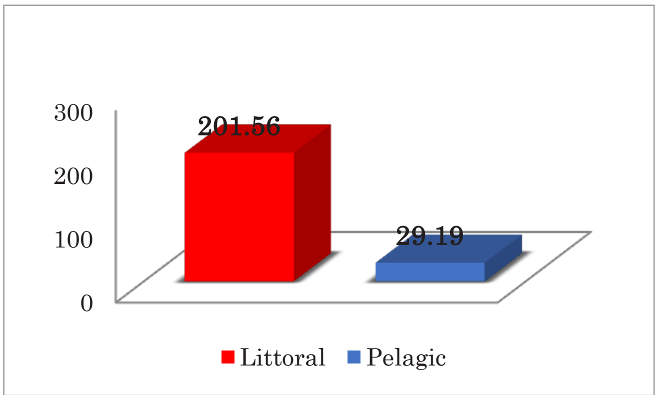


Fig 9. Average ciliate abundance (cells/m^3) in littoral and pelagic zones

4. CONCLUSION

Ciliates species under genera *Paramecium*, *Vorticella*, *Podophrya*, *Tetrahymena*, *Oxytricha*, and *Loxodes*; *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella, Glaucoma Opercularia* sp. *and Euplotes* were observed in the Littoral zones while *Glaucoma, Opercularia*, *Paramecium*, *Podophrya*, *Tetrahymena, Vorticella and Euplotes in pelagic zone.* Species of *Paramecium, Vorticella, Podophrya, Tetrahymena* were observed in both zones reflective of their cosmopolitan distribution. *Oxytricha* sp. and *Loxodes sp.* were observed in littoral zone only while *Glaucoma* sp.*, Opercularia* sp. *and Euplotes* sp. in pelagic zone only. Littoral zone had higher ciliate abundance than pelagic and *Vorticella* spp. dominated the ciliates in littoral area possibly indicating higher organic nutrient present in the shallow waters during sampling. However, the ciliates abundance in both zones were quite low against standard, indicating the waters in sites during sampling were ultraoligotrophic, that is, the waters were still clean and safe to drink.

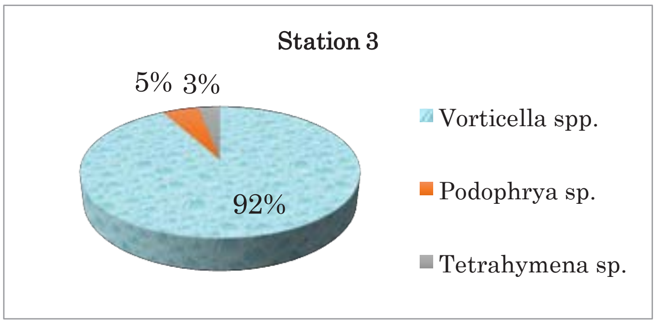


Fig 10. Percentage distribution of ciliates found in station 3, littoral zone

Table 1. Trophic state classification standard for lakes set by Beaver and Crisman (1989) utilizing planktonic ciliate abundance [3]

Trophic state	Range of observed abundances (cells/mL)
Ultraoligotrophic	2.4
Oligotrophic	2.3-10.8
Mesotrophic	18.0-70.9
Eutrophic	55.5-145.1
Hypereutrophic	90.0-215.0

5. REFERENCES

[1] Palm, H. W., & Dobberstein, R. C. (1999). Occurrence of trichodinid ciliates (Peritricha: Urceolariidae) in the Kiel Fjord, Baltic Sea, and its possible use as a biological indicator. *Parasitology Research, 85*(8-9), 726-732.
[2] Bernard, C., & Fenchel, T. (1996). Some microaerobic ciliates are facultative anaerobes. *European Journal of Protistology, 32*(3), 293-297.
[3] Beaver, J. R., & Crisman, T. L. (1989). The role of ciliated protozoa in pelagic freshwater ecosystems. *Microbial Ecology, 17*(2), 111-136.
[4] Jahn, T. L., Bovee, E. C., & Jahn, F. F. (1979). *How to know the protozoa.*(2nd Ed.).
[5] Mohr, J. L. (1952). Protozoa as indicators of pollution. *Sci Mon, 74*(1), 7-9.
[6] https://www.worldatlas.com/articles/what-are-oligotrophic-mesotrophic-and-eutrophic-lakes.html

Acknowledgement
This study is funded by the National Research Council of the Philippines (NRCP)-Grants-In-Aid.

P3-3

Relative importance of physical and biological factors regulating tintinnid populations: a field study with frequent samplings in Sendai Bay, Japan

Takehiro Kazama[1] and Jotaro Urabe[2]

[1]National Institute for Environmental Studies, [2]Tohoku University

Keywords: estuaries, microbial food web, micro-zooplankton, population dynamics, selective feeding

ABSTRACT

To examine factors regulating the summer population dynamics of tintinnid species, temporally high- frequency observations of tintinnid ciliates were performed in Hiroura Estuary in Sendai Bay. Sampling was conducted on alternate days from 5 July to 2 August 2010 at three estuary sites to examine which environmental (water temperature, salinity and tidal level change) and biological (abundances of Chl- *a*, bacteria, protozoans and zooplankton) factors are important for determining temporal changes in abundance and apparent population change rates for tintinnid species. During the study period, 20 tintinnid species were found and showed drastic population changes within a few days, resulting in different tintinnid assemblages from the first to the second half of the study period. Multivariate analysis and generalized linear mixed models showed that several environmental and biological factors were related significantly with the abundance and apparent population change rate of each tintinnid species, but no effect of potential predators such as copepods was found for the abundance and change rate. These results suggest that physicochemical and food conditions play more important roles than predation pressure in short-term temporal changes of tintinnid populations during summer in estuary environments.

1. INTRODUCTION

Estuaries are highly variable ecosystems in which the water temperature, nutrient concentration, salinity and water level exhibit short-term fluctuation related to the tidal cycle and mixing of flows from river water and offshore marine water. These harsh conditions prevailing in estuaries produce good habitats for tintinnid ciliates [1].

Monthly to weekly observations showed some physical and biological factors affect the population dynamics of tintinnid species [1–3]. Although few reports describe predation effects on tintinnid ciliates population, the study in offshore waters suggests copepod predation affects the distribution of tintinnid species [4]. Therefore, the population dynamics of tintinnid ciliates might be affected by copepods as well as several environmental factors. However, if environmental conditions change in the short-term or fluctuate along with the tide, the abundance and species composition of tintinnid ciliates might change rapidly, since generation times of tintinnids are as short as a day [5,6]. Moreover, copepods are known to prey less on ciliates when phytoplankton are abundant [7].

We hypothesized that (1) the population dynamics of tintinnid ciliates in estuaries are changing drastically in short intervals because of changes in prevailing physical and biological conditions, and (2) the predation pressure on tintinnid populations can be negligible when algal food for copepods is abundant. We performed frequent samplings of tintinnid populations along the tidal cycle in an estuary located on the Pacific Coast of Japan.

2. MATERIALS AND METHODS

This study was conducted at the Hiroura Estuary on the coast of Sendai Bay, Japan. Sampling was done at high tide slack water at three sites every two days from 5 July to 2 August 2010. The seawater level was recorded with a water level logger (U20; HOBO) placed at Site 2. The tidal trend was calculated as the difference in maximum elevation between two successive dates. This variable is positive during the transition from the neap to spring tides, and vice versa.

At each site, 30-L of integrated seawater was collected from the bottom to the surface using a 2.4-L tube sampler. An aliquot of the water sample was used to measure water temperature and salinity with a CTD sonde (556 MPS; YSI Inc.). For bacteria, heterotrophic nanoflagellates (HNF) and phytoplankton, 100-mL of the water sample was fixed with glutaraldehyde (1% final conc.) and stored at 4°C. For tintinnid ciliates, 10-L of the water sample was sieved using a 20-μm mesh net, concentrated into 100 mL, fixed with Lugol's solution (5% final conc.) and stored in the dark. For crustacean planktons, another 10-L of the water sample was concentrated to 100-mL using a 100-μm mesh net and fixed with formalin (5% final conc.). A 1-L of the water samples were separated into three size classes (<2, 2-10 and >10 μm) by filtration and analyzed Chl-*a* concentration in laboratory. Algal biomass was calculated using C:Chl-*a*=30 [8].

This study examined the population dynamics for major tintinnid species, which were defined as those found in at least 15 out of the total 45 samples (15 date×3 sites). To examine the putative relations between environmental variables and the abundance of tintinnid populations, redundancy analysis (RDA) was done by using the vegan package [9] of the software R [10].

To examine the effects of environmental variables on population dynamics of tintinnids, generalised linear mixed model (GLMM) with Gaussian error was done by using the R package lme4 [11]. The apparent population change rate (μ day^{-1}) for major tintinnid species was estimated as follows;

$$\mu = \ln(N_i - N_{i-1}) \times 24/(t_i - t_{i-1})$$

where N_i stands for abundance at time i; t_i denotes the elapsed time from the first sampling. Salinity, tidal range, bacteria, HNF and total copepods were selected as explanatory variables based on the result of correlation matrix. Note that the effects of salinity, bacterial abundance and HNF abundance in this analysis included water temperature or Chl-*a*. Similarly, the effects of copepod abundance included other zooplankton such as nauplii and cladocerans. All possible models were generated using R package MuMIn [12], and chose the best models according to AICc [13].

3. RESULTS

During the study period, tidal range and salinity varied from 1.4 to 1.8 m, and 3.18 to 31.0, respectively. The mean algal biomass of each size class were 15, 54, and 15 μg C L^{-1} for <2, 2-20 and >20 μm, respectively, among the study sites. Mean copepods abundance were 1.3–1.5, 0.67–2.1, and 1.8–2.9 individuals L^{-1} for *Acartia* spp., *Paracalanus* spp., and *Oithona* spp., respectively, at all sites.

In tintinnids, species composition changed drastically from 15 to 19 July (Fig. 1). For example, *Amphorellopsis*

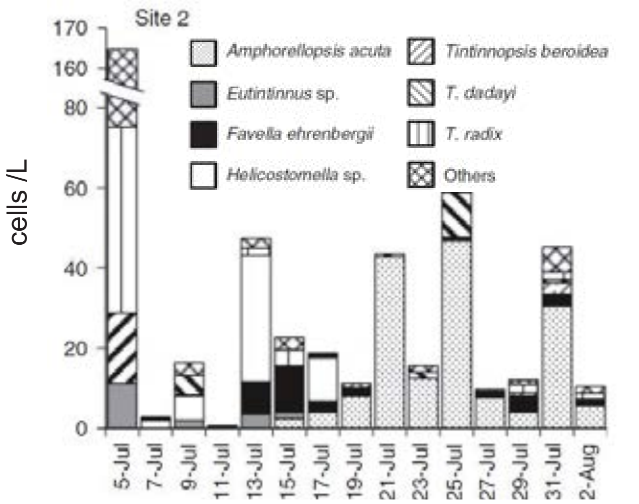


Fig. 1. Typical result of temporal changes in abundances of tintinnid species at Site 2 in Hiroura Estuary.

acuta was not found in the first half of the study period (5–13 July), but it was the most numerous species in the second half (15 July–2 August). *Eutintinnus* sp. and *Helicostomella* sp. were abundant in the first half of the study period, but were rare in the second half. The total tintinnids biomass was 0.21–0.43 mg C L^{-1} among the sites.

The relationship between tintinnid abundance and environmental variables was examined by RDA (Fig. 2).

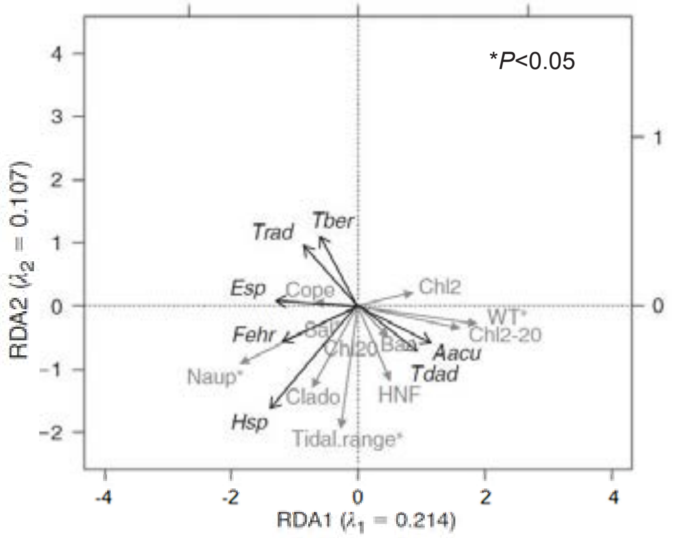


Fig. 2. Biplots of redundancy analysis (RDA) for (*a*) abundance of tintinnid species (thin black arrows) and environmental variables (bold grey arrows). The first two axes explain 32.1% of variation in abundance of tintinnid species and 76.0% of variation in environment data. WT, water temperature; Sal, salinity; Bac, bacteria; Naup, nauplius; Cope, copepods; Aacu, *Amphorellopsis acuta*; Esp, *Eutintinnus* sp.; Fehr, *Favella ehrenbergii*; Hsp, *Helicostomella* sp.; Tber, *Tintinnopsis beroidea*; Tdad, *T. dadayi*; Trad, *T. radix*.

The RDA with forward selection yielded four significant environmental variables, water temperature, tidal range, salinity, and nauplii abundance. The GLMM with model selection procedures revealed that the apparent population change rates of tintinnid species were related more or less with tidal trends, and abundances of bacteria and HNF (Table 1). For no tintinnid species, however, was the abundance of total copepods incorporated in the best models.

4. DISCUSSION

Tintinnid ciliates are protozoans with a short generation time (<25 h [5,6]). Therefore, we hypothesised that the species composition and abundance of tintinnids changed during short-term intervals. Supporting this hypothesis, the abundance and species composition of tintinnids changed drastically in a few days in the Hiroura Estuary (Fig. 1). In this estuary, physical and biological environmental conditions change temporally and spatially, probably because of tidal trends and cycles. These changes cause drastic changes in the abundance and species composition of tintinnids (Fig. 2, Table 1). However, both analyses with RDA for abundance and GLMM for apparent population change rate showed no sign of

Table 1. Results of GLMM showing the best models (top 3 or ΔAICc<2) for apparent population change rate of tintinnid species with fixed effects for salinity, tidal trend, bacteria and copepods, and random effects for sites. Results of Chi-Square tests against the null model and *p*-values (*, <0.05; **, <0.01) are shown. Abbreviations are same as in Fig. 2.

	sal	tidal tr	bac	hnf	cope	k	AICc	X^2	*p*
Aacu		-	+	+		6	132.5	15.6	**
		-		+		5	133.3	11.6	**
		-	+			5	133.4	11.5	**
*E*sp.	+			+		5	123.0	7.5	*
				+		4	123.3	4.2	*
	+		+	+		6	123.5	10.2	*
Feh		+	-			5	136.3	7.5	*
		+				4	136.5	4.6	*
	+	+				5	137.6	6.3	*
*H*sp.		+	-	-		6	128.0	15.8	**
		+		-		5	128.7	11.4	**
			-	-		5	129.6	10.5	**
Tber		-	-	+		6	118.7	12.6	**
			-	+		5	119.1	8.7	**
		-		+		5	119.3	8.6	**
Tdad		-	+	+		6	141.9	15.0	**
		-	+			5	142.7	10.9	**
		-		+		5	143.7	9.9	**
Trad		+		+		5	138.7	13.2	**
		+	+	+		6	139.1	15.8	**

copepod effects on the numerical responses of major tintinnid populations, although copepods density in Hiroura estuary could be sufficient to affect the tintinnids abundance [14–16].

Some reports of experimental studies have described that copepods prey on phytoplankton such as diatoms and dinoflagellates in preference to ciliates when the latter are scarce [17,18]. Calbet and Saiz [19] demonstrated that ciliates accounted for 49% of copepod diets in ocean area with low phytoplankton biomass (<50 mg C L^{-1}), while only 22–25% of those in area with high phytoplankton biomass (50< mg C L^{-1}). In Hiroura estuary, the phytoplankton biomass was 55–99 mg C L^{-1}. Also, it was much greater than the total tintinnids biomass (~0.43 mg C L^{-1}). Consequently, because of the low biomass, tintinnids might not be affected negatively by copepod predation in this study. The vulnerability of tintinnid species to copepod predation might therefore depend on their abundance relative to those of other potential food organisms such as diatoms.

5. CONCLUSION

The abundance and species composition of tintinnids in Hiroura Estuary varied temporally and changed rapidly within a few days in relation with short term variations of environmental and biological factors and temporally ephemeral factors such as HNF and bacterial abundance. The results imply that frequent samplings are essential to understand the population dynamics of tintinnid populations in estuaries. Although tintinnids are potentially food for copepods, tintinnid abundance and species composition were unaffected by copepods, especially under high phytoplankton biomass.

REFERENCES

1. Quinlan, E. L., Jett, C. H. & Phlips, E. J. Microzooplankton grazing and the control of phytoplankton biomass in the Suwannee River estuary, USA. *Hydrobiologia* **632,** 127–137 (2009).
2. Godhantaraman, N. & Uye, S. Geographical and seasonal variations in taxonomic composition, abundance and biomass of microzooplankton across a brackish-water lagoonal system of Japan. *J. Plankton Res.* **25,** 465–482 (2003).
3. Kamiyama, T. & Tsujino, M. Seasonal variation in the species composition of tintinnid ciliates in Hiroshima Bay, the Seto Inland Sea of Japan. *J. Plankton Res.* **18,** 2313–2327 (1996).
4. Gómez, F. Trends on the distribution of ciliates in the open Pacific Ocean. *Acta Protozool.* **32,** 188–202 (2007).
5. Stoecker, D. K. & Evans, G. T. Effects of protozoan herbivory and carnivory in a microplankton food web. *Mar. Ecol. Prog. Ser.* **25,** 159–167 (1985).
6. Dolan, J. R. & Gallegos, C. L. Estuarine diversity of Tintinnids (Planktonic ciliates). *J. Plankton Res.* **23,** 1009–1027 (2001).
7. Fessenden, L. & Cowles, T. J. Copepod predation on phagotrophic ciliates in Oregon coastal waters. *Mar. Ecol. Prog. Ser.* **107,** 103–111 (1994).
8. Wetsteyn, L. P. M. J. & Kromkamp, J. C. Turbidity, nutrients and phytoplankton primary production in the Oosterschelde (The Netherlands) before, during and after a large-scale coastal engineering project (1980-1990). *Hydrobiologia* **282/283,** 61–78 (1994).
9. Oksanen, J. *et al. Package 'vegan'*. (2018).
10. R Development Core Team. *R : A Language and environment for statistical computing*. (2018).
11. Bates, D., Maechler, M., Bolker, B. & Walker, S. *Lme4: Linear mixed-effects models using 'Eigen' and S4 v1.1-12*. (2016).
12. Barton, K. *MuMIn: multi-model inference v1.15.1*. (2015).
13. Burnham, K. P. & Anderson, D. R. Model selection and inference: a practical information-theoretic approach. *Springer-Verl. N. Y.* (1998).
14. Nakamura, Y. & Turner, J. T. Predation and respiration by the small cyclopoid *Oithona similis*: How important is feeding on ciliates and heterotrophic flagellates? *J. Plankton Res.* **19,** 1275–1288 (1997).
15. Turner, J. T. & Anderson, D. M. Zooplankton grazing during dinoflagellate blooms in Cape Cod Embayment, with observations of predation upon tintinnids by copepods. *PSZNI Mar. Ecol.* **4,** 359–374 (1983).
16. Jang, M.-C., Shin, K., Lee, T. & Noh, I. Feeding selectivity of calanoid copepods on phytoplankton in Jangmok Bay, south coast of Korea. *Ocean Sci. J.* **45,** 101–111 (2010).
17. Stoecker, D. K. & Capuzzo, J. M. Predation on Protozoa: its importance to zooplankton. *J. Plankton Res.* **12,** 891–908 (1990).
18. Irigoien, X. *et al.* Feeding selectivity and egg production of *Calanus belgolandicus* in the English channel. *Limnol. Oceanogr.* **45,** 44–54 (2000).
19. Calbet, A. & Saiz, E. The ciliate-copepod link in marine ecosystems. *Aquat. Microb. Ecol.* **38,** 157–167 (2005).

P3-4

炭素・窒素安定同位体比及び脂肪酸分析によるイシガイの藍藻同化の評価

菅原 巧太朗[1], 藤林 恵[1], 遠田 幸生[2], 岡野 邦宏[1], 一関 晋太朗[3], 谷口 吉光[1], 宮田 直幸[1]
[1]秋田県立大学, [2]秋田県産業技術センター, [3]秋田水生生物保全協会

キーワード：富栄養化, アオコ, 二枚貝, 濾過摂食

抄録

湖沼の水質改善を目的として、二枚貝の濾過摂食機能を利用した藍藻に対するバイオマニピュレーションが検討されているが、二枚貝が藍藻を摂食した後どの程度同化するのかほとんど明らかになっていない。本研究では、夏季に藍藻ブルームが発生する八郎湖にイシガイを設置し、イシガイの藍藻同化能力を評価することを目的とした。底質直上水中の懸濁物の炭素・窒素安定同位体比は、藍藻ブルーム発生時期に大きく変動したが、イシガイ生体中の各安定同位体比はほぼ一定であり、懸濁物の同化は検出されなかった。一方、藍藻ブルーム発生時期にイシガイ中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比が有意に増加するとともに、イシガイの肥満度と藍藻由来脂肪酸の寄与率にも正の相関が示された（$r = 0.8272$, $P < 0.01$）。本研究により、イシガイは藍藻を濾過摂食した後同化することが明らかになり、イシガイのバイオマニピュレーションツールとしての有用性が示された。

1. はじめに

富栄養化した湖沼で異常増殖した藍藻対策として、濾過摂食動物の機能を利用したバイオマニピュレーションが検討されている。しかし、藍藻は巨大コロニーを形成し摂食を免れやすいことや、摂食されたとしても水生生物の消化器官を通過し、その後、環境中に回帰して増殖する事例が報告されている[1]。そのため、バイオマニピュレーションによって藍藻の増殖を抑制するためには、コロニーを形成した藍藻を摂食してさらに同化できる生物を選定することが重要となる。

二枚貝は、濾過摂食動物の中でも高い濾水速度を有することから藍藻を含む懸濁物の効率的な除去が期待されている。著者らは無機懸濁物質を用いた室内実験において、イシガイ*Unio douglasiae*が350 µm程度の大型粒子でも濾過できることを示した[2]。しかし、イシガイが実際の環境中で藍藻を餌として同化しているかは知られていない。本研究では、夏季に藍藻ブルームが発生する秋田県八郎湖にイシガイを設置し、餌資源の利用性を評価することにより、イシガイによる藍藻の同化能力を明らかにすることを目的とした。

2. 方法

2017 年 7 月に八郎湖南岸部の岸から 10 m ほど離れた水深約 70 cm の地点に面積 0.36 m^2 のケージを設置し、その中に八郎湖で採集したイシガイの成体 50 個体を投入した。その後、2017 年 11 月まで 2 週間おきに、ケージからイシガイ 3～5 個体を採集し、殻長及び殻高、殻幅、凍結乾燥後の乾燥重量を測定した。そして、肥満度（乾燥重量÷殻長×殻高×殻幅）を求めた。さらに、足の筋肉を採取し、炭素及び窒素の安定同位体比分析及びガスクロマトグラフィーによる脂肪酸分析を行った。イシガイ採集時にピストン式採水器を用いて底質直上付近の水を採水し、顕微鏡観察により藻類を計数した。また、懸濁物質の粒径分布、炭素・窒素の安定同位体比、脂肪酸組成の分析を行った。

なお、本研究ではエイコサペンタエン酸（20:5ω3）を珪藻由来の脂肪酸、リノール酸（18:2ω6）とα-リノレン酸（18:3ω3）を藍藻由来脂肪酸とみなし、バイオマーカーとして用いた。

3. 結果

調査期間中、イシガイの肥満度は 8 月～9 月にかけて微増し、その後 10 月以降に大幅に増加したことが確認された（図 1）。

懸濁物の顕微鏡観察から、植物プランクトンでは、主に 8 月～9 月に *Anabaena* 属や *Microcystis* 属の藍藻が

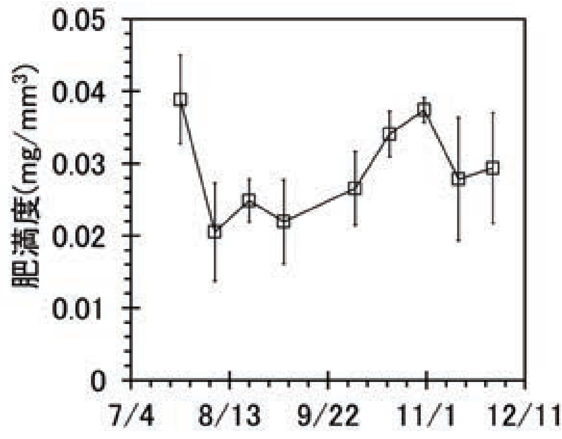


図 1 イシガイの肥満度の変動

優占し、10 月以降は、*Aulacoseira* 属や *Cyclotella* 属を主とする珪藻が優占していた。さらに、調査地点で観測された粒径分布の D_{90} 値は、調査期間を通して 100～350 μm 程度であった。すなわち、湖水中の懸濁粒子の 90％は、イシガイの可食粒径範囲内の 350 μm[2]よりも小さい粒子であることが示された。

イシガイの懸濁物の同化状況を調べるために、イシガイ生体中の炭素・窒素の安定同位体比と底質直上水中の懸濁物の各安定同位体比の経時変化を比較した。底質直上水中の懸濁物の炭素安定同位体比は、*Anabaena* 属が優占していた 8 月初旬に相対的に高い値を示し、*Microcystis* 属が優占していた 9 月初旬には低い値を示した（図 2）。窒素安定同位体比は、対照的に、8 月初旬に低い値を示し、9 月初旬には高い値を示した（図 3）。一方で、イシガイ生体中の炭素と窒素の安定同位体比は、ほとんど変動しなかった（図 2 及び 3）。

次に、バイオマーカー脂肪酸を用いて懸濁物の同化状況を調べたところ、藍藻ブルーム発生時期の 8 月～9 月にかけてイシガイ生体中の藍藻由来脂肪酸が微増するとともに、珪藻由来脂肪酸が減少していた（図 4）。藍藻ブルームが衰退し、珪藻優占状態になった 10 月以降には、珪藻由来脂肪酸の大幅な増加が観測された（図 4）。図 4 をもとに、イシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比を比較したところ、試験開始時に対して藍藻ブルーム発生時期に存在比の有意な増加が示された(図 5)。

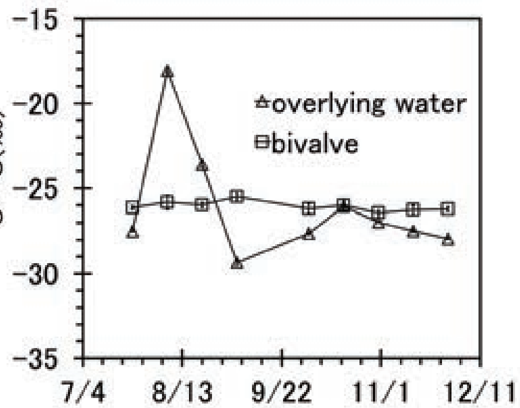


図 2 底質直上水の懸濁物質とイシガイ生体中の炭素安定同位体比の経時変化

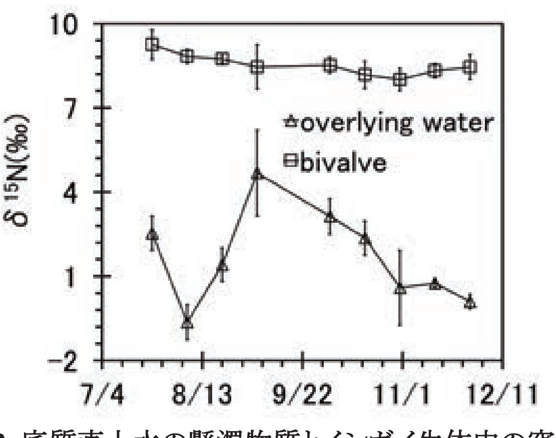


図 3 底質直上水の懸濁物質とイシガイ生体中の窒素安定同位体比の経時変化

4. 考察

肥満度の増加傾向からイシガイの餌の同化が示唆された（図 1）。藍藻ブルーム発生時期と 10 月の珪藻優占時期の肥満度の増加傾向を比較すると、10 月の珪藻優占時期の方が肥満度の増加が大きいため、珪藻優占時期に最適な餌が豊富だったと示唆された。

炭素・窒素安定同位体比分析により、イシガイの懸濁粒子の摂食傾向の評価を試みた。アオコ発生時期である 8 月～9 月に注目すると、底質直上水の懸濁物中の炭素、窒素安定同位体比は、大きく変動しているのに対し、イシガイ中の炭素・窒素安定同位体比はほとんど変化が無く（図 2,3）、イシガイ生体中の炭素・窒素安定同位体比は、懸濁物質の各安定同位体比を反映して

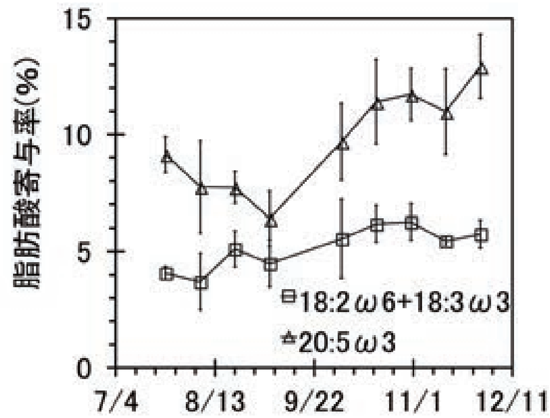


図 4 イシガイ生体中のバイオマーカー脂肪酸の経時変化

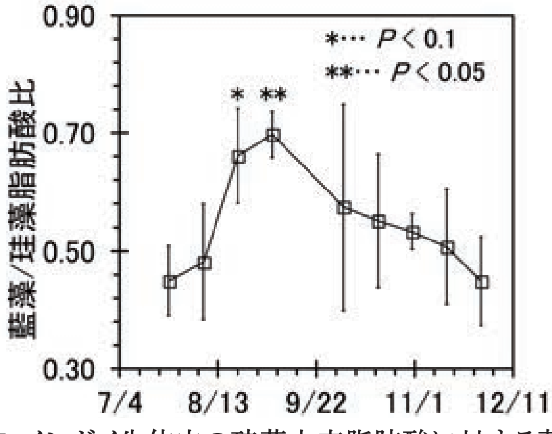


図 5 イシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比（Dunnett 法による多重比較検定, *は、$P < 0.1$, **は、$P < 0.05$ を示す）

いなかった。懸濁物を摂食、同化していてもイシガイの炭素・窒素安定同位体比に反映されるほどの量ではない可能性があるほか、イシガイが底質粒子を多く摂食し、水中の懸濁物をほとんど摂食しなかったと考えられた。

次に、バイオマーカー脂肪酸を用いて懸濁粒子の同化傾向の評価を試みた。藍藻ブルーム発生時期にイシガイ生体中の珪藻由来脂肪酸に対する藍藻由来脂肪酸の存在比が有意に増加し、イシガイの藍藻同化が示唆された。さらに、アオコ発生時期の8月～9月のイシガイの肥満度と藍藻由来脂肪酸寄与率は正の相関関係を示した（図 6, $r = 0.8272$, $P < 0.01$）。すなわち、イシガイは、藍藻ブルーム発生時期に藍藻由来脂肪酸を取り込み、肥満度を増加させたことが示唆された。脂質の回転速度が全炭素・窒素の回転速度よりも速いため、炭素・窒素安定同位体比では捉えることができなかった藍藻の摂食、同化をバイオマーカー脂肪酸によって評価できたと考えられた。

本研究結果から、イシガイの藍藻類に対する同化能が示唆されたことにより、八郎湖ではイシガイをバイオマニピュレーションツールとした藍藻除去が期待される。

5. 結論

本研究調査から以下のことが明らかになった。

1. アオコ発生時期及び珪藻優占時期の両方でイシガイの肥満度は増加傾向を示した。
2. 炭素・窒素安定同位体比分析では、イシガイの懸濁物の餌利用状況を明らかにすることはできなかったが、バイオマーカー脂肪酸分析では、イシガイの懸濁物質の摂食状況を捉えることができた。
3. アオコ発生時期の 8 月～9 月においてイシガイの肥満度と藍藻由来脂肪酸寄与率に正の相関関係が認められ、環境中でのイシガイの藍藻同化が示唆された。

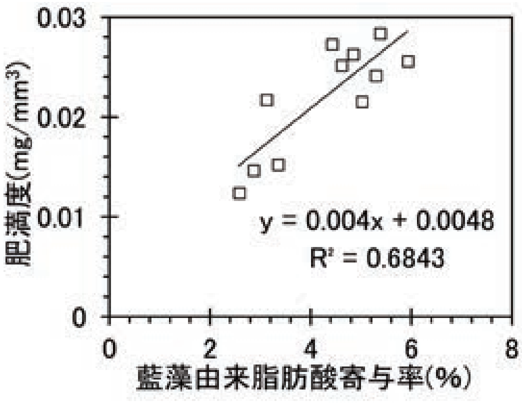


図 6 アオコ発生時期におけるイシガイの肥満度と藍藻由来脂肪酸寄与率の関係

引用文献

[1] Kolmakov, V.I.: Role of *Microcystis aeruginosa* Passing Through the Digestive Tracts of Filter-Feeding Animals in Eutrophic Water Reservoirs (Review) Contemp Probl Ecol, Vol. 7, No. 4, pp. 455-464 2014.

[2] 菅原巧太朗，藤林恵，岡野邦宏，遠田幸生，一関晋太朗，谷口吉光，宮田直幸：二枚貝の可食粒径範囲とアオコ粒径の鉛直分布に着目した二枚貝の濾過摂食機能の評価，第 51 回日本水環境学会年会要旨集，pp. 598, 2017.

P3-5

八郎湖におけるアオコ形成藻類を含む細菌叢と環境因子の関係

岡野 邦宏[1], 松尾 歩[2], 荒木 美穂[1], 太田 栞[1], 藤林 恵[1], 宮田 直幸[1]
[1]秋田県立大学, [2]東北大学大学院

キーワード: 富栄養化, アオコ, 八郎湖, 次世代シーケンサー

抄録

本研究では2014年から2016年までの秋田県八郎湖の表層水における細菌叢の16S rRNAアンプリコン解析を行い, 水温, 降水量, 栄養塩濃度などの環境因子の影響を評価した。2014 年は 6 月から 8 月までの降水量が 2015 年と2016年の同時期の2.5倍と多かったが, 8月と10月に短いアオコの発生があった。2015年と2016年は6月から10月まで長期間アオコが観察されたが, 秋季の *Microcystis* 属によるアオコ発生は全ての年で起きていた。さらに, アオコ形成藻類を含む細菌叢は採水日前 7 日間の雨量と水温の影響を受け, 優占種が高水温かつ少降雨頻度では *Microcystis* 属, 多降雨頻度では *Anabaena* 属に変化しやすいことが示唆された。本研究のような長期間に渡った次世代シーケンサーによる細菌叢解析は例がなく, 本手法により細菌叢と環境因子の具体的な関係性を見出だせる可能性が初めて示された。

1. はじめに

富栄養化湖沼におけるアオコの発生は世界的に大きな社会問題となっている。秋田県八郎湖（八郎潟残存湖）もアオコ発生が常態化している湖沼であり, 富栄養化の進行とアオコの発生などから平成19年12月より湖沼法の指定を受けた。現在も様々な水質改善対策が進められているが, 毎年 6 月から 10 月まで長期的なアオコ発生が確認されており[1, 2], 抜本的なアオコ対策の創出が必要と言える。

そこで本研究では, 八郎湖におけるアオコ対策創出の基盤研究として, アオコ形成藻類を含む細菌叢と環境因子の関係を明らかにすることを最終目的とした。具体的には, 2014 年より 3 年間定期調査を行い, 次世代シーケンサーにより細菌叢をクロノシーケンスで解析した。また, 細菌叢の β 多様性（サンプル間での違い）と水温や各態窒素・リン濃度などの水質や平均気温, 降水量, 日照時間などの外的因子との関係を解析した。

2. 方法

2.1 調査方法及び測定項目

湖水試料は, 秋田県北西部に位置する八郎湖の距離の離れた 3 地点（図 1）で 2014 年 3 月から 2016 年 12 月まで毎月 1〜3 回表層水をヒシャクにより採取した。現地にて水温, pH, 電気伝導度（EC）, 実験室にて Chl.*a*, 各態窒素・リン濃度を測定した。また, 湖水試料を酢酸抽出後, Presep®-C C18（WAKO）により粗精製・濃縮してミクロシスチン類を分析した[2]。

2.2 遺伝子解析

湖水を孔径 0.2 μm のフィルターでろ過し, ISOIL for Beads Beating（NIPPON GENE）によりDNA抽出を行った。抽出した DNA を用いて真正細菌を対象とした 16S rRNA 遺伝子アンプリコン解析を行った[2, 3]。得られた配列は Claident v.0.2（https://www.claident.org）により分子系統学的に分類した。また, 細菌叢の類似度解析は R パッケージの vegan 2.4-4 を用いて行った。

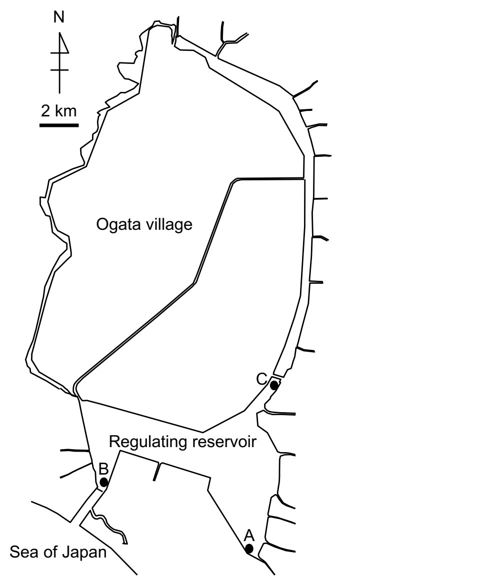


図 1 八郎湖の概要と採水地点

A: 野村港（北緯 39°42’48”500, 東経 140°02’14”470）, B: 防潮水門（北緯 39°54’25”046, 東経 139°57’31”055）, C: 大潟橋（39°56’58”784, 東経 140°03’22”760）

3. 結果

3.1 野村港における細菌叢変化と環境因子との関係

野村港（A）において2014年から3年間の定期調査を行った。2014 年は夏季の水温が低く，観測期間中のアオコの観察は2回だったが，10月に *Microcystis* 属主体のアオコが確認された[2]。2015 年は 6 月から 10 月まで長期間アオコが観察されたが，9 月以降は *Microcystis* 属がアオコ形成の主体となっていた[2]。また，2016 年も 6月から10月まで長期間のアオコが観察されたが，9月には 2015 年とは異なり *Planktothrix* 属が優占した。

一方で，各年の細菌叢の β 多様性には有意な差があり（$p < 0.05$），特に 2014 年が明確であった。この β 多様性と水温，pH，EC，Chl.*a*，ミクロシスチン濃度，各態窒素・リン濃度に加えて，採水日前 7 日間の平均気温，日照時間，降水量との関係を解析した結果，採水日前 7 日間の合計雨量と水温の影響を強く受けていた。

3.1 2016 年における 3 地点の細菌叢変化

2016 年はアオコ形成藻類として 3 地点共通して *Anabaena* 属と *Microcystis* 属，そして *Planktothrix* 属が優占した。3 地点の細菌叢の変化は概ね一致していたが，野村港でのみ *Microcystis* 属が 9 月下旬にも優占した。一方で，3 地点の細菌叢の β 多様性は季節的な変動はあるものの 3 地点間で有意な差は確認されなかった（$p > 0.05$）。

4. 考察

2014 年から 2016 年の夏季の降水量には大きなばらつきがあり，特に 2014 年は 6 月から 8 月までの降水量が極めて多かった（2015 年比で約 2.7 倍）。そのため，各年でのアオコ発生状況は異なっていたが，秋季の *Microcystis* 属主体のアオコ発生には周期性が認められ，これは八郎湖特有の現象であると考えられた。

また，今回解析に用いた環境因子の中ではアオコ形成藻類を含む細菌叢は降水頻度と水温の影響を強く受けており，高水温かつ少降雨頻度では *Microcystis* 属が，多降雨頻度では *Anabaena* 属が優占した細菌叢に変化しやすいことが示唆された。

一方で，1 年間のデータではあるが距離の離れた 3 地点での細菌叢に有意な差がなかったことから，アオコ形成藻類を含む細菌叢は湖内流動や流入水などの影響よりも季節的な変動の方が大きいことが示唆された。本研究のような長期間に渡った次世代シーケンサーによる細菌叢解析は例がなかったため，さらに継続的に調査を行うことで，アオコ形成藻類を含む細菌叢と環境因子の具体的な関係性を見出だせる可能性が初めて示された。

5. 結論

秋田県八郎湖の表層水の細菌叢を 3 年間に渡り解析した結果，下記のことが明らかになった。

1. 秋季の *Microcystis* 属主体のアオコ発生には周期性があり，八郎湖特有の現象であることが考えられた。
2. 細菌叢の β 多様性（サンプル間での違い）は，地点間よりも季節変動，さらに年次変動による違いが大きいことが明らかになった。
3. 細菌叢の β 多様性は，今回解析に用いた環境因子の中では特に降水頻度と水温の影響を受けており，高水温かつ少降雨頻度では *Microcystis* 属，多降雨頻度では *Anabaena* 属が優占した細菌叢になることが示唆された。

引用文献

[1] Okano K, Suzuki E, Ohta S, Miyata N, Tani Y, Ozaki Y: Seasonal changes in cyanotoxin microcystin and toxic cyanobacteria in Lake Hachiro. *J. Jpn. Soc. Water Environ.*, **38**(1), 23–30, 2015 [in Japanese].

[2] Araki, M., Okano, K., Ohta, S., Suzuki, E., Fujibayashi, M., Miyata, N.: Characteristics of harmful algal blooms during a low water temperature season in Lake Hachiro. *Journal of Water and Environment Technology*, in press 2018.

[3] Caporaso, J.G, Lauber, C.L, Walters, W.A, Berg-Lyons, D, Lozupone, C.A, Turnbaugh, P.J, Fierer, N, Knight, R: Global patterns of 16S rRNA diversity at a depth of millions of sequences per sample. *Proc. Natl. Acad. Sci. USA*, **108**(SUPPL. 1), 4516-4522, 2011.

謝辞

本研究は JSPS 科研費 JP16K16206 の助成を受けたものです。

P3-6

One individual and one cell PCR of predatory microorganisms for cyanobacteria

Thakong Watcharapong[1], Duangduean Yuenyongkirimard[1] Shimizu Kazuya[2] Iwami Norio[3], Niwooti Whangchai[4], Tomoaki Itayama[1]

[1]Graduate school of Engineering, Nagasaki University, [2]School of Life and Environmental sciences, University of Tsukuba, [3]School of Science and Engineering, Meisei University, [4]Faculty of Fisheries Technology and Aquatic Resources, Maejo University

Keywords: eutrophication, harmful algal bloom and toxic cyanobacteria

ABSTRACT

It is important to investigate protozoa and metazoan which can prey on toxic cyanobacteria, because the predation microorganisms affect the population of toxic cyanobacteria involving worldwide problems. Moreover we can apply such microorganisms to control or remove toxic cyanobacteria. Therefore, we developed a method without monoculture to determine the 18S rRNA gene sequences for establishing local database in molecular ecological studies. The experimental procedure using a micro glass capillary for uncultured protozoa and metazoan are shown as follows. Each swimming individual was captured by a glass capillary with the tip diameter of around 100micron meter under an inverted microscope. Then it was transferred into a drop of autoclaved water to wash the individual. This washing step was repeated 5 times at least. Then it was transferred into a PCR tube, and 70% EtOH of 100micro L was put in the tube to fix the individual. After drying completely, PCR mixture of 40 micro L (Tks-GFlex, Takara bio inc., Japan) was added to the tube. A universal primer set for metazoan Metaz 2-F and Metaz 5-R [1] (Machida, R., J. and Knowlton, N. PLOS ONE, Vol 7(9), e46180, 2012) was used for the PCR. Because DNA template concentration from one individual was very low, the optimal condition for the PCR had to be found to obtain the enough quantity of amplicons for DNA sequence. As a result, DNA sequences of several rotifer species were determined.

1. INTRODUCTION

Free-living Metazoan and Protozoa are ubiquitous in natural freshwater environments, but also proliferate in engineered water systems, including water treatment systems. These Protozoa have an important role in maintaining a good balance in biological ecosystems. Many Metazoan and Protozoan inhabits in the biological water treatment system. But almost species are uncultured microorganisms can prey toxic cyanobacteria Microcystis sp. . However, information about the presence and identity of Metazoan and Protozoa can prey the toxic cyanobacteria in water supplies in relation to the quality of treated water is scarce, which may be attributed to the limitations of microscopic techniques and cultivation methods for detection and identification of these organisms, e.g., low detection limits and selectivity for specific groups. Thus, it is important to study such Metazoan and Protozoan using molecular ecological methods without monoculture method. To analyze the 18S rRNA gene, commonly used for phylogenetic inference of eukaryotes due to its highly conserved sequence and ability to resolve relatively deep nodes. This is the first description of the general utility of environmental DNA sequencing approaches for identified character and population dynamic of Protozoa and Metazoan species.

2. METHOD

The several species of Microcystis sp. were collected fish pond water of Maejo University in the 50 ml tube, after that collect Microcytis bloom again from the surface of 50 ml tube to a 50 ml tube, we mix all Microcystis samples from several fish pond into a flask and a culture Microcystis cell in the glass tank in the filtrated influent fish pond water by GFF 55 mm. we collect Microcytis bloom again from the surface of the glass tank, treat the microcystis sample by using Ultrasonicator to separate the single cell or small colony from each colony. Adjust the Chl-a 200 ug/L dilutes by filtrated influent water. Protozoa and Metazoa were isolated from fish pond area and biofloc system (Chiang Mai Province, Thailand) and from a natural pond (Nagasaki, Japan). The isolation of Protozoa and Metazoa species was achieved using a handmade glass capillary (with 100µm tips) under the inverted microscope with x100 ~ x400 magnifications. Furthermore, the isolated Protozoa and Metazoa were transferred to 24-well micro-plates containing the filtrated water fish pond and M11 medium was sterile, containing Microcystis cell under dark condition and observation them can prey Microcystis cell or not. If can prey, we collect one cell to the washing step and put into PCR tube. To analysis 18Sr RNA gene of the isolated Protozoa and Metazoa using the new molecular ecological method, one individual direct PCR without the culture will be developed for the identification of uncultured Protozoa and Metazoa. Then us using the Real time PCR to get the cDNA, next step we get the PCR product to do molecular cloning method for 18S rRNA will be applied to obtain the DNA sequence data. Finally, I will add each sequence in the database.

3. RESULTS AND DISCUSSION

Result of Protozoa and Metazoa species can prey mixculture Microcystis sp. were isolated 5 species from fish pond in Thailand and 3 species from natural pond in Shimabara city Nagasaki Japan. The Protozoan species were isolated include *Vorticella sp.*, *Paramecium sp.*, *Coleps hirtus.*, *Euglena sp.* The metazoan species were isolate include *Brachionus sp.*, *Colurella uncinata bicuspidate.*, *Filinia longiseta.*, *Philodina sp.*, *Lepadella sp.*, *Monostyla sp.*, as rotifer, and *Aeolosomes sp.*, was isolated as the other metazoa. The PCR purified product by the gel electrophoresis. Then cut gel and purified gel electrophoresis product. The results of 18s rRNA sequences with the previously isolated rotifer are searched by BLAST.

Figure 1 Show *Vorticella sp.*, *Stylonychia sp.* and *Philodina sp.* can prey *Microcystis sp.* were isolated from fish pond, Chiang Mai, Thailand

4. CONCLUSION

1. Protozoa and Metazoan species in such observed microorganisms possibly can remove the cyanobacteria cells by the predation and the decomposition.

2. Success to develop an isolation method using micro capillary for uncultured Metazoa and Protozoa from the biological water treatment system, reservoirs, fish ponds etc.

3. Compare efficiency the conventional method and the new method we develop to collect the Protozoa and Metazoa without the monoculture method is having a good efficiency.

REFERENCES

[1] Ryuji J. Machida and Nancy Knowlton: PCR Primers for Metazoan Nuclear 18S and 28S Ribosomal DNA Sequences, PLOS ONE, Vol. 7(9): e46180 pp., 2012.

P3-7

Regulation of Diatoms on Silicon Dynamics in the Xiangxi River

Yubo Huang[a,b], Wujuan Mi[a], Zhengyu Hu[a], Yonghong Bi[a,*]
[a] State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of Hydrobiology, Chinese Academy of Sciences, Wuhan 430072, China
[b] University of Chinese Academy of Sciences, Beijing 100049, China
*corresponding author. E-mail address:biyh@ihb.ac.cn; Tel/fax: +86 27 68780016

Keywords: Diatom; cell density; DSi; BSi;

Abstract

In order to get insight into the impact of Three Gorges Dam operation on diatom structure and its function on silicon cycle due to diatom assimilation in the reservoir, the Xiangxi River was chosen as the delegate of the tributary in the Three Gorges Reservoir to screen the effects of diatom. Our results indicated that diatom composition and their relationship with silicon concentration were different between lacustrine site and riverine site, which represents the diatom growth with and without direct dam effects, respectively. Diatom cell density in the lacustrine zone was significantly higher than the riverine zone. Centric diatom (Melosira and Cyclotella) were the dominant genus in the lacustrine zone during the whole study period. However, there was an increasing proportion of pennate diatom in the riverine zone during the flood period. DSi has a significantly negative relationship with diatom cell density in the lacustrine site while no correlation was found in the riverine site. BSi has a significant linear relationship with diatom cell density. BSi transformation efficient is higher while the standing BSi is lower in the riverine zone than the lacustrine zone. The results imply that TGD decrease the flow velocity dramatically, contributing to a stable diatom composition, causing longer diatom growth period and progressive silicon depletion, enhancing silicon retention in the long term in the reservoir.

Introduction

In this study, Xiangxi River was selected as a delegate of the tributary in the TGR, silicon and diatom in Xiangxi River were screened in two distinct zones: the riverine zone and lacustrine zone. It is assumed that different hydrodynamic conditions in these zones may affect diatom community, consequently changed the silicon dynamics. To verify this hypothesis, monthly investigation was conducted including diatom density, silicon concentration and environmental parameters. This study will help us better understand how silicon changes with diatom growth in the TGR.

Methods

Sites and samples

Figure 1 Sketch map of sampling stations in the Xiangxi River

Statistical analysis:Origin 9.1 and SPSS 19.0 package. CANOCO version 4.5.

Results

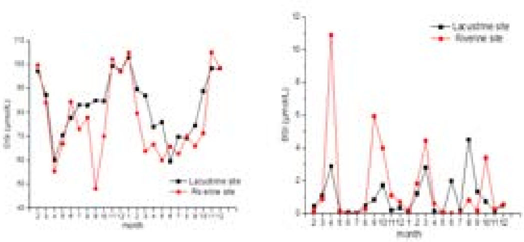


Figure 2 Monthly DSi and BSi variation from

February 2015 to December 2016

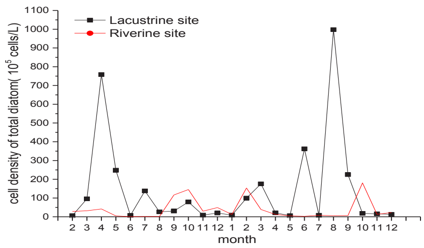


Figure 3. Seasonal cell density during the study period

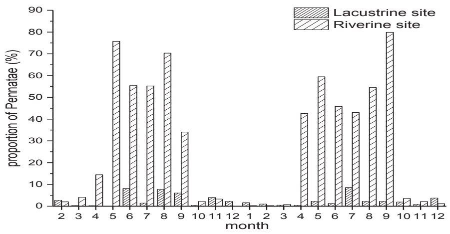


Figure 4. Seasonal variation of pennatae diatom in the lacustrine site and riverine site

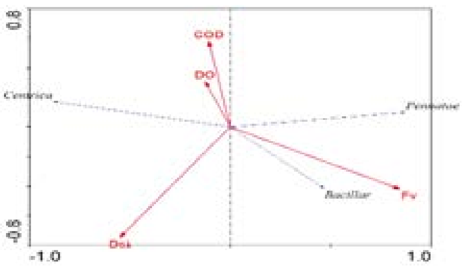


Figure 5. Biplot diagrams for RDA

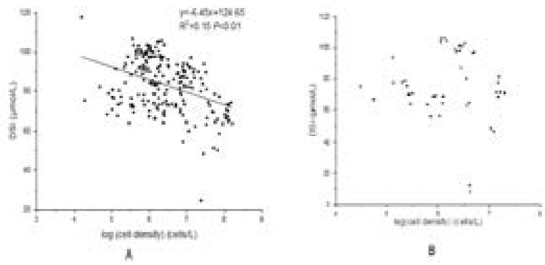


Figure 6. Relationships between diatom cell density and DSi in the lacustrine zone(A) riverine zone(B)

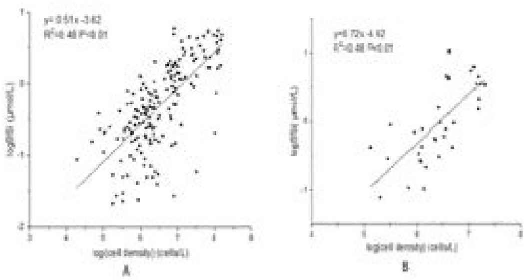


Figure 7 Relationships between diatom cell density and BSi in the lacustrine zone(A) and riverine zone(B)

Discussion

Our results showed that diatom cell density has a negative relationship with flow velocity in both riverine zone and lacustrine zone (table 1). In general, negative coefficient between diatom cell density and flow velocity was higher in the riverine zone than the lacustrine zone (table 1), indicating a stronger influence of flow velocity compared with lacustrine zone. the lacustrine zone. So diatom growth is more likely to be influenced by hydrodynamics[13]. It was found that diatom growth period in the lacustrine zone is longer than the riverine zone. Three peaks of diatom cell density were observed in the lacustrine zone. Besides spring and autumn, summer during June and August is also a favorable time for diatom growth. While in the riverine zone, there was a low diatom cell density in summer (Figure 3).

Diatom community structure is different in these two zones. Although centric diatom is the dominant species in both zones during the dry season (Figure 4). RDA analysis showed that centric diatom has a significant negative correlation with flow velocity while pennate diatom has a positive relationship with flow velocity (Figure 5). These studies demonstrated that pennate diatoms have its physiological and morphological advantage over centric diatoms in a turbulent environment.

Diatom was the main contributor to the BSi because a significant correlation was found between diatom cell density and BSi in the lacustrine zone(r=0.672) and riverine zone(r=0.878) (Table 1). This indicated that BSi originated from watershed terrestrial phytolith makes little difference to the BSi pool in the Xiangxi Rivr, which is different from some other studies. It's noticed that high diatom cell density in the lacustrine zone didn't account for higher BSi concentration in spring (from March to May) compared with the riverine zone. Cell density in the lacustrine zone is significantly higher than the riverine zone, but BSi concentration in the lacustrine zone was lower than the fluvial zone. Linear regression model showed that cell density was positively related with BSi significantly at both zones. And diatom cell density has the same explanation coefficients for the BSi variation. But the slope in the riverine zone in significantly higher than the lacustrine zone (Figure7). It was estimated that BSi increased by 3.24μmol/L when diatom cell density increased by an order of magnitude in the lacustrine zone. However, it can be implied that BSi will increase by 5.25μmol/L when diatom cell density expands an korder of magnitude from the linear regression model. Moreover, a higher correlation coefficients between diatom cell density and BSi, Chla in the riverine zone indicated diatom contributes more to the biomass of the phytoplankton than the lacustrine zone (Table 1).

The results showed that DSi was negatively correlated with the diatom cell density in the lacustrine zone (Table 1). Despite that the regression model coefficients was low, the correlation was significant. The model indicated that diatom assimilation is the primary reason for DSi decline in the lacustrine zone (Figure6A). It can be speculated that when cell density increase by an order of magnitude , the DSi concentration will decrease by 6.45μmol/L. However, no correlation was found between DSi and diatom cell density in the fluvial zone(Figure 6B). It is suggested that diatom would dominate the phytoplankton community irrespective of season when DSi concentration exceeded the threshold of 2μmol/L.[7] This value is below the actual DSi concentration in the lacustrine zone and riverine zone even in the diatom growth period when DSi was assimilated intensively (Figure 2A). Moreover, during winter when diatom cell density is low at both zones, DSi concentration was relatively high without significant difference between these two zones. If diatom in two zones is taken into consideration together, the diatom cell density had little correlation with DSi (Figure 5.) It can be concluded that DSi concentration alone cannot be a limiting factor regulating the diatom community composition. It is more likely that flow condition was a main factor affecting diatom succession in the two zones.

Conclusion

This study verified that dam construction transform part of the river into lacustrine zone. Low flow velocity and stable environmental conditions contributed to an increase of diatom cell density. A stable diatom composition was observed in the lacustrine zone, which was dominated by centric diatom comprising Melosira and Cyclotella. Lotic diatom proportion in this zone was below 10% during the study period. Longer diatom growth period compared with the riverine zone was shown because longer residence time foster diatom growth even in summer. Diatom was strongly coupled with DSi assimilation in the lacustrine zone. Although centric diatom contributed less BSi at the same cell density compared with pennate diatom, their high cell density and longer growth period would contribute a great amount of BSi in the reservoir. And consequently cause a mass silicon trap in the reservoir in the long term.

Table 1. Spearman correlation between cell density and environmental parameters in the lacustrine zone (L-CD) and riverine zone(R-CD).

	DSi	BSi	Chla	pH	WT	DO	COD	Cond	Flowvelocity
L-CD	-0.513**	0.639**	0.722**	0.625**	0.164	0.506*	0.522*	-0.024	-0.549*
R-CD	0.017	0.830**	0.755**	0.258	-0.071	0.265	0.415*	0.497*	-0.745**

*Correlation was significant at 0.05 level **Correlation was significant at 0.01 level

P3-8

浅水富栄養化水域における溶存酸素等鉛直分布の季節変動

辻 盛生[1], 東梅 佳菜[1], 鈴木 正貴[1]
[1]岩手県立大学総合政策学部

キーワード：富栄養化，植物プランクトン，成層現象，貧酸素，水生生物

抄録

浄化処理水が主な水源の常時湛水型浅水調整池における水質鉛直分布の季節変動を評価した。凍結期は風雨による攪乱を受けないことから成層状態が卓越した。氷と積雪により水中に達する光は少なく，底層はほぼ 0 lux であったことから光合成は行われず，速度は遅いものの有機物の分解によって底層の DO 濃度は低下した。解氷と共に混合が生じ，植物プランクトンが活発に光合成を行うことで DO と pH は上昇した。特に pH は生物の生息への影響が懸念される 11 を越えた。夏期には昼夜を通した成層が確認され，底層の DO 濃度は低くなった。一方で，強光阻害による植物プランクトンの活動抑制が見られた。秋季は大雨による希釈が生じたが，底層の DO 濃度は低かった。景観形成や鳥類を中心とした生物生息空間としての機能を持つ調整池であるが，水中環境は厳しい状況であった。水生生物の生息環境を整え，より多様な生物の拠り所とするためにも水質改善が望まれる。

1. はじめに

調査地は，岩手県滝沢市に位置する岩手県立大学の 1998 年に竣工した常時湛水型の調整池である（図 1）。水源は，雨水と学内の浄化槽処理水であり，その多くは浄化槽処理水が占め，流入量は 70～150m³/日である。面積は約 4500 ㎡，周囲は 2m～5m の幅で水深約 30cm～50cm の浅水域があり，そこから急に水深が増して水深約 1m～1.2m の平らな池底（深水域）となる。池底は遮水シートであり，5～10cm 程度ヘドロ状の有機物が堆積した状態であった。池の外縁はヤナギやノリウツギなどの木本のほか，浅水域にはガマやクサヨシ，カサスゲ，さらにスイレンが生育し，スイレンの一部は深水域に進出した。木々が生育する中に湛水面があり，バンやヨシゴイなど，レッドリストに掲載される種も含め，2008 年の記録では 38 種の野鳥の飛来が確認された。さらにその外側は緩傾斜草地に囲まれ，自然豊かなたたずまいの池であるが，流入する浄化槽処理水に含まれる栄養塩の影響で富栄養化が進行している。2012～2014 年の水質調査結果（表 1）では，流入水（学内排水処理水）平均値（n=16）が T-N：25.4mg/L，T-P：3.53mg/L，COD：9.27mg/L，流出水の平均値が T-N：10.2mg/L，T-P：1.24mg/L，COD：21.5mg/L であり，典型的な富栄養化水域である。排水処理方法や在学生数，教職員数に大きな変動は無いことから，調査を実施した 2016～2017 年も概ねこのような水質で推移していると考えられる。

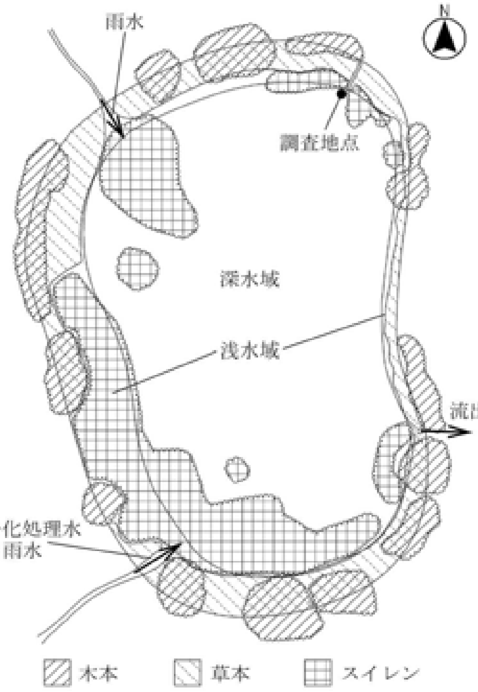


図 1　調査地の状況

調整池には 2000 年にアブラハヤ，モツゴ，ドジョウ，メダカ，ゲンゴロウブナ，ヌカエビあるいはスジエビと思われるエビ類，タニシ類が放流された。しかし，2012 年から複数回に渡って実施した魚類調査では，モツゴ，ギンブナ以外の魚種は捕獲されておらず，ギンブナは大型の個体のみが確認されていたことから，再生産が滞っていると考えられた。（ギンブナの放流は確認されていないが，ゲンゴロウブナとして放流された中に含まれていた可能

表１　調整池流入・流出水質

	流入（浄化処理水）		流出	
	値	S.D.	値	S.D.
pH	7.3	1.26	8.3	1.4
EC（mS/m）	44.1	19.4	26.4	11.6
DO（mg/L）	5.35	2.49	13.8	5.29
Chl-a（μg/L）	3.13	0.79	67.7	68.3
SS（mg/L）	8.94	8.42	26.3	22.7
BOD（mg/L）	2.26	1.42	7.62	3.62
COD（mg/L）	9.27	3.52	21.5	16.3
T-N（mg/L）	25.4	16.7	10.2	8.97
NO_3-N（mg/L）	12.1	12.6	3.8	3.88
NH_4-N（mg/L）	5.00	4.45	1.73	2.47
T-P（mg/L）	3.53	1.76	1.24	0.87
PO_4-P（mg/L）	2.38	1.63	1.07	0.87

測定は2012年11月6日～2014年2月24日（n=16）

表２　調査日の気象データ

	日照時間	最高気温	平均風速	最大風速	雨量
	時間	℃	m/s	m/s	mm/日
3/10	3.7	3.8	2.2	5.2	0
3/30	2.7	12.8	3	6.1	5.8
4/25	4.9	19.9	3.1	7.3	0
6/30	11.1	32.3	1.7	4.4	0.1
8/29	0.0	24.2	1.7	4.9	11.8

性がある。）なお，個体数は不明であるが，モツゴの生息数は多く，再生産も順調に行われた。また，アメリカザリガニの生息も確認された。ここでは，池内の環境条件の季節変動について，生物の生息に直接的に関わる溶存酸素濃度を中心に評価する。

2.　方法

調査地点は，池の北側に作られた池の深水部の際まで至るデッキを利用した（Fig.1）。水深は約 1.05m であった。水質測定は，2016 年 9 月から 2017 年 10 月まで，月 1 回を目処に朝（9 時頃），夕（16 時頃）に携帯測定機器を用いて水温，DO，電気伝導度，pH を表層（0 ㎝）から底層（100 ㎝）まで約 20 ㎝毎に測定した。また，ハイロート採水器を用いて各層で採水した後，実験室にて Chl-a（蛍光法）および濁度の測定を行った。なお，採水は採水器の高さの関係で，底層は水深 80cm までの採水となった。雨量，風向，風速は，学内で測定されたデータ，日照時間は盛岡アメダスのデータに基づいた。水中照度は，2016 年 11 月から調整池の調査地点において，表層（20 ㎝），中層（50 ㎝），底層（80 ㎝）の 3 か所でロガーを用いて 10 分間隔で測定した。

3.　結果

ここでは，降雨の影響が少なく，季節の状況を比較的よく表していると考えられる 5 日を抽出した。各調査日の気象条件を表 2 に，水温，DO，pH，Chl-a の鉛直分布を図 2 に示した。なお，3 月 30 日，8 月 29 日共に測定後

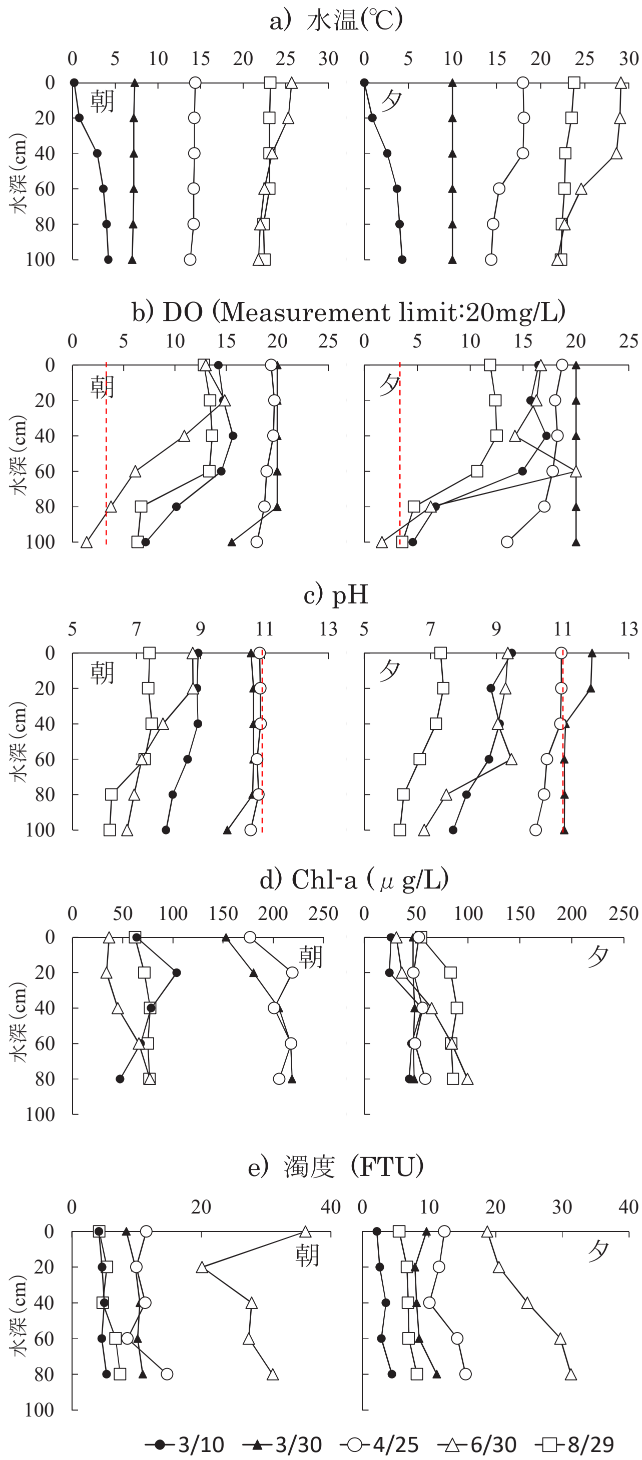


図２　各水質項目の鉛直分布

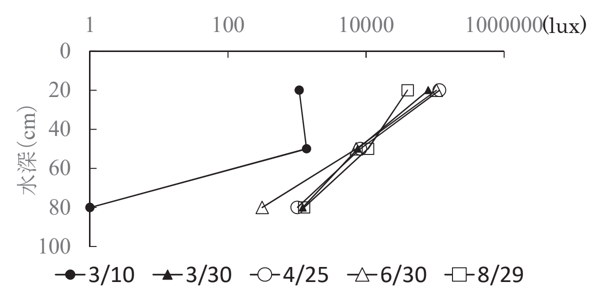


図３　水中照度の鉛直分布

の降雨を，8 月 29 日に測定前の降雨も確認されたが，午前4時以前に観測したものである。調整池について測定日毎にみると，3 月 10 日は全面凍結していたため，表層は 0℃，底層は約 4℃で安定した。氷に覆われていることから水中の光は少なく，表層 20cm で比較した場合，照度は日照が強い非凍結日の 1％未満であり，底層はほぼ 0 lux であった。最表層の DO および pH が夕方に若干上昇する傾向がみられた。水温は低いものの底層の DO は消費され，低い傾向が見られた。3 月 30 日は，解氷直後である。朝夕ともに表層から底層まで水温差が見られず，かつ夕方において表層から底層まで均一に水温が上昇する傾向が見られた。また，pH は朝夕ともに 11 前後を記録し，DO も使用機器の測定上限である 20mg/L 以上の高い状態を維持すると共に，Chl-a 濃度は朝において高い傾向が見られた。4 月 25 日の pH は，朝夕ともに 11 前後を示し，高い状態を維持した。さらに，夕方において，表層の水温が上昇し，底層では DO が減少する傾向が見られた。Chl-a 濃度は朝において高い傾向が見られた。6 月 30 日は，表層で夕方に約 29℃まで水温が上昇し，朝においても表層と底層で水温差が見られた。濁度は他の時期よりも高い傾向が見られた。日照時間は長かったが，底層の照度は 310 lux と低く，底層の DO と pH も低い傾向が見られた。8 月 29 日は曇りであり，朝夕の水温の変化は小さかった。その結果，表層の DO，pH の上昇は見られず，底層の DO のみが日中に低下した。濁度が低下しているが，これは 8 月 22 日から 25 日かけて，総雨量 250mm を越える降雨があり，雨水によって希釈されたためと考えられた。

4. 考察

凍結期においては，表層が 0℃，底層が約 4℃に安定しており，成層が形成され水の動きはほとんど見られないものと推察された。植物プランクトンの光合成による酸素供給はごく表層に限られ，光が届かない底層では DO 濃度の低下が確認されたことから，水温は低いものの，緩やかに底層の有機物を微生物が分解することによって酸素が消費されたと考えられる。解氷後は，表層から底層まで均一に温度が上昇していることから，全層で活発に混合が生じていることが示唆された。植物プランクトンによる光合成によって DO は過飽和の状態であり，夕方の表層 pH 値は生物の生息に影響を与える数値[1]とされる 11 を越えた。また，気温が上昇し日射も比較的多かった 4 月 25 日の夕方において，中層付近に弱い水温躍層が見られたことから，日中には混合が生じていないことが示唆された。その結果として夕方の底層の DO が若干低下する傾向が現れ始めた。3 月 30 日，4 月 25 日共に，朝に Chl-a 濃度が高く，夕方に下がる傾向が見られた。夕方の Chl-a 値を見ると，全体的に表層よりも底層の方が高い傾向が見られたことからも，浅い水域における強光阻害[2]が生じたと考えられる。6 月 30 日は夏期晴天時のデータであるが，朝においても表層と低層の温度差が見られたことから，後田・橋本によって確認された夏期浅水域における日中の成層[3]だけではなく，昼夜を通して成層が確認された。その結果，底層の DO がバクテリアによる有機物の分解によって低下し，生物の生息に支障をきたすとされる 3mg/L[4]を下回った。一方，表層の DO，pH 共に高くなったものの，春の値よりは低かった。さらに，濁度は高かったが Chl-a 濃度は他の時期よりも低い傾向が見られ，表層付近の値が低い傾向が見られたことから，強光阻害によって植物プランクトンの活動が制限されていることが示唆された。濁度は底層の値が高い傾向が見られた。これは表層で発生した植物プランクトンが強光によるストレスで死に，底層付近に沈降して漂っているのかもしれない。8 月 29 日の結果を見ると，大雨による水の入換が生じたことから，濁度，pH 共に下がったものの，DO は表層では過飽和，底層で低下する傾向が見られた。表層と底層の温度差は見られないことから混合が生じている可能性が高いものの，底層の DO が低いことから，水温の高い条件で底層の DO が有機物分解によって迅速に消費されているものと考えられる。

5. 結論

春期の pH が 11 を超えるような条件や，多くの季節で観察された底層の貧酸素状態などは，水生生物にとって致命的となる可能性がある。本研究は，調整池内の 1 地点における評価であることから，調整池全体の環境に当てはめることはできないが，本調整池において浄化処理水による富栄養化が水生生物の生息を制限している可能性が示唆された。鳥類をはじめとする陸域の生物の生息を支える水域生態系をより豊かなものとするためにも，水質改善は不可欠である。

引用文献

[1] 小野国雄・宇野源太（1967）河川汚濁物質の魚類に及ぼす影響，生活衛生，11(4)，164-176.

[2] Masayuki Takahashi, Sooji Shimura, Yukuya Yamaguchi, Yoshihiko Fujita (1971) Photo-inhibition of phytoplankton photosynthesis as a function of exposure time, Journal of the Oceanographical Society of Japan 27(2), 43–50.

[3] 後田俊直・橋本俊子（2011）浅い貯水池における貧酸素化及び富栄養化要因の解析，広島県総合技術研究所保健環境センター研究報告 19，27-36.

[4] 中央環境審議会（2015）水質汚濁に係る生活環境の保全関する基準の見直しについて（答申），中環審第 875 号 10.

P3-9

A Review on the Pelagic Ecology in Lake Lanao, Mindanao Is., Philippines

Ephrime B. Metillo[1*] and Carmelita G. Hansel[2]

[1]Department of Biological Sciences, Mindanao State University-Iligan Institute of Technology, Iligan City, Philippines 9200, [2]Department of Biology, Mindanao State University Marawi City, Philippines; *Corresponding author

Keywords: Lake Lanao, ancient lake, zooplankton, phytoplankton, freshwater ecology

ABSTRACT

Lake Lanao, one of the world's ancient lakes, is scarcely studied. This review focuses on the lake's hydrodynamics and planktonic system since it was first investigated in the 1960s to arrive at objective insights for an ecosystem-based management of the Lake Lanao Watershed. Sustaining the lake water is the intact forest and unstudied major rivers of the watershed. Having an atelomictic epilimnion, the warm monomictic Lake Lanao is spatio-temporally heterogeneous as seen in its dynamic hydro-meteorology and relatively diverse planktonic communities. Water quality analysis in the past indicated high sensitivity to dissolved nutrients suggesting a pelagic ecosystem that is bottom-up or resource controlled, but recent analysis indicates a eutrophic, coliform-contaminated, and invasive zooplankton species-dominated state with anthropogenic input as the possible main driver. Hence, the flux of dissolved nutrients should be a top priority of an ecosystem-based management effort that is participatory, multisectoral, multidisciplinary and science-based co-management approach. Also part of the framework is the looming climate change, which may undoubtedly lead to loss of biodiversity services of Lake Lanao.

1. INTRODUCTION

A major freshwater volcanic lake, Lake Lanao is the largest freshwater body in Mindanao Island[1]. Its watershed provides socioeconomic services that include food, goods, 727.1 megawatts of electricity, freshwater supply, and home to the *Meranaos* or people of the lake[3]. Lake Lanao is one of the 17 world's ancient lakes[3],[27], but studies are few with some published in 1969[2], 1970s[5],[6], [7],[8],[9],[10],[11],[12],[13],[14],[15], followed by others years later[16],[17],[18],[20],[19],[21], [22],[23],[24]. The aims of this review are to describe the pelagic ecology of Lake Lanao and discuss implications to a sustainable lake watershed.

2. METHOD

This review focuses on literature that deals with the hydrodynamics and planktonic ecology of Lake Lanao including other relevant studies on tropical lakes and climate change. The search for literature was conducted using online sources (e.g., Science Direct, Springer, Elsevier, Journal Storage, Wiley Online, Mendeley, ResearchGate), libraries, and high quality unpublished literature. Information was synthesized according to major themes on lake pelagic ecology.

3. RESULTS AND DISCUSSION

Geophysical Features

The lake (Figure 1) was formed about 3.6-5.5 Mya as a result of a lava dam and tectonic movements[27]. The triangular-shaped lake has a mean depth of 60.3 m[23], a surface area of 356 km^2, a pondage volume of 21.25 km^3, a discharge volume of 3.304 million km^3 annually, and a water level at 701.89 masl[2]. 60% of steep surrounding areas are susceptible to erosion[23]. In the past, 1% level of light intensity varied from 11 to 25m with Secchi disk reading of 6 m[2],[5],[6], but recent massive phytoplankton blooms decreased mean Secchi depth to 2.6 m[21].

Hydrology, Thermal Stratification and Circulation

The 1,323.8 Km^2 watershed is still dominated by forests (60%) and farmlands (40%)[23]. Four major inflowing river systems are located at the eastern portion, and water exits at the Agus River[2]. Maximum rain period occurs from June to September, and a dry period in March to April[23]. The average annual rainfall ranges from 1,329 to 5,235 mm[2]. The Lake overturns from December to early March, but stratification is re-established by late March. The mean air temperature is 23.0^{o}C but February is the coldest (17.8^{o}C), while May the warmest (24.5^{o}C-28.0^{o}C). The mean relative humidity ranges from 82%- 89%[2].

Lake Lanao is a warm monomictic lake with the water column isothermal at 24.4^{o}C during overturn[23]. The March stratification begins with the top 30 m warming up rapidly to 26.5^{o}C, and a sharp thermocline forms at 21-23 m that persists through April to December[2]. However, atelomixis creates secondary and tertiary thermoclines within the epilimnion[5], namely the breeze thermocline at 5-20 m, broken down by light winds; the squall thermocline at 20-30m deep is broken by moderate winds, and the deepest storm thermocline broken by strong storm winds[5].

Chemical Profile

The oscillation of the mixed layer at the metalimnion can resupply incremental nutrients to the epilimnion, but major resupply is during the annual mixing[29],[30]. Overturn homogenizes different strata, while atelomixis homogenizes the epilimnion without disturbing the hypolimnion[5]. The 24°C temperature of the hypolimnion means high microbial nutrient regeneration rates, at a cost of oxygen at 2.6-4.3 mgC m^{-3} hr^{-1}[13], but the lake can sustain dissolved oxygen in deep waters[28]. Mean oxygen content of water column rises from its low overturn level of 4.3 ppm to a maximum stratified level of 6.4 ppm[5]. Past levels of nitrates averaged 9 ugl^{-1} in the euphotic zone, while average phosphates was 29 ugl^{-1} PO_4-P[2] with nitrogen as a limiting nutrient for autotrophs[14]. Silicate averages 2.2 mgl^{-1} which is non-limiting to diatom growth[13]. The pH at 10 m ranged from 8.2-8.9 then pH gradually declined to 7.2 at 45 m[2].

Planktonic Diversity

Recent bacterial analysis indicated positive for fecal coliform[21] as against national standards of zero total coliform per 100 ml of water[23]. A lone study on protists reported high density of 1,900 flagellate individuals ml^{-1}, which can help regulate bacterial abundance[30].

70 phytoplankton species that can show succession were recorded[7],[8],[10],[12],[13], but 70 is lower than in temperate lakes but comparable with other tropical lakes[11]. 13 species accounted for 90% of the annual mean biomass as chlorophyll *a* values of 6.9±0.6 mg l^{-1} placing the lake in a mesotrophic status[11], but its 6 m transparency makes it oligotrophic[31]. Past blooms occurred mainly during circulation[13], but recent blooms occur even before circulation[21], and confirming a eutrophic state, with dissolved nutrients registering higher maximum values (10-40 ugl^{-1} NO_3-N; 20-40 ugl^{-1} PO_4-P)[21], compared to past levels of 9 ug l^{-1} NO_3-N and 29 ug l^{-1} PO_4-P[11].

The diverse zooplankton (25 species of Cladocera, 18 Rotifera and 8 Copepoda) is important to achieving high fish yields[2],[19]. Recently, the eutrophication indicator and invasive calanoid copepod species *Arctodiaptomus dorsalis* is now abundant in the lake [24].

Primary and secondary production

Average respective primary production in the 1960s[2] and 1970s[6] were 382.33 ± 94.11 SD mgC m^{-2} day^{-1} and 2.6 gC m^{-2} day^{-1}. Photoinhibition occurred at insolations ranging from 101 to 133 kerg cm^{-2} sec[6]. The annual variation of primary production is controlled by resource (e.g., nutrient, sunlight) supply rather than temperature or biomass removal (grazing and sinking)[12].

Secondary production via grazing by zooplankton is controlled by autotrophic phytoplankton biomass[9],[14], manifesting a bottom-up control[32]. Grazing mainly occurs at the upper layers at night, but it only accounts 6.8% per day loss for autotrophs since the average replacement rate of autotroph biomass is 80% per day. The zooplanktivorous *Chaoborus* keeps prey abundance in check[9], but the impact of this species needs research as reduction in dissolved oxygen due to eutrophication and climate change may favor it with consequential reduction of zooplankton prey populations and a possible decline in fish production of up to 90%[15].

Potential Sources of Aquatic Pollution

In 1963, a 5-ha fishpond and hatchery was established stocking the lake with carp and tilapia fingerlings[20], but aquaculture is not common in the area at present. The major agriculture activities are cattle raising[1] and cultivated of cash crops, tree crops, fruit trees, corn and rice mainly at the eastern alluvial deltaic plain[23].

4. CONCLUSION

The geology of the lake is understood but the influence of hydrodynamics and chemistry on productivity is a major gap. The pelagic ecosystem is bottom-up driven, so that changes in water quality will have disastrous effects on the entire lake ecosystem. The lake now is largely eutrophic, and main drivers are anthropogenic activities.. We recommend priority research and development on climate change impact, top-down models, lotic subsystem, proper valuation of the watershed biodiversity, and the implementation of a multisectoral, participatory, and science-based co-management system.

REFERENCES

[1] Baconguis, S.R., Cabahug, D.M., Alonzo-Pasicolan, S.N.: Identification and inventory of Philippine forested-wetland resource, Forest Ecology & Management, Vol. 33, pp. 21-44, 1990.

[2] Frey, D.G.: A limnological reconnaissance of Lake Lanao. Verhandlungen Internationale Vereinegung Limnologie, Vol. 17, pp. 1090-1102, 1969.

[3] Naga, P.O.: Lake Lanao: An ancient lake in distress. In 13th World Lake Conference in China, 2010.

[4] Schön, I., Martens, K.: Adaptive, pre-adaptive and non-adaptive components of radiations in ancient lakes: a review. Organisms Diversity & Evolution, Vol. 4(3), pp. 137-156, 2004.

[5] Lewis, W.M. Jr.: The thermal regime of Lake Lanao (Philippines) and its theoretical implications for tropical lakes, Limnology and Oceanography, 18(2), 200-217, 1973.

[6] Lewis, W.M. Jr.: Primary production in the plankton

community of a tropical lake, Ecological Monographs, Vol. 44(4), pp. 377-409, 1974.

[7] Lewis, W.M. Jr.: Surface/volume ratio: implications for phytoplankton morphology, Science, Vol. 192(4242), pp. 885-887, 1976.

[8] Lewis, W.M. Jr.: Ecological significance of the shapes of abundance-frequency distributions for coexisting phytoplankton species, Ecology, Vol. 58(4), pp. 850-859, 1977a.

[9] Lewis, W.M. Jr.: Feeding selectivity of a tropical *Chaoborus* population, Freshwater Biology, Vol. 7, pp. 311-325, 1977b.

[10] Lewis, W.M. Jr.: Net growth rate through time as an indicator of ecological similarity among phytoplankton species, Ecology, Vol. 58(1), pp. 149-157, 1977c.

[11] Lewis, W.M. Jr.: A compositional, phytogeographical and elementary structural analysis of the phytoplankton in a tropical lake: Lake Lanao, Philippines, Journal of Ecology, Vol. 66(1), pp. 213-226, 1978a.

[12] Lewis, W.M. Jr.: Analysis of succession in a tropical phytoplankton community and a new measure of succession rate. The American Naturalist, Vol. 112(984), pp. 401-414, 1978b.

[13] Lewis, W.M. Jr.: Dynamics and succession of the phytoplankton in a tropical lake: Lake Lanao, Philippines, Journal of Ecology, Vol. 66(3), pp. 849-880, 1978c.

[14] Lewis, W.M. Jr.: Comparison of temporal and spatial variation in the zooplankton of a lake by means of variance components, Ecology, 59(4), 666-671, 1978d.

[15] Lewis, W.M. Jr.: Evidence for stable zooplankton community structure gradients maintained by predation. Limnology and Oceanography Special Symposium No.3, Zooplankton Community Structure, C. Kerfoot, editor, 1978e.

[16] Escudero, P.T., Gripaldo, O.M., Sahay, N.M.: Biological studies of the *Glossogobius giurus* (Hamilton & Buchanan) and the *Puntius sirang* (Herre) in Lake Lanao, Journal of Fisheries and Aquaculture, Vol. 1(1), pp. 1-154, 1980.

[17] Escudero, P.T., Demoral, M.A.: Preliminary studies on the biology and fishery of *Hypseleotris agilis* Herre (Eleotridae), Journal of Fisheries and Aquaculture, Vol. 4(1–2), pp. 3–89, 1983.

[18] Escudero, P.T.: Lake Lanao fisheries: problems and recommendations, Philippine Biota, Vol. 27(1), pp. 8-18, 1994.

[19] Mamaril, A.C.: Zooplankton diversity in Philippine lakes. In CB Santiago, ML Cuvin-Aralar and ZU Basiao (Eds.). Conservation and Ecological Management of Philippine Lakes in Relation to Fisheries and Aquaculture. Southeast Asian Fisheries Development Center, Aquaculture Department, Iloilo, Philippines; pp. 81-93, 2001.

[20] Rosagaron, R.P.: Lake Lanao: Its past and present status, In CB Santiago, ML Cuvin-Aralar and ZU Basiao (Eds.). Conservation and Ecological Management of Philippine Lakes in Relation to Fisheries and Aquaculture. Southeast Asian Fisheries Development Center, Aquaculture Department, Iloilo, Philippines; pp. 29-39, 2001.

[21] Lagmay, J., Hansel, C.G., Escudero, P., Autor, N., Dagot, D., Estoista, R.V., Lopez, L., Mero, D., & Nacua, S.: Hydrobiological assessment of Lake Lanao: subsequent to its unusual greening in 2006, Mindanao Journal, Vol. 29, pp. 85-100.

[22] Ismail, G.B.: The status and life history traits of endemic, native and introduced species in Lake Lanao, Philippines. Unpublished Master of Science in Fisheries Science Thesis, Oregon State University, USA, 210 pp, 2011.

[23] Department of Environment and Natural Resources [DENR]: Protected Area Suitability Assessment (PASA) of Lake Lanao Watershed. Department of Environment and Natural Resources Region 10, Cagayan de Oro City, 2012.

[24] Metillo, E.B., Masorong, A.M., Macabangkit, S.A.N., Licayan, J.R.U., Tordesillas, D.T., & Papa, R.D.S.: First record of the invasive *Arctodiaptomus dorsalis* (Marsh, 1907) (Copepoda: Calanoida: Diaptomidae) in Lake Lanao (Mindanao Is., Philippines), Acta Manilana, Vol. 62, pp. 19-23, 2014.

[25] Myers, G.S.: The endemic fauna of L. Lanao and the evolution of higher taxonomic categories, Evolution, Lancaster, Pa., Vol. 14(3): 323-333, 1960.

[26] Martens, K.: (1997). Speciation in ancient lakes, Trends in Evolution and Ecology, Vol. 12(5), pp. 177-182.

[27] Harrison, I.J., Stiassny, M.L.: The quiet crisis. In Extinctions in near time, Springer US, pp. 271-331, 1999.

[28] Lewis, W.M. Jr.: Basis for the protection and management of tropical lakes, Lakes & Reservoirs: Research and Management, Vol. 5, pp. 35–48, 2000.

[29] Lewis, W.M. Jr.: Comparisons of phytoplankton biomass in temperate and tropical lakes, Limnology and Oceanography, Vol 35(8), pp. 1838-1845, 1996.

[30] Sheela, A.M., Letha, J., Joseph, S.: Environmental status of a tropical lake system, Environmental Monitoring and Assessment, Vol. 180, pp. 427–449, 2011.

[31] Lewis, W.M. Jr.: Protozoan abundances in the plankton of two tropical lakes. Archiv fur Hydrobiologie, Vol. 104(3), pp. 337-343, 1985.

[32] Gliwicz, Z.M.: On the different nature of top-down and bottom-up effects in pelagic food webs, Freshwater Biology, Vol. 47, pp. 2296–2312, 2002.

Figure 1. Bathymetric map of Lake Lanao. Red line demarcates the watershed. Insert: Map of Mindanao and Philippines showing the location of Lake Lanao. Source: DENR 2012

P3-10

霞ヶ浦湖水の白濁化と魚類生産について

岩崎 順[1]

[1]技術士(水産部門〔水産水域環境〕)

キーワード:霞ヶ浦,白濁化,植物プランクトン,ワムシ類,ワカサギ

抄録

霞ヶ浦の白濁化の発生・解消とワカサギ資源の低水準期から増加期への変化との関連性について比較検討を行い、以下のプロセスが介在していることが考えられた。FSS が減少し白濁化が解消されると,透明度が上昇し光環境が改善される。すると,植物プランクトンが増加し,それを餌とするワムシ類等の小型動物プランクトンが増加する。その結果,ワカサギ仔魚の生残率が向上し,ワカサギ資源量も増加する。以上から、白濁化が起こると、太陽光が湖水中に入射する量が不足して植物プランクトンによる光合成が阻害され,基礎生産量を低下させることになり,本来の生態系の健全な構造が歪められることが示唆された。

1. はじめに

霞ヶ浦(西浦)は,ワカサギ *Hypomesus nipponensis*,シラウオ *Salangichthys microdon*,テナガエビ *Macrobrachium nipponense* 等の水産資源に恵まれ,古くから多種多様な漁業が盛んに行われている湖である。

霞ヶ浦では,1999～2007 年頃にかけて,湖水が白く濁り,透明度が著しく低下する白濁化が発生した[1]。この現象の原因物質は,無機態の鉱物結晶であることが明らかになっている。

一方,霞ヶ浦の重要水産資源であるワカサギは,1999～2008 年の漁獲量が 200 トン以下の低水準で推移したが,2009 年以降増加に転じ 200～500 トン台を維持している。

ワカサギ資源の減少要因は,初期餌料発生量が少ないことによる孵化初期の生残率低下とされている[2]。今回の研究では,白濁化の発生・解消とワカサギ資源の低水準期から増加期への変化との関連性について比較検討を行った。

2. 方法

本研究では,国立環境研究所が公開している霞ヶ浦データベースから1977～2013 年の霞ヶ浦湖心の懸濁物質量(SS)とクロロフィル a 量(Chl.a)のデータ[3],及び国土交通省霞ヶ浦河川事務所が公開している水質調査データのうち 1972～2013 年の湖心の SS と Chl.a のデータ[4]を用いた。そして,SS から Chl.a 補正して求めた揮発性懸濁物質量(VSS)を SS から差し引いて,無機態懸濁物質量 (FSS)を算出した。なお,本研究では,FSS,Chl.a ともに,月別の 5 点移動平均値を用いて考察した。

植物プランクトン量は,茨城県企業局水質年報の藻類検査結果を参照した。ワカサギの初期餌料であるワムシ類の発生量は,霞ヶ浦の湖岸 7 地点で 2003～2012 年の 3 上旬～4 月下旬に週 1 回の頻度で採集し,現存量の平均値を算出した。

ワカサギ初期資源量は,霞ヶ浦 4 水域で 2003～2012 年の 6 月下旬～7 月上旬に 1 回試験操業を行い,ワカサギ仔稚魚現存量の平均値を算出した。

ワカサギ漁獲量は,農林水産統計年報を参照した。

3. 結果及び考察

(1)FSS の長期変動傾向

FSS は,国立環境研究所,霞ヶ浦河川事務所の両者とも,1977～1998 年まで,1 時期を除き 0～10 mg/L を維持していたが,1999 年以降増加し始め,2007 年まで高レベルを維持していた。ピークは 2004～2005 年であった(各々,25 mg/L,14 mg/L)。2008 年以降,FSS は減少する傾向にあった(図 1)。FSS の高レベルの時期は,湖水の白濁化の時期と一致していた。

(2)Chl.a と植物プランクトンの長期変動

Chl.a は,国立環境研究所,霞ヶ浦河川事務所の両者とも,1977～1998 年まで 30 μg/L から 80 μg/L へと徐々に増加する傾向にあったが,1999 年以降急減し,2007 年まで低レベルを維持していた。2008 年に Chl.a

は一気に 80 μg/L に達したが，その後徐々に減少していった（図 2 上）。

植物プランクトン個体数は，1996～2009 年の調査期間中，珪藻類には変動はあるものの大きなトレンド変化は認められなかった。藍藻類は 1999 年以降減少し始め，2007 年まで低レベルを維持していたが，その後増加に転じた。（図 2 下）。

Chl.a，藍藻類の低レベルの時期は，FSS の高レベルの時期，すなわち湖水の白濁化の時期と一致していた（図 1，2）。

（3）ワムシ類の発生量

ワムシ類の発生量は 2003～2007 年まで低位安定であったが，2008 年以降増加する傾向にあった。また，ワムシ類の種組成は 2008 年と 2009 年を境にして大きく変化した[5]。すなわち，2003～2008 年まではドロワムシ *Synchaeta* sp.が優占種であったが，2009 年以降はツボワムシ *Brachionus* spp.，ハネウデワムシ *Polyarthra* sp.が優占種となった。

2008 年以降のワムシ類の発生量増加は，植物プランクトンのうち藍藻類の増加に起因すると考えられた。しかし，2009 年以降のワムシ類の種組成変化の時期と白濁化解消の時期がほぼ一致している原因は明らかではない。

（4）ワカサギ初期資源量

ワカサギ初期資源量は，2009 年以降増加する傾向がみられた[6]。

ワムシ類の発生量とワカサギ初期資源量には正の相関がみられることから，ワカサギ資源量は孵化初期に摂餌量が改善されて生残率が向上したため，増加傾向に転じたと考えられる。また，2009 年以降ワムシ類の種組成が変化していることから，低次生産を含む霞ヶ浦全体の生態系が変化していると推察された。

4. 結論

ワカサギ資源量の増加には，以下のプロセスが介在していると考えられた。すなわち，FSS が減少し白濁化が解消されると，透明度が上昇し光環境が改善される。すると，植物プランクトン（Chl.a が指標）が増加し，それを餌とするワムシ類等の小型動物プランクトンが増加する。その結果，ワカサギ仔魚の生残率が向上し，ワカサギ資源量も増加する。ただし，仔魚期以降の成長期（稚魚，未成魚）では，ワムシ類以外の大型動物プランクトンやイサザアミ等が餌料として重要になるので，それらの量がワカサギ資源量に影響を及ぼすことになる。

以上から、霞ヶ浦で白濁化が起こると，太陽光が湖水中に入射する量が不足し植物プランクトンによる光合成が阻害され，基礎生産量を低下させることになり，本来の生態系の健全な構造が歪むことになる。すなわち，基礎生産に依存する動物プランクトンやそれを餌にする魚類が増えにくくなるという問題をはらんでいることが示唆された。

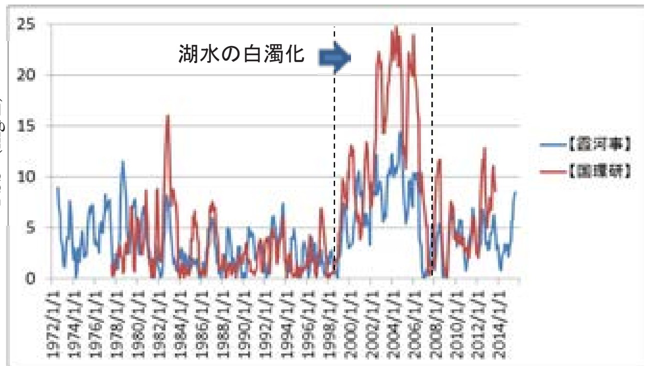


図１．霞ヶ浦(湖心)における FSS(無機態懸濁物質量)の長期変動傾向

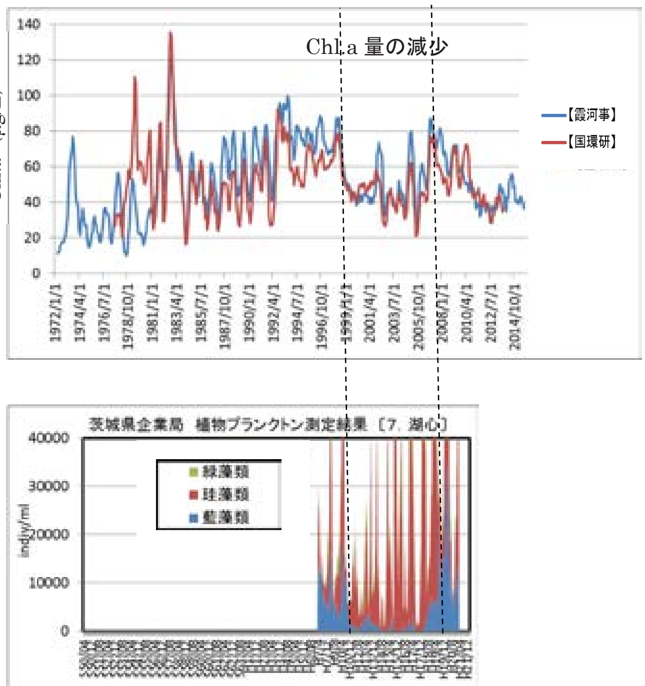


図２. 霞ヶ浦（湖心）におけるクロロフィル a 量（上図）と植物プランクトン個体数（下図）の長期変動傾向とその関連性

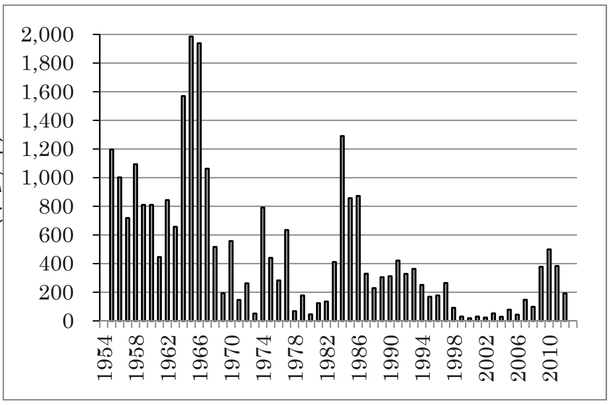


図３．霞ヶ浦におけるワカサギ漁獲量の推移
（農林水産統計年報）

引用文献

[1] 岩崎　順・外岡健夫（2000）：1999 年 7 月に霞ヶ浦で発生した濁水について，茨城内水試調研報，第 36 号，16-19.

[2] 熊丸敦郎（2003）：霞ヶ浦における近年のワカサギ資源変動要因について，茨城内水試調研報，第 38 号，1-18.

[3] 国立環境研究所（2016）：霞ヶ浦データベース，http://db.cger.nies.go.jp/gem/inter/GEMS/database/kasumi/. 2016 年 1 月 14 日時点.

[4] 霞ヶ浦河川事務所（2016）：霞ヶ浦の水質データ，http://www.ktr.mlit.go.jp/kasumi/kasumi00145.html. 2016 年 1 月 14 日時点.

[5] 須能紀之・岩崎　順・丹羽晋太郎・根本　孝（2013）：孵化初期餌料発生量の変化に起因するワカサギ資源量の増加，平成 25 年度日本水産学会春季大会要旨.

[6] 茨城県水産試験場内水面支場（2016）：平成 21～24 年ワカサギ漁期前調査結果報告，http://www.pref.ibaraki.jp/nourinsuisan/naisuishi/index.html. 2016 年 1 月 14 日時点.

P3-11

SENSITIVITY LEVEL OF PHYTOPLANKTON TOWARDS NUTRIENTS AND ZOOPLANKTON IN EBONY LAKE, PIK RESIDENCE, NORTH JAKARTA

Niken TM Pratiwi[1], Sigid Hariyadi[1] and Reza Zulmi[1]

[1]Bogor Agricultural University

Keywords: sensitivity level, phytoplankton, zooplankton

ABSTRACT

Lake Ebony in Pantai Indah Kapuk Residence, North Jakarta received input of organic materialwhich lead a dynamic of nutrients and plankton community. This study aimed to analyze phytoplankton sensitivity level to water quality and zooplankton the lake. Water and plankton were collected from January to December 2015. There were 36 genera of phytoplankton from six classes, and seven genera of zooplankton from Three groups. Cyanophyceae and Chlorophyceae sensitive towards zooplankton; and Euglenophyceae and Dinophyceae sensitive towards orthophosphate.

1. INTRODUCTION

Ebony Lake is one of ornamental lake at coastal residence area, Pantai Indah Kapuk, North Jakarta. This small and shallow waters with about 6 ha wide and 1.2 m depth, received high content of inorganic and organic materials from residence drainage. This material input influences water quality of lake. Furthermore, this change influences any living there [1, 2, 3, 4].

Plankton, especially phytoplankton, is one of the most responsive community due to the change water quality [5, 6, 7]. Its composition, densities, and community structure have functional relationship to water condition, such as nutrients availability, light intensity, and other water quality parameters. On the other hand, phytoplankton community is also correlated to the presence of zooplankton.

The input of inorganic materials leads increasing of inorganic nutrients, which means that there is an increasing of biological available nutrients. This type of nutrients can directly utilized by phytoplankton. Furthermore, the input of organic materials is directly used by some spesies of zooplankton.

One year data series of nutrients condition, and the densities of the two community of plankton are used to study the relationship among others and the sensitivities between phytoplankton densities with water quality, nutrients, and zooplankton densities in Ebony Lake, Pantai Indah Kapuk (PIK), North Jakarta.

2. METHOD

Sampling was done at Ebony Lake that is located in Pantai Indah Kapuk (6°6,265'-6°6,594' S dan 106°44,630'-106°44,885'E), North Jakarta. Five sampling sites were set at square ring shaped of waters, the north eastern (St 1), eastern (St 2), south eastern (St 3), south western (St 4) that relatively close to the inlet, and north western (St 5) that relatively close to the outlet. The sampling was done monthly from January to December 2015.

The identifikacion of plankton followed some identification references [8, 9, 10, 11]. The density of plankton was counted using Sedgewick Rafter Counting cell (SRC) at 10x10 magnification. There were some parameters that measured or analyzed in situ, such as depth, water transparency, temperature, pH, salinity, conductivity, and dissolved oxygen/DO. Some chemical parameter that were analyzed in laboratory were ammonia (NH3-N), amonium (NH4-N), total nitrogen, nitrite (NO2-N), nitrate (NO3-N), orthophosphate (PO4-P) and total phosphate. All of those analysis methods were based on APHA 2012[12].

As statistical analysis, Pearson correlation test[13] was used to analyze relationship between phytoplankton densities with nutrients and zooplankton. Moreover, the sensitivity of phytoplankton towards nutrients and zooplankton were determined by the value of regression coefficient (βi) of each specific independent variable. The sensitivity levels of phytoplankton were derived from first differential of regression formulations as follows.

$$Y_{phyto} = \beta_0 . X^{\beta1}_{NH4\text{-}N} . X^{\beta2}_{NO3\text{-}N} . X^{\beta3}_{PO4\text{-}P} . X^{\beta4}_{NZoo}$$

$$dy/dx_{\ NH4\text{-}N} = \beta_0 . \beta_1 X^{\beta1\text{-}1}_{NH4\text{-}N} . (X^{\beta2}_{NO3\ N} . X^{\beta3}_{PO4P} . X^{\beta4}_{NZoo})$$

$dy/dx_{NO3\text{-}N} = \beta_0 . \beta_2 X^{\beta 2\text{-}1}{}_{NO3\text{-}N} .(X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P} . X^{\beta 4}{}_{NZoo})$

$dy/dx_{PO4\text{-}P} = \beta_0 . B_3 X^{\beta 3\text{-}1}{}_{PO4\text{-}P} .(X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 4}{}_{NZoo})$

$dy/dx_{NZoo} = \beta_0 . B_4 X^{\beta 4\text{-}1}{}_{NZoo} .(X^{\beta 1}{}_{NH4\text{-}N} . X^{\beta 2}{}_{NO3\text{-}N} . X^{\beta 3}{}_{PO4\text{-}P})$

Hence, the values of each nutrient and zooplankton level that could change the Population of phytoplankton were calculated as follows.

$$X_{NH4\text{-}N} = \frac{\pm 1}{\beta_\cap . \beta_1 . X^{\beta_2}{}_{NO3\text{-}N} . X^{\beta_3}{}_{PO4\text{-}P} . X^{\beta_4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{NO3\text{-}N} = \frac{\pm 1}{\beta_\cap . \beta_2 . X^{\beta_1}{}_{NH4\text{-}N} . X^{\beta_3}{}_{PO4\text{-}P} . X^{\beta_4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{PO4\text{-}P} = \frac{\pm 1}{\beta_\cap . \beta_3 . X^{\beta_1}{}_{NH4\text{-}N} . X^{\beta_2}{}_{NO3\text{-}N} . X^{\beta_4}{}_{NZoo}} \{1/\beta_1 - 1\}$$

$$X_{NZoo} = \frac{\pm 1}{\beta_\cap . \beta_4 . X^{\beta_1}{}_{NH4\text{-}N} . X^{\beta_2}{}_{NO3\text{-}N} . X^{\beta_3}{}_{PO4\text{-}P}} \{1/\beta_1 - 1\}$$

3. RESULTS

There were found 36 genera of phytoplankton and seven genera of zooplankton in total. The phytoplankton community comprise six class groups. The phytoplankton were Cyanophyceae (7 genus), Bacillariophyceae (12 genus), Chlorophyceae (20 genus), Euglenophyceae (4 genus), then Dinophyceae and Cryptophyceae, each with one genera. The zooplankton were Protozoa (1 genera), Rotifera (3 genus), and Crustaceae (3 genus).

The most varied of phytoplankton was found in March, and for zooplankton were in January to April. The least varied of phytoplankton was found in November, and for zooplankton were in September to November.

The densities of phytoplankton were ranged from 106x106 to 2981x106 cell/m3; the found in March, with dominance of Cyanophyceae although in low number of genera. The zooplankton were ranged from 298 to 1852 ind/m3; that most dense in January with domination of Rotifers. Water quality and nutrients (N/P ratio) condition is shown in Figure 1. The result of correlation test between phytoplankton and nutrients and zooplankton is shown in Table 1.

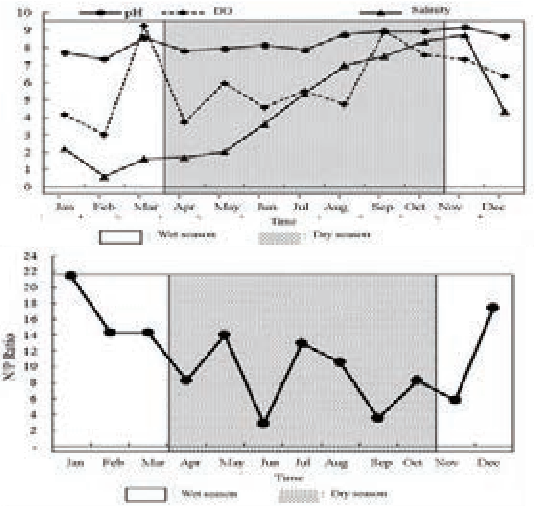


Figure 1 Water quality (A) and nutrients (N/P ration) condition (B) in Ebony Lake

Table 1 Correlation and sensitivity between phytoplankton towards nutrient and zooplankton in Ebony Lake

Group of Phytoplankton	Coefficient of regressoni (β)* and sensitivity ( ) value							Intercept (β0)	R^2	F value	F Sig.
	NH_3-N	NH_4-N	NO_3-N	NO_2-N	PO_4-P	Ro	Cr				
Cyanophyceae	-9.677	17.828		-5.464	-3.032		5.873* (0.787)	-13.585	0.962	14.696	0.003
Bacillariophyceae					-0.783	-0.917		9.927	0.648	3.256	0.086
Chlorophyceae		0.833				1.429*(0.763)		3.745	0.854	12.106	0.003
Euglenophyceae	-3.411	3.391	0.756*(0.715)		-0.457* (-0.532)			7.002	0.959	20.093	0.001
Dinophyceae					-2.080* (-0.694)			-1.578	0.694	9.307	0.012
Cryptophyceae					1.595	2.733	2.353	-11.205	0.718	2.843	0.106

4. DISCUSSION

Figure 1 and table 1 is shown that some groups of phytoplankton have a significantly correlated to nutrients and zooplankton. This was more clear in dry than in wet season. The variation of densities and number of genera fluctuated along with N/P ratio with one month lag periode, especially in dry season. The positive correlations were shown between Euglenophyceae towards nitrate, Cyanophyceae with Crustacea, and Chlorophyceae towards Rotifers. The negative correlations were shown between Euglenophyceae and Dinophyceae towards orthophosphate.

Although there was built a relatively good model of the relationship between Cyanophyceae and most of all measured nutrients and zooplankton component, the most influence was shown significantly by Crustacea component ($p<0.05$). Furthermore, there will result an explaination as above. Furthermore, the sensitivity value of Cyanophyceae towards Crustaceae was 0.787. It means that one unit change of Crustacea will change 0.787 in proportion of Cyanophyceae. The other values are also shown the same illustration.

Some interesting things are the existence of Bacillariophyceae that dominant in the last periode of dry season and clear sensitivity of least common of phytoplankton. Usualy, nutrients are the most important component that role as limiting factors for phytoplankton Yet, the result showed that the dominance of this group was led by the increasing of salinity, not by nutrients condition. This bear a pressumption that nutrients were not only component that roles as limiting factor for the growth and development of phytoplankton in Ebony Lake. It was mentioned that sometimes other water quality parameter could role as limiting factor for phytoplankton. The high organic material that dominates the input of Ebony Lake leads the change of water quality, especially oxygen in decomposition process. Those processes and two extreme condition is occured naturally. With spesies specific charasteristics of phytoplankton, there will appear a dynamic condition of phytoplankton.

5. CONCLUSION

Cyanophyceae and Chlorophyceae sensitive towards zooplankton; and Euglenophyceae and Dinophyceae sensitive towards orthophosphate.

REFERENCES

[1] Zhao HJ, Wang Y, Yang LL, Yuan LW, Peng DC. 2015. Relationship between phytoplankton and environmental factors in landscape water supplemented with reclaimed water. Ecological Indicators. 58: 113-121.

[2] Piehler MF, Twomey LJ, Hall NS, Paerl HW. 2004. Impacts of inorganic nutrient enrichment on phytoplankton community structure and function in Pamlico Sound, NC, USA. Estuarine Coastal and Shelf Science. 61: 197-209

[3] Buyukates Y and Roelke D. 2005. Influence of pulsed inflows and nutrient loading on zooplankton and phytoplankton community structure and biomass in microcosm experiments using stuarine assemblages. Hydrobiologia. 548: 233-249

[4] Shen PP, Li G, Huang LM, Zhang JL, Tan, YH. 2011. Spatio-temporal varibility of phytoplankton assemblages in the Pearl River estuary, with special reference to the influence of turbidity and temperature. Continental Shelf Research. 31: 1672-1681

[5] Wetzel RG. 2001. Limnology: Lake and River Ecosystems, 3rd ed. London (UK): Academic Press

[6] Phlips EJ, Badylak S, Grosskopf T. 2002. Factors Affecting the Abundance of Phytoplankton in a Restricted Subtropical Lagoon, the Indian River Lagoon, Florida, USA. Estuarine, Coastal and Shelf Science. 55: 385–402

[7] Wu Z, Cai Y, Liu X, Xu CP, Chen Y, Zhan L. 2013. Temporal and spatial variability of phytoplankton in Lake Poyang: The largest freshwater lake in China. Journal of Great Lakes Research. 39: 476-483

[8] Edmonson WT. 1963. Fresh Water Biology: 2nd ed. Washington (USA): John Wiley & Sons inc

[9] Prescott GW. 1970. The Freshwater Algae. Dubuque Lowa (USA): Brown Company Publishers

[10] Belcher H, Erica S. 1978. A Beginner's Guide to Freshwater Algae. Cambridge (UK). Institute of Terrestrial Ecology

[11] Mizuno T. 1979. Illustrations of The Freshwater Plankton of Japan, revised ed. Osaka (J): Hoikusha Publishing Co., LTDOdum EP. 1971. Fundamentals of ecology. Third Ed. W.B. Saunders Company. Philadelphia. 574 p.

[12] Rice EW, Baird RB, Eaton AD, Clesceri LS. 2012. APHA (American Public Health Association): Standard Method for The Examination of Water and Wastewater 22th ed. Washington DC (US): AWWA (American Water Works Association) and WEF (Water Environment Federation).

[13] Usman H, Akbar PS. 2006. Pengantar Statistika. Jakarta (ID): Bumi Aksara

P3-12

Trophic and Ecological States of Garden House Ornamental Lake, Pantai Indah Kapuk, North Jakarta

Inna Puspa Ayu[1], Arik Pangesti[1], Niken TM Pratiwi[1], Sigid Hariyadi[1]

[1]Bogor Agricultural University

Keywords: Plankton, nutrient, management

ABSTRACT

Garden House Ornamental Lake is one of the artificial ponds in Pantai Indah Kapuk, and it has received high input of organic matter from domestic activities. Input of organic matter may change water quality, increase trophic states, and effect the ecological conditions of the water. The purpose of this research is to analyze trophic and ecological states of Garden House Ornamental Lake. Water quality, especially nutrient was measured to support tropical state. The tropical state of lake was analyzed using Nygaard Index while the ecological state with MedPTI Index (Mediterranean Plankton Trophic Index). Concentration of orthophosphate in the lake is more than 0,1 mg/l. Nutrient parameters at Garden House Lake are high showed by high concentration. The trophic state of Garden House Lake is eutrophic, shown by 9,5-10,5 value of Nygaard index and an ecological state is poor until bad, shown by 1,46-1,85 of MedPTI index. Ornamental lake could be overwhelmed by wastewater treatment to restore lake state.

1. INTRODUCTION

Pantai Indah Kapuk, known as an estate area in Jakarta, Indonesia, has many ornamental lakes. One of the ornamental lakes is Garden house. Garden house has 11615 m^2 wide and less than 1 m depth. The function of garden house ornamental lake is for flood controlling & landscape.

The ornamental lake has received domestic waste from houses. This impact degrades lake because of organic matter caused by water quality changes [1], which can be shown from colour and smell of water. Research in 2017 also showed Garden house ornamental lake has low dissolved oxygen, high nutrient concentration, and cyanophyceae domination.

This condition leads to eutrophic condition or even may have happened eutrophic condition. Identification of trophic and ecological state of this lake is important step to define lake management, especially for landscaping necessary.

The aim of this research is to describe trophic and ecological states of Garden House Ornamental lake in Pantai Indah Kapuk, Jakarta Utara.

2. METHOD

Records of phytoplankton were applied to identify trophic states; meanwhile plankton and nutrient were applied to identify ecological status. Samples of phytoplankton and water for nutrient were taken from five stations in ornamental Lake of Garden House (Fig. 1).

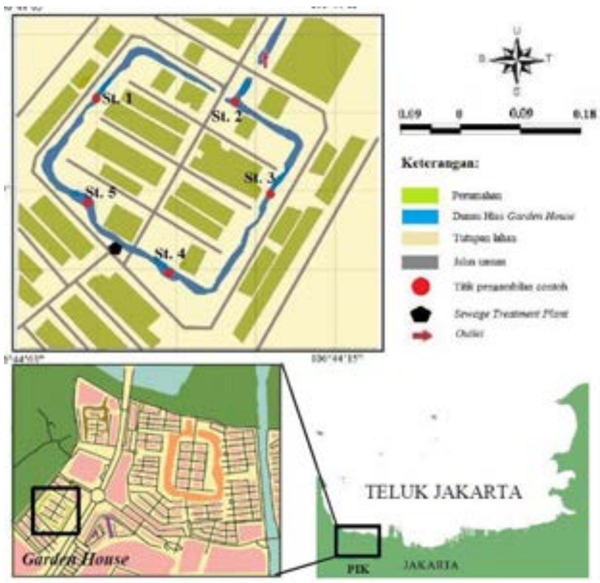


Fig. 1 Sampling site of phytoplankton in Garden House Ornamental Lake, Pantai Indah Kapuk, Jakarta

Water quality (dissolved inorganic nutrient, orthophosphate, N:P ratio) was measured in-situ & ex-situ. The degree of similarity in phytoplankton abundance between five stations was analyzed using Canberra Index[2]. Trophic state was analyzed using Nygaard Index (In), which is based on Phyoplankton species composition. Ecological status was analyzed using MedPTI index (Mediteranian Plankton Trophic Index), which involves phytoplankton biomass.

Nygard index formulation was obtained from number species of phytoplankton of Cyanophyceae (Cyano), Chlorococcales (Chloro), Diatom centrales, Euglenophyceae (Eugleno), Desmidiacea.

$$In = \frac{N\ Cyano + N\ Chloro + N\ Diatom\ Centrales + N\ Eugleno}{N\ Desmidiaseae}$$

MedPTI index was using biovolume of phytoplankton ($B_{j,k}$), trophic value (v_k), and indicator value (i_k). The trophic value of the *k*-th taxon (*v'k*) represents the trophic preference of that taxon; it is obtained from the annual mean total phosphorus concentrations (TP) and biovolume (B) of that taxon in all the *n j*-th reservoirs of the calibration data set using the following formula [3]:

$$v'_k = \frac{\sum_{j=1}^{n} B_{j,k}\ x \log(TP_j)}{\sum_{j=1}^{n} B_{+k}} \qquad (1)$$

$$v = 8.5 - 3.5 \cdot v'_k \qquad (2)$$

$$i_k = \frac{\sum_{j=1}^{n} B_{j,k}}{\sum_{j=1}^{n} B_{j,k}\ x\ D_{j,k}} \qquad (3)$$

$$D_{j,k} = [v_k - \log(TP_j)]^2 \qquad (4)$$

$$MedPTI_i = \frac{\sum_{k=1}^{m} B_{j,k}\ x\ v_k\ x\ i_k}{\sum_{k=1}^{m} B_{j,k}\ x\ i_k} \qquad (5)$$

Ecological state of aquatic ecology was grouped based on MeDPTI calculation (Table 1).

Table 1. MedPTI class boundaries

Class limit	MedPTI
high – good	2.77 0.89
good – moderate	2.45 0.79
moderate – poor	2.13 0.69
poor – bad	1.81 0.59

3. RESULTS

Ornamental lake has N:P ratio less than 7,2, which means N is a limiting factor at the lake. Orthophosphate concentration in Ornamental lake garden house showed more than 0,1 mg/l. Dissolved inorganic nutrient or DIN also showed high concentration (Table 2).

Spatially, similarity of phytoplankton abundance was forming 3 groups in 70% confidence level. Group 1 consist of station 1, 2, and 4, meanwhile group 2 consist of station 3, and group 3 consist of station 5 (Fig. 2).

Table 2. Nutrient analysis in Garden House Ornamnetal Lake PIK Jakarta

Station	DIN (mg/L)	Ortofosfat (mg/L)	Ratio N:P
1	4,964	1,030	4,82
2	4,642	0,760	6,11
3	4,742	0,560	8,47
4	4,364	0,680	6,42
5	5,964	1,170	5,10
Average			6,18

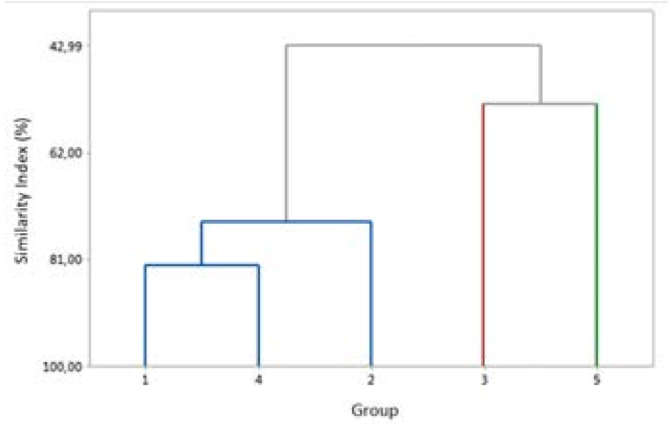


Fig. 2. Simillarity index of phytoplankton abndance in Ornamental Lake between stations.

Trophic state of Ornamental Lake Garden Housae was shown by value of Nygaard index, 9,5-10,5. Three groups of sites have eutrophic condition (Fig 3).

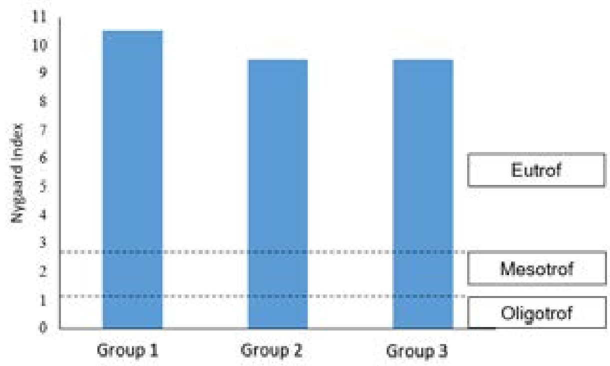


Fig 3. Trophic state of Ornamental lake Garden House based on Nygard Index

The value of ecological state of Garden House lake based on MeDPTI index was 1,46-1,85 (Fig 4). Group 1 is bad, temporarily group 2 and 3 are poor.

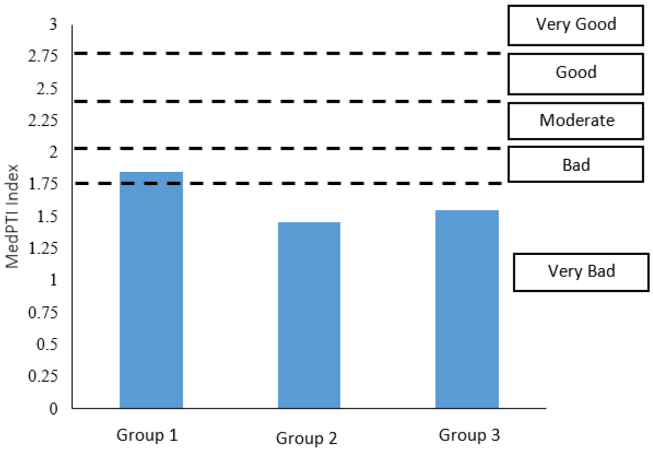


Fig 4. Ecological state of Garden House Ornamental Lake PIK Jakarta based on MeDPTI

4. DISCUSSION

Trohic state of aquatic ecosystem could develop from water quality parameters. Nutrient analysis showed low N:P ratio, which means N as limiting factor and Bacillariophyceae is predominant group in the lake. Nonetheless N:P ratio records is not adequate to describe trophic state in aquatic ecosystem. Orthophosphate concentration in ornamental lake is high and indicates hyper-eutroph state[4]. High concentration of DIN indicates eutroph state in Ornamental lake Garden House. Eutroph state was occurred in Ornamental Lake Garden House. Group 1 has the highest value of Nygard index. The eutroph condition was caused by direction of the wind and water flow to the north of lake, which is moving organic material to north site. Station 1 and 2 was located in north of lake, outlet of ornamental lake have higher organic material than other stations. Ecological state also showed bad up to poor boundaries class of ornamental lake. MedPTI is a sensitive tool, since involve orthophosphate concentration in the calculation. Nutrient in ornamental lake also showed high concentration, which is also determine eutrophic condition[5] (Goldman dan Horne 1983).

This condition was caused by nutrient input from houses. To restore this condition, waste water treatment should be managed. When water quality is in good quality, thropic and ecological state may also good.

5. CONCLUSION

Based on Nygard index, trophic state of Garden House Ornamnetal Lake is Eutroph, which is indicated by nutrient parameters. Based on MedPTI index, Ecological state of Garden House Ornamnetal Lake is bad.

REFERENCES

[1] Smith VH, Tilman GD, Nekola JC. Eutrophication: impacts of excess nutrient inputs on freshwater, marine, and terrestrial ecosystems. Environmental Pollution, Vol. 100, pp. 79-96, 1999.

[2] Krebs CJ. Ecological Methodology. New York (USA): Harper Collins Publishers. 1989..

[3] Marchetto A, Padedda BM, Mariani MA, Luglie A, and Sechi N. A numerical Index for evaluating phytoplankton response to change in nutrient levels in deep Mediterranian reservoirs. Journal of Limnology, Vol. 68(1), pp. 106-121. 2009.

[4] Wetzel RG. Limnology Lake and River Ecosystem. California (US): Academic Press. 2001

[5] Goldman CR, Horne AJ. *Limnology*. New York (USA): L McGraw-Hill Book Company. 1983.

P3-13

小川原湖における塩分躍層と循環水深の現状と近年の変化

原田 航汰[1], 眞家 永光[2], 静 一徳[3], 長崎 勝康[3], 柿野 亘[2], 丹治 肇[2]
[1]北里大学大学院獣医学系研究科, [2]北里大学獣医学部, [3](地独)産業技術センター内水面研究所

キーワード: 貧酸素, 富栄養化

抄録

青森県東部に位置する小川原湖は, 南西部から流入する淡水と, 北東部から流入する塩水により, 汽水環境が保たれている。そのため, 小川原湖では内水面漁業が盛んに行われており, 全国でもトップクラスの漁獲量を誇る。しかし, 近年の小川原湖では, 富栄養化が進行しており, 水質悪化の対策が求められている。そこで, 本研究では, 小川原湖の水質に大きく影響を及ぼす水文環境を把握するため, 塩分躍層と循環水深の現状と経時的変化を把握することを目的とし, 2006 年から 2017 年にかけてモニタリング調査を行った。春季と秋季には 15m 付近まで鉛直循環が見られたが, 夏季には 5m 付近に温度躍層が形成されていた。また, 1年を通して, 塩分躍層が 16m付近にみられた。16mの密度には経年的な変化が見られたが, その理由として, 風により 16mまで鉛直混合されたことが, ウェダーバーン数より推察された。

1. はじめに

青森県の東部に位置する小川原湖は、内水面漁業が盛んであり, ヤマトシジミ, シラウオ, ワカサギは, 全国でもトップクラスの漁獲量を誇る。また, 湖畔にはキャンプ場や公園などがあり, 地域の人々の憩いの場としても知られている。しかし近年の小川原湖では, 富栄養化が徐々に進行しアオコの発生や, 糸状藍藻類が生成する 2-MIB(2-メチルイソボルネオール)によるカビ臭等の水質悪化が問題となっており, その対策が求められている。湖水の水質には, 水文環境が大きく影響していると考えられることから, 水文環境を理解することは重要な課題である。特に, 塩分躍層や循環水深は, 小川原湖の富栄養化を考える上で欠かせない。そこで本研究では, 小川原湖の水文環境を把握するため, 2006 年から 2017 年にかけて, 小川原湖の湖心において水温, 塩分濃度, 溶存酸素の鉛直分布をモニタリングした。

2. 調査地概要

小川原湖は, 日本で 5 番目の面積を持つ汽水湖で, 面積 62.0km^3, 年間流入量 695×10^6 m^3, 最大水深 26.5 mと汽水湖の中では深い部類に入る[1]。小川原湖は, 南西部の河川から淡水が流入し, 北東部から海水が逆流することで, 汽水環境を保っている[2]。また, 小川原湖の滞留時間は約 1 年である。

図 1　調査地点

3. 方法

2006 年 4 月から 2017 年 10 月にかけて, 月に一度小川原湖の湖心(図 1)にて, 水文環境に関する水質調査を行った。多項目水質計を用いて水温, 塩分濃度, 溶存酸素濃度を表層から湖底まで 1m ずつ測定した。また, 水温と塩分濃度のデータから算出した密度と, 三沢観測所で測定した風速・風向のデータをもとにウェダーバーン数を求めた。

4. 結果および考察

2006 年から 2017 年の塩分濃度の結果を図 2 に示す。表層から 10mの塩分濃度は 10 月に低くなる傾向が見られたが, 調査期間を通して 1psu から 2psu で安定していた。16m の塩分濃度は後述するように経年的に大きく変動した。18mの塩分濃度は, 2010 年 10 月に大きく低下した。20m以深の塩分濃度は, 2012 年から 2014 年に低下したが, 2015 年以降に再び上昇した。また, 2015 年 2

月と2016年12月に20m以深の塩分濃度が上昇した。深さに伴う塩分濃度の変化量の最大値を塩分躍層とすると，小川原湖の塩分躍層の水深は，14m から 18m で推移していた(図3)。

次に，透明度が循環水深に比べて十分に浅いため，溶存酸素量を基に循環水深を算出した。その結果，秋と春では循環水深が深く，13mから15mまで循環していたが，夏季の循環水深は浅く，5mから7m付近であった。また，循環水深と塩分濃度の境界と考えられる16mの塩分濃度が減少した原因として，その時期に循環水深が16m 付近まで達しており，塩分濃度が減少したためと考えられる。

次に，2006年から2017年の水温と塩分濃度から密度を求めた(図 4)。この図が塩分濃度の図と似ていることから，密度は水温よりも塩分濃度の影響を受けていると考えられる。16m の密度は、経年的に見てみると変動が大きくかった。特に，2006年，2010年，2011年，2013年，2017年では大きく減少し，表層の密度と近い値を示していた。この原因を調べるため，三沢観測所の風速と密度から，ウェダーバーン数を算出し(2009年～2017年)，風による混合の影響について考察した(図 5)。ウェダーバーン数は，W<1 の場合は風の影響により混合し，W>1の場合は混合しにくいとされる[2]。2010年，2011年，2013年と2015年以降にW<1となる時期が見られた。特に2010年，2011年，2013年の4月から5月のウェダーバーン数は他の年よりも低くなっており，この時期に16mの密度も表層に近い値をとっていた。したがって，4月から5月に吹く強風により16mが巻き上げられ塩分濃度が減少し，密度も低くなったことが示唆された。また，16mの密度が 4 月以降も低下していたことから，風の影響は長期的にわたり続くと考えられた。測定期間のその他の時期は，ウェダーバーン数がW>1であったため，風の影響は塩分躍層まで届かないと考えられる。しかし，2016年8月の台風10号と2017年9月の台風18号が上陸した際には，ウェダーバーン数が W<1 となっていたことから，極端な気象が生じると，塩分躍層まで影響が及ぶと示唆された。

5. 結論

近年の小川原湖の塩分躍層は 16m 付近に形成されており，年により2m程度の変動はあったものの，経年的なトレンドは見られなかった。また，小川原湖の春季と秋季には 15m 付近まで循環が起こっているが，夏季は 5-7m に温度躍層が形成されていた。16mの密度は，年により大きく変動したが，湖の変動には特に 4 月から 5 月における風の影響が大きく影響していた。また，台風といった極端な気象によっても，影響が見られた。この変化は数カ月続くことから，春の大風や台風は，小川原湖の浅層の水質に大きな影響を与える可能性が示唆された。

謝辞

小川原湖の調査に際しては，小川原湖漁協の蛯名秀樹氏，および(地独)青森県産業技術センター内水面研究所の研究員諸氏にご協力頂きました。記して謝意を表します。また，この研究は，科研費 20780233 と 15K07532の助成を受けたものです

引用文献

[1] 国土交通省国土地理院．”調査実施湖沼一覧-GSI HOME PAGE-国土地理院”．国土地理院 http://www.thr.mlit.go.jp/takase/2-2-2.html

[2] 新谷哲也・梅山元彦：湧昇域の斜面が成層湖の湧昇・混合に与える影響，水工学論文集， 第47巻，pp.1190，2003. https://www.jstage.jst.go.jp/article/prohe1990/47/0/47_0_1189/_pdf

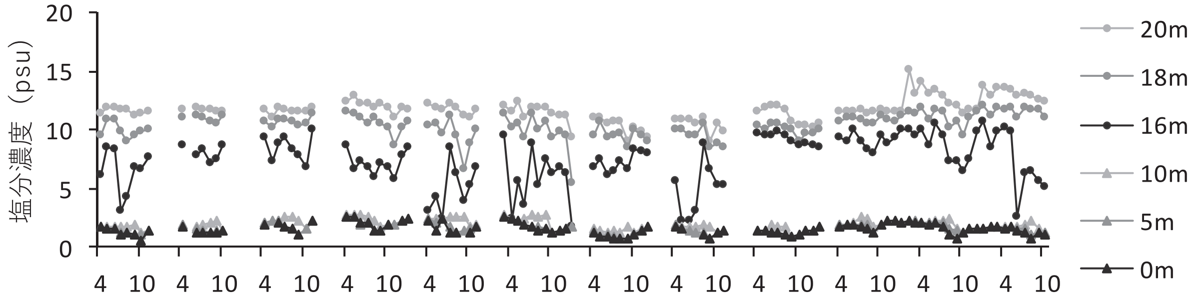


図2 塩分濃度の経時的変化

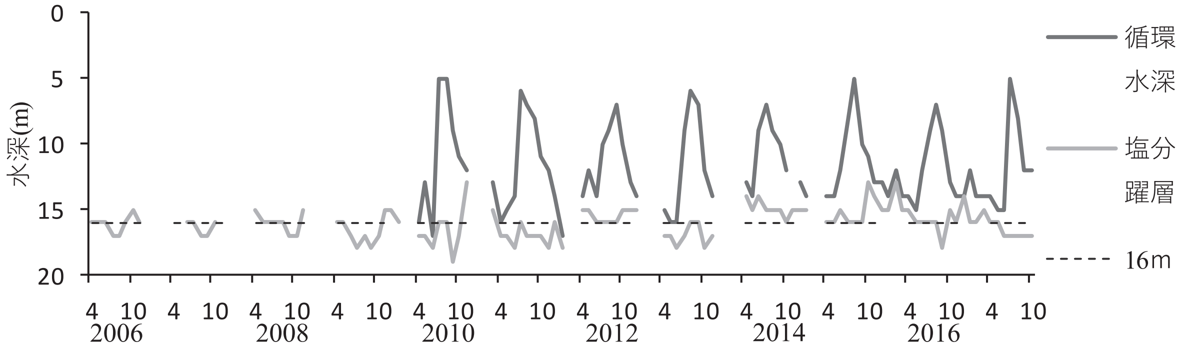


図 3　塩分濃度と循環水深の経時的変化

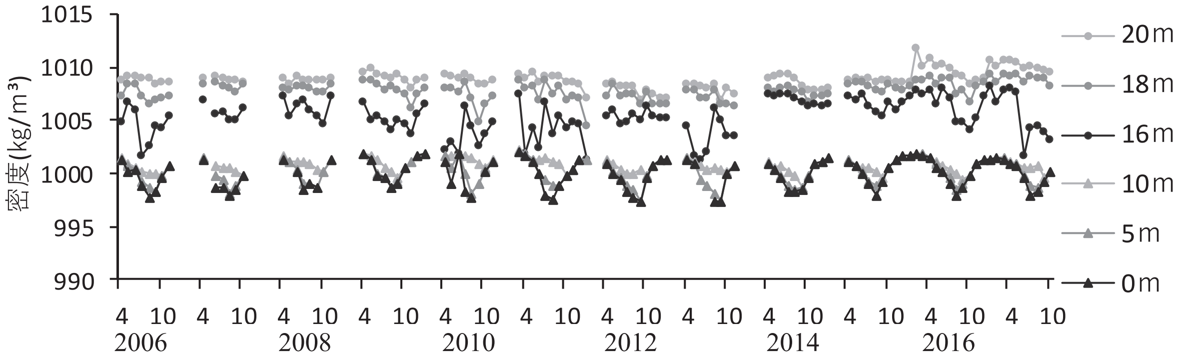


図 4　密度の経時的変化

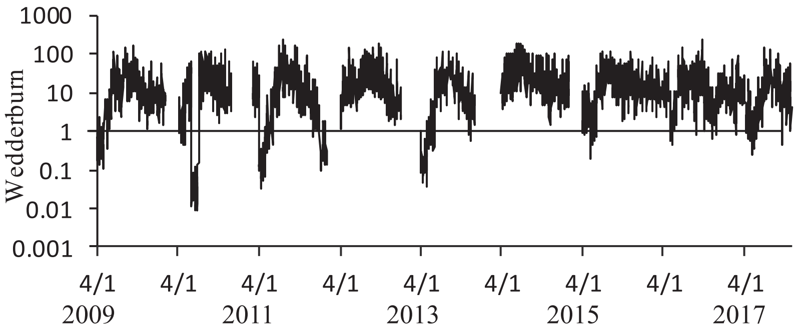


図 5　ウェダーバーン数

P3-14

浮葉植物群落を有するため池における TN／TP 比と主成分得点との関係

近藤　雅秋 [1], 岩倉　朱里 [1], 加治佐　隆光 [1]

[1] 三重大学大学院生物資源学研究科

キーワード：　一次生産，ため池，水生植物，統計解析

抄録

浮葉植物であるヒシ属が群落を形成するため池である大沢池において、その池水の水質傾向を把握するとともに池内の 1 次生産の状況を統計的に把握することを目的とした。そのために水質やヒシ葉被度などに関する現地調査を実施した。得られた毎月の水質 14 項目と浮葉植物の繁茂状態の計 15 項目について主成分分析を行い、池内の 1 次生産者である植物プランクトンと浮葉植物の繁殖と繁茂状態を主成分軸とする 2 次元に集約することができた。TN/TP 比が示す池水の栄養状態の転換時期は、統計解析で得られた主成分得点図の特徴的な位置を示した。

1.　はじめに

東海地方にあるため池の代表的な浮葉植物はヒシ属やカガブタである[1]。ヒシ属の生育はカガブタと同じく PH,栄養塩類などについての適応範囲が広いとされる[2][3]ものの、近年ヒシ属の出現頻度が減少しつつあり[1]、ヒシ属の一つであるヒメビシは絶滅危惧 II 類である[4]。水生植物の減少の原因には水質汚濁や池の改修埋立にともなう要因というように様々に指摘されている。カガブタに見られるように水生植物が同じ1次生産者であるアオコとの競争に負ける事例も見られる[1]。

本研究では、浮葉植物であるヒシ属が自生し群落を形成する農業防災ため池である津市大沢池において、その池水の水質傾向を把握するとともに池内の 1 次生産の状況を統計的に把握することを目的とした。

2.　方法

2.1 現地水質調査

2017 年 4 月から 12 月まで毎月 1 回調査を行った。8 月は農業用水として取水を終わる時期のため、取水終了の前後で2回実施した。灌漑期は 2017 年 4 月 16 日から 8 月 10 日であった。このうち 6 月 10 日～7 月 2 日は中干しにあたり、ため池からの取水は中断された。

大沢池（貯水量 128,000m^3、満水面積 0.06km^2）の形状は東西に細長く、西側上手に流入水路があり、東側末端に取水口が 1 箇所ある。このため、流入水路から取水口方向に池内を上流域、中流域、下流域の 3 水域に均等に分けた。池内 3 水域の表層水と流入水を採水し、水温、透視度、PH,電気伝導度 EC,溶存酸素 DO, 濁度、全窒素 TN,NO3-N,NO2-N,NH4-N,全リン TP, 化学的酸素要求量 CODcr,クロロフィル a を測定した。

当該ため池には近隣の貯水池から補給水を受ける施設が整えられているが調査年も含め過去の補給実績はない。

2.2 ヒシ葉被度と色彩の現地調査

ヒシ葉による水面の被度、およびヒシ葉の色彩を把握するために、無人航空機（UAV）を用いて撮影した。このためにコロラード（2m×2m）を池内の 3 水域に設置した。そして、水質調査日の前後で UAV を飛ばし、付属のデジカメによる撮影観察を行った。

観察方法はコロラード観察と高度水域観察とした。コロラード観察では、UAV をコロラードに近接させて撮影した。高度水域観察では、各水域全体が見渡せるような様々な高度から撮影した。 真下撮影を行っていないため、太陽光の向きを考慮してコロラードや各水域を様々な高度や方向から記録した。

コロラード観察と高度水域観察から、それぞれ得られる被度や色彩割合を平均して各水域の値とした。3 水域の被度値や色彩割合値を、さらに平均して池全体の値とした。

2.3 主成分分析

水質項目（14 項目）およびヒシ葉被度について、池平均値を用いて主成分分析を行った。水質項目は、水温、透視度、PH、EC、DO、濁度、TN、NO3-N、NO2-N、NH4-N、TP、d-COD、クロロフィル a、P-COD を選んだ。

3.　結果

3.1 ヒシ葉の被度や色彩

図 1（L）にヒシ葉被度の変化を示す。4 月下旬からヒシ葉が水面に見られ始まるが、5 月連休明けになるとまとまった被度となった。7 月末はほぼ 100％となり水面を

覆い尽くした。8月も同様であるが過密となり葉が立つ様子が見られた。8月下旬になると徐々に被度が減少し始め10月下旬になると水面にはかなり少なくなった。

ヒシ葉色彩の変化について、4月～8月の成長期でありヒシ葉は緑色であった。8月に入ると少しずつであるがヒシ葉に赤みを帯び始めた。9月に入ると赤色が緑色の割合を超え、光合成をしなくなり枯死しつつあった。

3.2 流入水の水質

流入水の透視度や DO は高く、溶存態 COD の割合が高く、外見上は透明感があった。しかし窒素とくに NO3-N が高かった。これは集水域内で過去に牛豚の畜産（現在廃業）が営農されたことの影響と考えられる。さらに PH、EC が比較的高かった。

3.3 池水の水質

図1（A～K）に池水平均の結果を示す。ヒシ葉被度が増加する4～8月は代掻きから始まる灌漑期に当たり池水の交換性が高まる。特に調査した2017年は少雨のため池水の利用が増えた。ヒシ葉被度が減少・ゼロになる8月～12月は非灌漑期に相当し池水の交換性は低下した。

灌漑期は、ヒシ葉被度が増加するに伴い表層水のクロロフィル a が減少したことから、ヒシ葉による遮光効果により植物プランクトンが減少したと考えられる。連結的に PH や DO は減少した。有機成分が減ることで TN や TP は減少したと思われる。負の相関にある透視度・濁度は、この時期にそれぞれ増加・減少した。さらにヒシ葉の消波効果により有機懸濁成分は沈降することで COD は減少し溶存態の割合が高くなり、透明感のある表層水を観察することができた。

非灌漑期は、ヒシ葉被度が減少するに伴いヒシ葉の遮光や消波効果は消失していった。COD は植物体であるヒシが枯死しているにもかかわらず増加せず懸濁態の割合も低いことから、枯死ヒシは沈降懸濁態のままで池底へ堆積はすれど表層水までは大きく影響していないと考えられる。次に表層水のクロロフィル a が増加したことから植物プランクトンが増加していったと考えられる。ただし植物プランクトンは一旦10月に極大を示し11月は減少に転じた。連結的に PH や DO は増加したが極端に高くならなかった。植物プランクトンなどの浮遊性有機成分が増えることで TN や TP は増加傾向を示し、10月は無機態 N が減少する一方で TN が増加した。11月は植物プランクトンが減り無機態 N が増えたので過度の分解が生じた可能性がある。透視度・濁度は灌漑期から反転しそれぞれ減少・増加した。

3.4 池水のTN/TP 比（重量比）

図2にTN/TP 比の変化を示す。TN/TP 比は栄養塩のバランスを示す指標であり、レッドフィールド値では TN/TP 比=7.2となる。池平均の TN/TP 比は調査期間中でほぼ10を超えており対象池は窒素過多の池と考えられる。しかし、8月10日と11月に TN/TP 比が一時的に減少した。これらの時点の個別水域の TN/TP 比は10～7.2を下回り、リン過多を示した。この8月10日、11月はともに植物プランクトンが減少した時期であった。

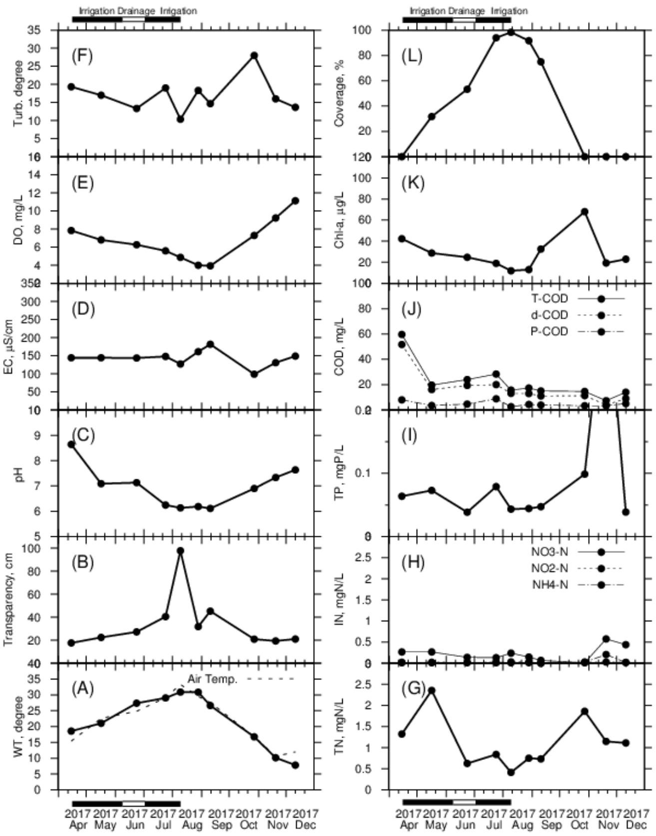


図1 （A～K）池水の水質および（L）ヒシ葉被度の変化

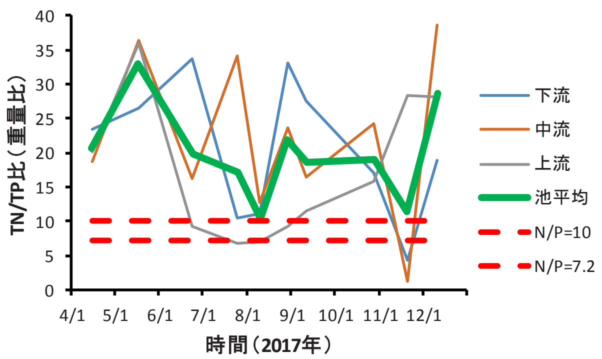


図2 池水の TN/TP 比（重量比）の変化

4. 考察

4.1 因子負荷量と主成分得点

図3に因子負荷量を示す。図中で NO3-N、NO2-N、NH4-N、TP はほぼ同一方向を示したため矢印が重なっ

た。同様にクロロフィル a、濁度、P-CODも矢印が重なっている。第 1 主成分と第 2 主成分を合算した積算寄与率は 0.61 であった。

第1、第2主成分軸の解釈では15項目の中から軸毎に成分値の大きいものに重点をおいた[5]。その結果、因子負荷量図に示される第 1 主成分軸は季節感がイメージされヒシの繁茂状態を表すとし、正方向ほど枯死の状態が大きく、負方向ほど繁茂の状態が大きいとみなした。第 2 主成分軸は逆に季節感をイメージできず、適温が異なっていつも繁殖できる植物プランクトンを表すものとして、正方向は植物プランクトンの死亡状態が大きく、負方向は植物プランクトンの繁殖が大きいと判断した。本研究ではヒシ植物体量ではなく水面を占めるヒシ葉の割合を対象にしたため枯死・分解を含む繁茂状態を表現しきれていないが、水槽での栽培実験では枯死後における水中での分解は緩慢であったため水面被度でヒシ繁茂状態を表すとした。

第1象限（右上）はヒシ繁茂が弱く、植物プランクトン繁殖も弱い状態にあたる。この象限には TN を除く無機態窒素やTPが集中していて、植物プランクトンの死亡、ヒシの枯死、それらの分解を表していると考えられる。総じて1次生産力が落ち、栄養塩が優勢となる状態と解釈した。第2象限（左上）はヒシの繁茂が優勢となるのを表すとみられる。第3象限（左下）は、ヒシが繁茂し植物プランクトンも繁殖していて、共存しながら共に優勢の状態と見て取れる。第4象限（右下）は植物プランクトン繁殖が優勢な状態を示す。中央の原点付近は、これらのヒシの繁茂・枯死や植物プランクトンの繁殖・死亡が平均的な状態を表すと解釈した。

因子負荷量図においてヒシの繁茂とは逆方向に DO のベクトルが向いている。これはヒシが繁茂すると、DO が小さくなることと読み取ることができる。これは既往の文献でたびたび指摘される現象であり、本論では統計的に示すことができた。

図4に主成分得点を示す。経時的に見ると、4月は植物プランクトンが優勢な状態にあり、季節が進みヒシが繁殖し始める5 月～6 月では平均的な状態になり、7 月～8 月 10 日にかけてヒシ繁茂が極端に優勢な状態を示す第2象限の隅に移行した。9月から10月へはヒシの繁茂が衰える時期となり、10月から11月には枯死・死亡が強くなり栄養塩が極端に優勢な状態である第1象限の隅へと移行した。

4.2 TN/TP 比の低下と主成分得点との関係

3.4 節で 8 月 10 日と 11 月に TN/TP 比が高い状態から TN/TP 比が 10 近くまで減少したことを指摘した。図 4 に示す主成分得点図では、これらの 8 月 10 日、11 月はそれぞれ第 2 象限と第 1 象限の隅に位置した。このようにTN/TP 比が 10 近くまで低下した時点は、主成分得点図の特異的な場所に位置することが分かった。

8 月 10 日はヒシ繁茂の最盛期に相当する。ヒシ葉の遮光効果によって植物プランクトンの増殖が抑制されたためにTN が減ることでTN/TP 比が減少するに至ったと考えられる。また、11 月では、ヒシは枯死していて、植物プランクトン繁殖も弱い状態にある。TN/TP 比が減少した理由は TP が極大を示したためであり、このときのNH4-N は増加が確認されたのでヒシ分解やプランクトン分解が進んだためと考えられる。

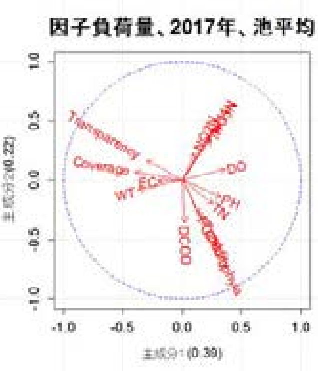


図 3 因子負荷量

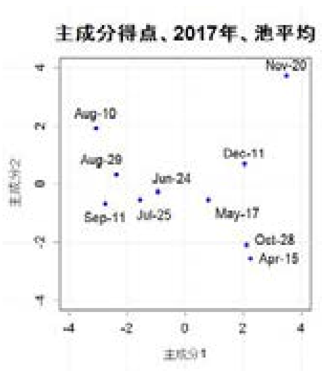


図 4 主成分得点

5. 結論

毎月の水質 14 項目と浮葉植物の繁茂状態の計 15 項目について主成分分析しため池の 1 次生産者である植物プランクトンと浮葉植物を主成分軸とする 2 次元の主成分得点図に集約させた。主成分得点図の特徴的な位置にTN/TP 比が示す栄養状態が窒素過多からリン過多へ転換する時点が配置された。

引用文献

[1] 浜島繁隆: 水草の世界－生態と東海地方の分布・変貌の記録－, シンプリブックス, 2013.

[2] 浜島繁隆: 池沼植物の生態と観察－おもにため池について－, ニュー・サイエンス社, 1979.

[3] KADONO, Yasuro: OCCURRENCE OF AQUATIC MACROPHYTES IN RELATION TO pH, ALKALINITY, Ca++, Cl- AND CONDUCTIVITY, Jap. J. Ecol. Vol.32, No.1, pp.39-44, 1982.

[4] 環境省: 環境省レッドリスト 2017 [報道発表：平成 29 年 3 月公表], http://www.env.go.jp/nature/kisho/hozen/redlist/index.html, 2018 年 2 月 1 日閲覧.

[5] 木下栄蔵: わかりやすい数学モデルによる多変量解析入門, 啓学出版, 1987.

P3-15

Potential Vegetation for Nitrogen Removal in Lake Riparian and Catchment Areas

Susi Abdiyani[1]

[1]Land and Vegetation Researcher Group, Watershed Management Technology Center (WMTC)

Keywords: eutrophication, Nitrogen, vegetation, riparian, water catchment areas

ABSTRACT

Eutrophication has worsened water quality in at least 15 priority lakes in Indonesia. Eutrophication level (oligotrophic, mesotrophic, eutrophic, and hypertrophic) is one of indicators in defining lake health status. Based on eutrophication level, only two lakes were oligotrophic, while the others were in eutrophic and hypertrophic conditions. To reduce lake degradation, vegetative rehabilitation in lake water catchment and riparian areas was proposed. Some studies provided information on vegetation for nutrient removal from water body. However, very few studies focused on measuring vegetation capability in Nitrogen (N) removal from soil. This research aims to assess N content of plant species growing in Rawapening riparian as preliminary information on plant potency for N removal. Plants and soil samples were taken in a relatively undisturbed riparian area in Bejalen village. Each plant was labeled with local name and identified using "Tumbuhan Berguna Indonesia" book to determine their scientific names. There were nine plants found: *Ampelas, Cangkring, Elo, Gempol, Dempul, Johar*, *Waru*, *Bunga Kuning* and *Mangsi*. Plant and soil N contents were analyzed in WMTC Laboratory. Riparian soil N content was 0.21%. *Ampelas, Mangsi* and *Cangkring* had the highest N content with 0.24, 0.13 and 0.12%, respectively. N content for *Bunga Kuning* was 0.7%, while for *Lo, Gempol, Dempul, Johar* were 0.5% each and for *Waru* was 0.3%. *Ampelas, Mangsi* and *Cangkring* are potential for N removal as their N contents were approaching N soil.

1. INTRODUCTION

Eutrophication is defined as the enrichment of surface waters with plant nutrients[6]. Since 18th century Vollenweider, et al. (1980) in Ongley (1996) had classified trophic status into nutrient poor (oligotrophic), mesotrophic, eutrophic and nutrient rich (hypertrophic). At that time, the major factor of eutrophication was agriculture. In 2009, besides agriculture, Selman and Greenhalgh included wastewater and burning fossil fuels as other factors in eutrophication.

In Indonesia, eutrophication has become a serious problem especially in lake management. Based on eutrophication status and other condition, the country has categorized 15 lakes as management priority[5]. They are spread throughout Sumatera (Toba, Maninjau, Singkarak, Kerinci), Sulawesi (Tondano, Limboto, Poso, Tempe, Matano), Kalimantan (Mahakam Cascade (Semayang, Melintang, Jempang), Sentarum), Papua (Sentani), Java (Rawadanau, Rawapening) and Bali (Batur). Among those priority lakes, only two were in oligotrophic status i.e. Matano and Poso lakes, while the others were eutrophic and hypertrophic.

Eutrophication sources in most priority lakes are from settlement in lake water catchment and riparian areas, agriculture, animal husbandry and aquacultures[5]. Some domestic waste management installations have been applied in some areas. Eight programs have been proposed to overcome lake degradation; they are (1) lake spatial arrangement, (2) conservation and rehabilitation of lake water ecosystem, (3) conservation and rehabilitation of lake ecosystem riparian zone, (4) conservation and rehabilitation of watershed and lake water catchment area, (5) utilization of lake water resources, (6) development of monitoring, evaluation and information system of lake ecosystem, (7) enhancement of capacities, institutionalization and coordination, and (8) improvement of community role and participation[5]. Vegetative rehabilitation both in lake water catchment and riparian areas was a part of program (3) and (4).

Nitrogen (N) removal from wastewater using different plant species have been applied in other countries. In China, Lu and Huang (2010) tested *Nymphea tetragona* Georgi.and *Pontederia cordata* L. in N and P removal and concluded that both of them have good removal in stagnant water [4]. Li *et al*. (2014) evaluated *Lolium multiflorum* N and P removals in floating mats experiment in China and resulted in 39-49 and 47-58 % decrease [3]. Wu *et al*. (2016) investigated removal of Nitrogen by *Typa augustifolia, Phragmites australis* and *Acorus calamus* in a-30-days hydroponic experiment in China[9]. The result indicated that three of them can remove almost all N in NH_4^+ form[9]. In Indonesia, Chrismadha *et al*. (2017) examined the ability of minute duckweed *(Lemna perpusilla),* greater duckweed *(Spirodella polyrizha),* water lettuce *(Pystia stratoites)* and water hyacinth *(Eichornia crassipes)* in eliminating nutrients, N and P from polluted water[1]. The result was promising as the N and P removals were around 80 %[1].

Although research on N removal from water body by vegetation in Indonesia is still limited, none has been found in studying plant effectiveness in removing N from soil. Therefore this research was aimed to measure N content of plant species growing in Rawapening riparian as preliminary information on plant potency for N removal.

2. METHOD

Plants and soil samples were taken in a relatively undisturbed riparian area in Bejalen village, Ambarawa Sub-district, Semarang District, Central Java in April 2017. Branches, leaves, flowers and fruit of trees and including roots for smaller plants were taken destructively then cleaned from dirty and dried from water in its surface and put in aerated sample bags to prevent from quick decaying. Each plant was labeled with local name and photographed. All samples were taken to Watershed Management Technology Center Laboratory (WMTC) to be treated and analyzed for their N contents. Local names were matched to those provided in "Tumbuhan Berguna Indonesia" book [2] to determine their scientific names.

3. RESULTS

There were nine plants found consisting of seven trees: *Ampelas (Ficus ampelas* Burm.f.), *Cangkring (Erythrina fusca* Lour.*), Elo (Ficus racemosa L.* synonyms *Ficus glomerata* Roxb.), *Gempol (Nauclea orientalis* L.*), Dempul (Glochidion sp), Johar (Senna siamea* Lamk.), and *Waru (Hibiscus sp)*, a shrub (*Bunga Kuning*) and a liana, *Mangsi*.

N content for riparian soil was 0.21%. *Ampelas, Mangsi* and *Cangkring* had the highest N content with 0.24, 0.13 and 0.12%, respectively. N content for *Bunga Kuning* was 0.7%, while for *Elo, Gempol, Dempul, Johar* were 0.5% each and for *Waru* was 0.3% (Table 1).

Table 1 Total N content in riparian vegetation and soil

No	Species local names	Water Content (%)	Total Organic Carbon (%)	Total Organic Matter (%)	Total N (%)
1	*Ampelas*	51.91	4.58	7.89	0.24
2	*Mangsi*	33.65	1.27	2.18	0.13
3	*Cangkring*	54.13	2.91	5.02	0.12
4	*Bunga kuning*	58.64	3.66	6.31	0.07
5	*Elo*	43.88	2.10	3.61	0.05
6	*Gempol*	48.61	1.07	1.84	0.05
7	*Dempul*	39.90	1.82	3.14	0.05
8	*Johar*	37.46	0.99	1.70	0.05
9	*Waru*	37.50	1.06	1.83	0.03
	Riparian Soil	39.98	0.36	0.62	0.21

4. DISCUSSION

Among the top three having the highest N content, *Mangsi* is the only non-tree species, while *Ampelas* and *Cangkring* are considered as tree species. *Ampelas* (*Ficus ampelas*) found in the research site was a-4-meters sapling with 3.5 cm diameter. *Ampelas* in Indonesia is a native to Sumatera, Java, the Lesser Sunda Islands, Sulawesi, the Molluccas and New Guinea and possibly Borneo[8]. It is an evergreen tree with small to medium height up to 15 (-20) m and usually found in lowland areas[8]. The latex has been used as medicine and the fruits are edible; the leaves can substitute sandpaper[8] (*ampelas*/Indonesian is sandpaper/English).

C*angkring (Erythrina fusca)* in research site was a tree with approximate height of 12 m and diameter at breast height of 20 cm. It is an exotic species in Indonesia originated from South America that may reach height of 10-15 (max. 26) m[7]. *Cangkring* can survive in bad drained soils: swamps, stream banks and marshes[7]. It research sites, some people harvested the leaves for medicine. Another species from the same genus, *Erythrina variegata*, was known as N fixing species[7], so it is possible that high content of N in *Cangkring* also come from N fixation from the air.

Mangsi (Javanese), in English called ink, together with *Bunga kuning* is species that have not been identified for their scientific name. *Mangsi* has dark blue/almost purple fruit and fruit content. *Bunga kuning* was found in waterlogged area and has densed rooted. It is called *Bunga kuning* for its flower color.

Elo (Ficus racemosa) is a deciduous tree (in drier area) of 20-30 m tall[7]. In April 2017, the tree was leaves-blooming after deciduous. *Elo* is commonly found in lowland area along river banks[7].

Gempol (Nauclea orientalis), is a familiar tree in research site which is still cultivated by local people for its economic and esthetic values. It is native to Indonesia, Malaysia, Thailand and Australia and can grow up to 30 m and 1 m of diameter[7]. *Gempol* are commonly found near stream and associated with *Melaleuca dealbata* and *Melaleuca leucadenron* in swampy land[7]. For its character as a pioneer species and prefer open areas[7], *Gempol* is likely suitable for replanting riparian and water catchment areas.

Johar (Senna siamea) is a legume tree usually growing in lowland area and can reach height of 18 m and 30 cm diameter[7]. The tree in research location was more than 5 m tall. *Dempul (Glochidion sp)* was still seedling with 90 cm height and *Waru (Hibiscus sp)* was an adult tree with 7 m height and already flowering.

5. CONCLUSION

Among the nine species found, *Ampelas, Mangsi* and *Cangkring* are potential for N removal as their N contents were approaching N soil and their habitat requirement matches riparian condition.

ACKNOWLEDGEMENT

This work was resulted under research titled The Governance of Rawapening Lake Restoration funded by Watershed Management Technology Center. Authors thank to Nunung Puji Nugroho, PhD for all suggestion and discussion, Agung Wahyu Nugroho and Santi Fandriani for data collection and for WMTC Laboratory team for all sample analysis

REFERENCES

[1] Chrismadha, Tjandra, Suryono, Tri, Mardiati, yayah, Mulyana, Endang: Phytotechnology application to control lake water quality: A preliminary trial to use floating plants for controlling water quality in a small lake of Situ Cibuntu, Cibinong, Indonesia, Proceedings of the 16th World Lake Conference Lake Ecosystem Health and Its Resilience: Diversity and Risks of Extinction, Vol. 4, pp. 411-419, 2017.

[2] Heyne, K.: Tumbuhan Berguna Indonesia (Indonesian)/Indonesian Useful Plants, Book 4 1st editiion, pp. 2217-2521, 1987.

[3] Li, Miao, Sheng, Guo-ping, Wu, Yue-jin, Yu, Zeng-liang, Banuelos, Gary S., Yu, Han-qing: Enhancement of nitrogen and phosphorus removal from eutrophic water by economic plant annual ryegrass (*Lolium multiflorum*) with ion implantation, Environmental Science and Pollution Research, Vol. 21, pp. 9617-9625, 2014.

[4] Lu, X.M and Huang, M.S: Nitrogen and phosphorus removal and physiological response in aquatic plants under aeration conditions, International Journal of Environmental Science and Technology, Vol. 4, pp. 665-674, 2010.

[5] Ministry Environment & Forestry of Republic Indonesia: The grand design of Indonesian Lake Conservation and Rehabilitation, pp. 1-94, 2016.

[6] Ongley, Edwin D.: Control of water pollution from agriculture, FAO irrigation and drainage paper 55, 1996. Retrieved March 27, 2018, from http://www.fao.org/docrep/w2598e/w2598e00.htm#Contents

[7] Orwa C, A Mutua, Kindt R , Jamnadass R, S Anthony. 2009 Agroforestree Database:a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)

[8] Rojo, J.P., Pitargue, F.C. & Sosef, M.S.M.: *Ficus ampelas* Burm.f.[Internet] Record from Proseabase. de Padua, L.S., Bunyapraphatsara, N. and Lemmens, R.H.M.J. (Editors). PROSEA (Plant Resources of South East Asia) Foundation, Bogor, Indonesia. 1999. http://www.proseanet.org. Accessed from Internet: 10Aug2016

[9] Wu, Hailu, Xu, Kaiqin, He, Xiaojuan, Wang, Xonze: Removal of nitrogen by three plant species in hydroponic culture: Plant uptake and microbial degradation, Water, Air and Soil Pollution, pp. 227-324, 2016.

P3-16

The inconvenience of traditional fishing practice on aquatic ecosystem of Lake Nokoue in Republic of Benin (West Africa)

ELEGBEDE MANOU Bernadin[1], Patric EDORD[2], LABITE Elysé Hervé Labikoué[1], KOUMOLOU Luc[2]

[1]Laboratoire des Sciences et Technique de l'Eau(LSTE), Département de Génie de l'Eau et Assainissement, Institut National de l'Eau, Université d'Abomey-Calavi01 BP : 526 Cotonou, Bénin

[2]Laboratoire de Recherche en Biochimie et Toxicologie de l'Environnement(LARBITE). Faculté des Sciences et Techniques (FAST), Université d'Abomey-Calavi 01 BP : 526 Cotonou,

Keywords: Traditional fishing practice- water pollution, Aquatic ecosystem Threat.

ABSTRACT

This case study has assessed the vulnerability of NOKOUE Lake to pollution by both "Acadja fishing practice" and domestic waste.

Situated in coastal area of Benin, where more than four millions of people are living, Nokoue Lake is the biggest lake in the West Africa due to his big surface and fishiness productivities. Unfortunately, this lake confronts a lot of challenges due to traditional system of fishing called "Acadja" and bad domestic waste management. This study highlights that "Acadja" practice and domestic waste destroy the aquatic fauna and therefore threaten and disrupt food security of the habitants by reducing fish productivity. As matter of fact, this practice of "acadja" reduces the transparency, light and increases water pollution through the proliferation of aquatic plant which reduces the amount of dissolved oxygen. The analysis was made by spectrophotometer DR/2000 Hach, multipara meter wtw 340i and atomic absorption spectrophotometry for Toxic metals (lead). The result was revealed that dissolved oxygen under 3 mg/L at the place of acadja, and the contents of nitrite 3.35 to 15.25mg/L while lead shows high values. This water quality influences dangerously fauna aquatic. It is necessary to mention that investigation made among the riverside habitants and has revealed that the weight of the fishes is reducing drastically year to year

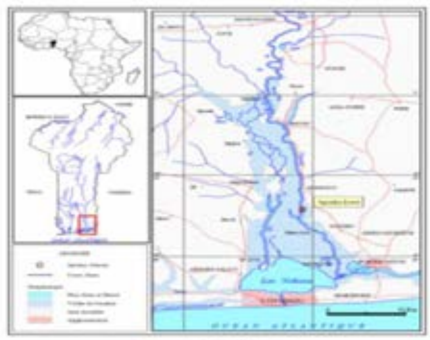
.

I-INTRODUCTION

Lake Nokoue is situated and located in the southern part of Benin in West Africa (Fig1). It covers approximately 150km2 areas. The lake is connected to Porto Novo lagoon (the executive capital lagoon) at the East by Totche canal at the south by atlantic ocean through Cotonou (Economic capital of Benin) channel at the north by river sô and Ouéme stream at the west which receives the large parts of its content (Fig 2). Its connection with Atlantic Ocean originates its salinity which it's sometimes advantageous for fishes.

As it was stated above, the lake is very important for the Benin development due to1/3 of Benin population, approximately 4000000 people live behind the lake and they survive depend on the lake. Thus, behind this lake there is a big international market called "Tokpa market" situated in economic capital of Benin, Cotonou where more than 250 "tonnes" of solid waste are produced per day and rejected in the lake. Apart from this anthropogenic pressure, the lake is confronted to another phenomenon called "Acadja (Fig 3) " and water pollution due to liquid and solid-waste. .

It is useful to mention that "acadja" is invented and built by the riverside habitants, fisher men and their relatives to protect the fishing family business. Map of lake situation below



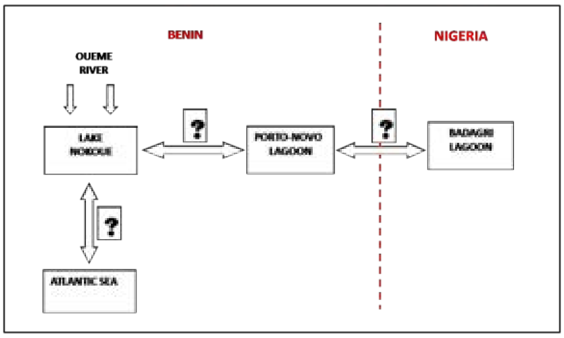


Figure:1 Lake Nokoue recharged and connection

II. METHODS

The Nokoue Lake is characterized by a subequatorial climate. It is recharged by Oueme river (the biggest river of Benin) and discharged into the Atlantic Océan . This study was carrying out during both dry and rainy season. . The parameters such as temperature, pH, dissolved oxygen, the redox potential are measured in situ. Multipara-meter/ox-meter-WTW-340i.Measurement of suspended solids (Methods 8006 with the multipara meter, colorimeter HACH DR/2000). Atomic absorption spectrophotometry has been used for Toxic metals especially lead.
Six sampling have been taken from both acadja side and non acadja side.

III. RESULTS

The results are grouped and analyzed by seasons: the intense rainy season and the intense dry season. At every sampling station,

Table 1: Data Results

Samples	1	2	3	4	5	6
pH	6,69	6,72	6,84	8,1	8,4	8,3
Température	37	36	35	29	25	27
Dissolved xygen(mg/L)	3,75	3,45	3,7	2,77	1,65	1,8
Supended solids	12,25	14,75	23,00	40,12	37,06	29,56
TURBIDITY (NTU)	07	05	10	25	40	
NO3- (mg/L)	2,75	2,5	1,5	8,5	10,5	7,25
NO_2-		3	4,25	7,15	5,83	5,90
Remark	Non	Non Acad	Non Acad	Acadja	Acadja	Acadja side

the redox potentials are negative especially in the Intense Rainy Season. The temperatures as are between 25°C and 37°C.

According to author [3], they are good condition of growth of the species fish. The pH ranges from 6.69 to 8.40. This value of pH is good at fish farming because situated between 6.5 and 9 . In case the pH values are not included in 6.5 to 9, then there are potential risks of negative chronic effects in long terms for the aquatic life protection [9].
We notice that the contents in oxygen dissolved in sampling stations vary from 1.65 to 3.75 mg/L as shown by **Figure** 2.

IV. DISCUSSION

This part will essentially based on dissolved oxygen and on suspended solids which are of important parameter of water pollution
The high dissolved oxygen contents are noticed at TCHOCHE where there aren't installations of acadjas. The dissolved oxygen is an essential ecological factor and plays an essential role in the preservation of the aquatic life. The oxygen dissolved contents in natural waters are mainly determined by the breath of the aquatic bodies, the oxidation, the degradation of pollutants, the photosynthetic activity of the flora and the exchanges with the atmosphere.. According to cerains authors , the quality of this lake is classified in the mediocre range because the content in dissolved oxygen is lower than 3 mg/L. We deduct from this that the acadjas asphyxiate the lake and therefore fauna aquatic.

The average contents of the suspended solids at TOCHE are 23.00, 40.12, 37.06 and 29.56 mg/L . The suspended solids include all the substances which are not dissolved. Their harmful effect due to formation of sediments and of a screen preventing the good penetration of the solar radiation (reduction of the photosynthesis) on the one hand, and the clogging of the fishes gills on the other hand. Their effect is also chemical by constitution of a potential reserve of pollution in sediments. The biodegradable suspended solids contribute in a significantly to the oxygen demand and cause therefore the decrease of the concentration in oxygen dis-solved in the aquatic environment . The suspended solids can asphyxiate some aquatic species and even the whole aqua tic environment when they are present in excess, or to provoke momentary anoxia. There are risks of long-term fatal chronic effects for the aquatic life protection if the value exceeds 5 mg/L.

. Furthermore, the higher the temperature and the dissolved oxygen are, the higher the micro-organisms decompose organic materials (the branches tons into the lake). This is also the reason for the high turbidity observed. The reducing power is still strongly correlated with the temperature. The high activity of microorganisms reduces dissolved oxygen content of the medium. This situation leads the aquatic environment to be reducing. This has very serious consequences on aquatic species. The results in Nokoue lake in Benin, are in accordance with those we have obtained and reveal disadvantages of acadjas practices

Figure 2. Contents in oxygen dissolved in in Nokoue Lake

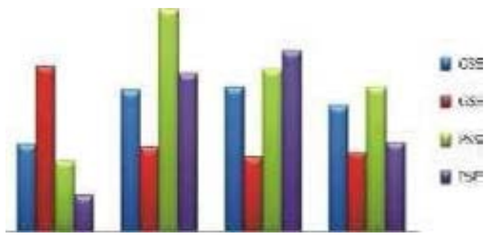


Figure 3. Variation of the suspension materials in in Nokoue Lake

Photo 1: Waste management and building house in Nokoue Lake.

Photo 2: System of Acadja on the lake

V. CONCLUSION

The practice of acadjas is a very old and wide-spread traditional fishing method observed in Benin's lakes and lagoons. It allows a good profitability of the fishing activities but it is the cause of the deforestation and erosion as well. Since several years, it is more and more forbidden by public authorities through the law n° 152/ MAEP of September 16th, 1970, concerning removal of acadjas from the Nokoué lake, the lagoons of Porto-Novo This study which we have just conducted reveals that the dissolved oxygen, which is one of the key factors of aquatic life becomes scarce because it is much more requested for the decomposition of tons of discharge woods in the Nokoue lake. And as a result, the aquatic environment becomes reducing, which allows the biochemical process of development and degrading of the original conditions of life in the aquatic medium. A program of reforestation of lagoon banks is then recommended due to its multiple advantages. IT is good to notice that the new government has decided to restorate aquatic ecosystem on this lake. Nowadays, the new government has forbiden the use of acadja

VI. REFERENCES

1° Baran, E. (1999) Rôle des estuaires vis à vis de la ressource halieutique côtière en Guinée. In: Domain, F., Chavance, P. and Diallo, A., Eds.,

2° *La pêche côtière en Guinée: Ressources et exploitation,* Boussoura (GIN), Paris, 137-157.

Lalèyè, P.A. (1995) Ecologie comparée de deux espèces de *Chrisichthys,* poissons siluriformes (Claroteidae) du complexe lagunaire lac Nokoué-lagune de Porto-Novo au Bénin. Thèse de Doctorat en Sciences, Université de Liège, Belgique.

3° Dovonou, F., Aïna, M. and et A. Alassane, M.B. (2011) Pollution physico-chimique et bactériologique d'un écosystème aquatique et ses risques écotoxicologiques: Cas du lac Nokoué au Sud Bénin. *International Journal of Biological and Chemical Sciences,* 5, 1590-1602

P3-17

湖水直接浄化施設の稼働による土浦港水質浄化効果について

志村 隆二[1], 小室 俊輔[1], 松本 俊一[1], 相馬 久仁花[2], 福島 武彦[1]

[1]茨城県霞ケ浦環境科学センター, [2]茨城県県民生活環境部環境対策課

キーワード: 富栄養化, 栄養塩動態, 水質浄化, 生態系機能

抄録

茨城県では, 植物プランクトンの増殖に必要なりんを湖水から直接除去するために, 凝集磁気分離技術を応用した直接浄化実証施設を 2013 年 9 月に土浦港湖畔に設置, 稼働した。本研究では, この浄化施設による水質改善効果を港内の水質を調査することによって検証することを目的した。処理水量増加に伴う土浦港のりんの減少量は, 浄化施設の稼働による処理水量の増加に伴って, 土浦港のりんの減少は高くなる傾向が認められ, 稼働後は稼働前より土浦港のりんが約 23 kg 減少された。特に, 水域 a のりんの浄化効果が大きい。さらに, 浄化施設の連続稼働も霞ヶ浦のりんの削減に寄与していたと考えられる。また, 浄化施設の稼働によって, 土浦港のクロロフィル a の減少が認められたことから, 土浦港水域の植物プランクトンの減少が示唆された。本研究結果より, 浄化施設の稼働は, 植物プランクトンの発生の抑制に対して有効であると考えられる。

1. はじめに

霞ヶ浦はいまだ富栄養化の状態にあり, 特に 2011 年には, 土浦港付近でアオコが大発生し, アオコの腐敗による悪臭被害が発生するなど, 霞ヶ浦の水質改善が求められている。既往研究から, 植物プランクトンの増殖は, 湖水中の窒素, りんなどの栄養塩の過増加による湖沼の富栄養化に関連していると報告されている。

茨城県では, 植物プランクトンの増殖に必要なりんを湖水から直接除去するために, 凝集磁気分離技術を応用した直接浄化実証施設を 2013 年 9 月に土浦港湖畔に設置, 稼働した。本研究では, この浄化施設による水質改善効果を港内の水質を調査することによって検証することを目的とする。

図1 土浦港調査地点及び浄化水域

2. 方法

2017 年は, 述べ 100 万 m^3 の処理水量の目標を達成するため, 6 月 16 日から 10 月 16 日まで湖水直接浄化施設を稼働し, 浄化効果を検証した。

直接浄化施設は, 凝集疑似分離方式を用いて, 1 日あたり 10,000m^3の水処理を行うことができる。急速撹拌槽, 緩速撹拌槽, 磁気分離装置により, 約5分間程度で処理が可能。目標水質は, 全りんが 0.03mg/L, 浮遊物質量(SS)が 5mg/L とした。

表1 2017年の湖水浄化施設の稼働状況

運転期間	期間	処理水量(万m^3/day)
第1クール	6月16日～8月10日	1.0(計画) 汚泥返送(24時間)
第2クール	8月17日～10月16日 (8月11日～16日原水循環運転)	1.0(計画) 汚泥返送(24時間)

土浦港内の水質調査方法及び評価方法は, 次のとおりである。

(1) 調査頻度: 稼働前: 2 回(平均値を取る), 第 1 クール: 6 回; 原水循環運転: 1 回; 第 2 クール: 7 回; 稼働後(浄化終了後): 2 回

(2) 水質分析項目: 全りん(TP), 全窒素(TN), 化学的酸素要求量(COD), クロロフィル a 等

(3) 直接浄化施設によるりん等の除去率及び除去量:

除去率(%) = (原水濃度ー 処理水濃度)/原水濃度 ×100 ・・・式 1

除去量(kg) = 原水濃度 × 処理水量× 除去率 ・・・式 2

(4)水質変化率:

変化率(%) ＝ (稼働前水質 ー 稼働後水質)/稼働前水質×100 ･･･式 3

(5)土浦港各調査水域のりん等の減少量:

減少量(kg) ＝ 稼働前現存量 ー 稼働後現存量 ･･･式 4

3. 結果

湖水直接浄化施設によるりん等の除去率及び除去量は，SS が 76%及び 9,417kg，TPが 81%及び 67kg，PO_4-P が 81%及び 27kg，TN が 21%及び 307kg，クロロフィル a が 91%及び 33kg であった(表 2，図 2)。

表 2　直接浄化施設によるりん等の除去率及び除去量

	SS	TP	PO_4-P	TN	Chlorophyll a
原水濃度(mg/L, SD)	12(3.2)	0.087(0.022)	0.037(0.021)	1.4(0.26)	0.033(0.012)
処理水濃度(mg/L, SD)	2.8(0.70)	0.017(0.0067)	0.0070(0.0072)	1.1(0.35)	0.0031(0.0018)
除去率(%, SD)	76(6.1)	81(5.4)	81(17)	21(12)	91(3.8)
除去量(kg)	9417	67	27	307	33

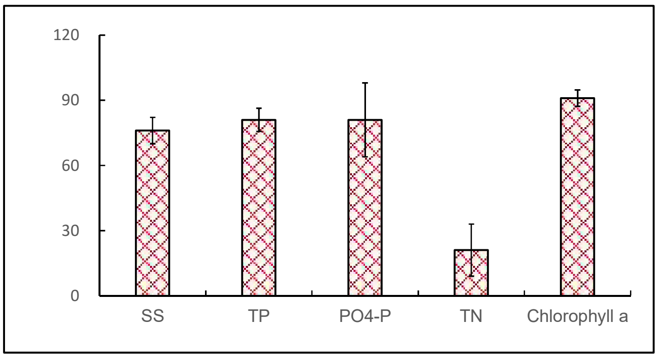


図 2　直接浄化施設の稼働によるりん等の除去率

土浦港の水質変化を以下に示す。りんの変化については，浄化施設の稼働により，土浦港の各地点のりんの低減が認められ，特に浄化対象水域のりんの減少が大きかった(図 3)。

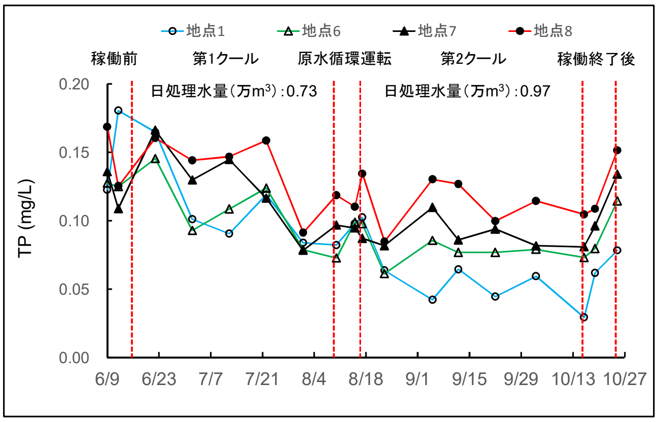


図 3　土浦港調査地点の TP（りん）の変動

植物プランクトン(クロロフィル a)の変化は，浄化施設の稼働により，植物プランクトンの現存量指標となるクロロフィル a の低減傾向が見られたことから，植物プランクトンの減少が示唆される。また，特に，浄化対象水域のクロロフィル減少が大きいことが分かった(図 4)。

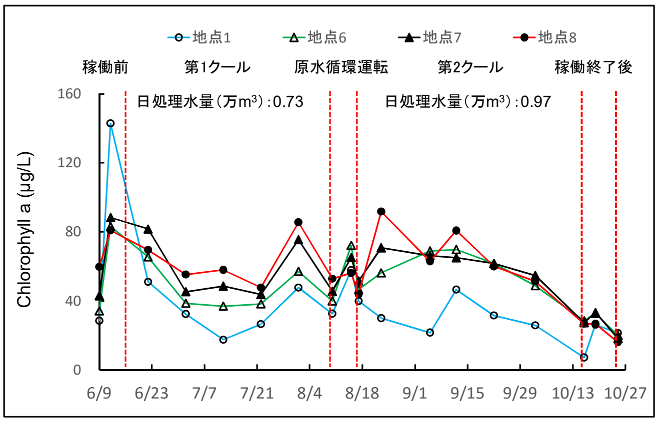


図 4　土浦港調査地点の Chlorophyll a の変動

処理水量増加に伴う土浦港のりんの減少量は，浄化施設の稼働による処理水量の増加に伴って，土浦港のりんの減少は高くなる傾向が認められ，稼働後は稼働前より土浦港のりんが約 23 kg 減少された(図 5)。特に，水域 a のりんの浄化効果が大きい。さらに，浄化施設の連続稼働も霞ヶ浦のりんの削減に寄与していたと考えられる。

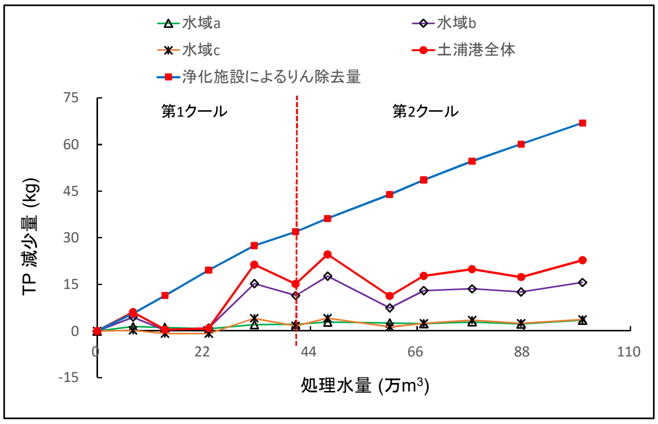


図 5　処理水量の増加に伴って，浄化施設による TP 減少量と土浦港の各水域の TP 減少量の変動

処理水量増加に伴う土浦港の植物プランクトンの減少量は，浄化施設の稼働によって，土浦港のクロロフィル a の減少が認められたことから，土浦港水域の植物プランクトンの減少が示唆された（図 6）。特に，土浦港の奥の水域 a の浄化効果が大きい。

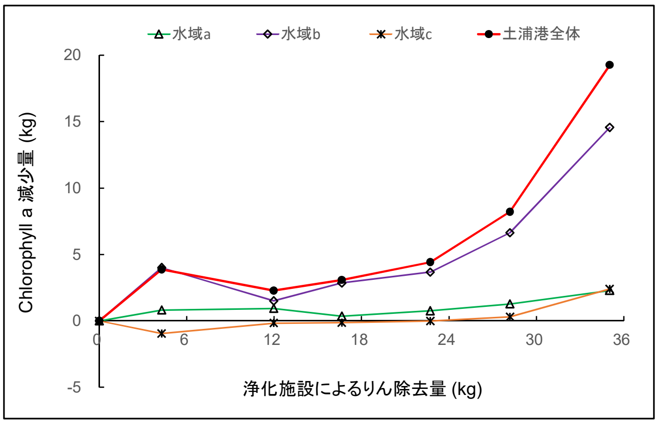


図 6　浄化施設の稼働によるりんの除去に伴って，土浦港の各水域の Chlorophyll a 減少量の変動

4.　まとめ

(1) 直接浄化施設の稼働により，土浦港の水質浄化効果が認められた。また，土浦港の奥の水域は浄化効果が高い。

(2) 処理水量の増加に伴って，土浦港のりんの減少は高くなる傾向が認められた。

(3) 浄化施設の稼働により，植物プランクトンの減少が示唆された。

(4) さらに，土浦港の底泥からのりん等の溶出の調査が必要であると考えられた。

本研究結果より，浄化施設の稼働は，植物プランクトンの発生の抑制に対して有効であると考えられた。

引用文献

[1]　Smith VH : Environ Sci Pollut Res Int , 10(2):126-39 , 2003

[2]　Ye et al : Environ Monit Assess , 135(1-3):217-25 , 2007

P3-18

浜名湖における栄養塩類・有機物の長期変動（1995～2017 年）

久保 篤史[1], 今泉 梨[1], 山内 悟[2]

[1] 静岡大学, [2] 静岡県環境衛生科学研究所

キーワード：富栄養化,窒素・リン循環,下水処理,マンケンドール検定

抄録

浜名湖は汽水湖であり，流域には農地・宅地が広がっている閉鎖性内湾である。静岡県が毎月取得している公共用水域データ（1995～2017 年）を用いて，栄養塩類・有機物濃度の長期変動解析を行った。浜名湖（12 点）においては，栄養塩類（アンモニウム塩，硝酸塩，リン酸塩）・全窒素・全リン・溶存酸素の鉛直データを，浜名湖流域河川（5 点）表層水においては，全窒素・全リン・化学的酸素要求量についての解析を行った。トレンド解析はマンケンドール検定を用いて行い、増減傾向を明らかにした。浜名湖におけるリン酸塩・全窒素・全リンはほとんどの観測点・観測深度で減少傾向であった（リン酸塩：1 定点底層水、全窒素：2 定点表層水で増減傾向無し）。流域河川における全窒素・全リン濃度も全ての観測点で減少傾向であった。そのため，浜名湖におけるリン酸塩・全窒素・全リン濃度の低下は流域での下水整備に伴う負荷量減少によると示唆された。

1. はじめに

沿岸域での人間活動により，水域への栄養塩・有機物負荷量は増加してきた。大量の栄養塩負荷は水域での植物プランクトンの大増殖を引き起こし，大量の有機物が生成・沈降する。その結果，底層での有機物分解に伴い貧酸素水塊が発生する。底層の貧酸素化により鉄は 3 価から 2 価へと還元され，吸着していたリン酸塩の一部が溶出する。そのため，貧酸素水塊が形成される水域では堆積物からの栄養塩類の溶出が富栄養化を進行させる要因になることが指摘されている [1]。そのため，水域の栄養塩収支を評価するためには，表層だけではなく鉛直的観測を行うことが必要である。

近年，著しく富栄養化した内湾である東京湾において，下水高度処理水の増加に伴い湾内での栄養塩濃度が減少，さらに貧酸素水塊が縮小し，底層のリン酸塩が減少してきていることが報告されている [2, 3]。そのため，流域下水の高度処理に伴い多くの沿岸海域でも同様の変化がみられる可能性がある。しかし，東京湾流域は下水整備率がほぼ 100%であるのに対し，本研究対象海域である浜名湖は約 80%である。さらに，流域での農業活動も盛んであるため大都市沿岸海域と同様の栄養塩動態が起こるかは不明である。そのため，本研究では浜名湖流域の下水整備が大きく進み始めた 1995 年から現在にかけての栄養塩類・有機物の増減傾向とその変動要因を明らかにすることを目的として研究を行った。

2. 方法

本研究では，静岡県が毎月行っている公共用水域調査データを用いた（1995 年 1 月～2017 年 3 月）。観測は浜名湖 12 定点，浜名湖流域河川 5 定点で行った（図 1）。浜名湖で得られた試水は栄養塩類（アンモニウム塩，硝酸塩，リン酸塩）・全窒素（TN）・全リン（TP）・溶存酸素（DO）の分析を行った。流域河川で得られた試水は TN，TP. 化学的酸素要求量（COD）の分析を行った。全ての分析は日本工業規格（JIS K0102）に従い行った。

各パラメータの増減傾向が統計的に有意であるか否かは系列誤差を補正するために改良されたマンケンドール検定を用いて検証した [4]。

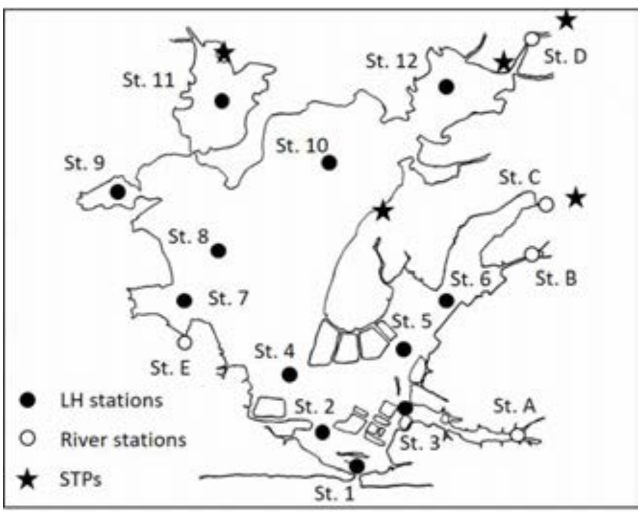


図 1 浜名湖と浜名湖流域河川の観測点

3. 結果

浜名湖表層水における，各パラメータのマンケンドール検定結果を表 1 に示した。減少傾向を示したものは“－”，増加傾向を示したものは“＋”，有意な増減傾向がみられなかったものは“±”で示した。また, *は有意水準 0.05, **は有意水準 0.005 を示している。

浜名湖では，リン酸塩は全ての観測点で減少傾向であった。鉛直観測データでも同様の結果がみられ，St. 3 の 2 m 以外全ての観測層で減少傾向であった。同様に TN，TP でも同様の傾向がみられ，ほとんどの観測点，観測深度で減少傾向がみられた。有意な増減傾向がみられなかった観測点は 2 点（St. 7, 11 の表層水）あり，増加傾向がみられた観測点はなかった。アンモニウム塩は St. 1～5 で減少傾向であったものの，その他の観測点では有意な増減傾向がみられなかった。一方，硝酸塩はほとんど有意な増減傾向がみられなかったものの，一部の観測点では有意な増加傾向がみられた。

浜名湖流域河川における，各パラメータのマンケンドール検定結果を表 2 に示した。TN, TP は全ての観測点で有意な減少傾向であった。さらに、COD も St. D を除いて有意な減少傾向がみられた。

表 1 浜名湖表層水における各パラメータの検定結果

観測点	NH_4^+	NO_3^-	PO_4^{3-}	TN
St. 1	−*	±	−**	−**
St. 2	−**	±	−**	−**
St. 3	−*	+**	−*	−*
St. 4	−*	±	−**	−*
St. 5	−*	+**	−**	−*
St. 6	±	+**	−**	−*
St. 7	±	±	−**	±
St. 8	±	±	−**	−**
St. 9	±	±	−**	−**
St. 10	±	±	−**	−**
St. 11	±	+**	−**	±
St. 12	±	±	−**	−**

表 2 流域河川における各パラメータの検定結果

観測点	TN	TP	COD	DO
St. A	−**	−**	−**	−*
St. B	−**	−**	−**	±
St. C	−**	−**	−**	±
St. D	−**	−**	±	±
St. E	−**	−**	−**	+**

4. 考察

浜名湖・浜名湖流域河川共に TN，TP 濃度が減少していたことから，流域河川からの流入負荷減少が浜名湖における栄養塩濃度減少に寄与していることが示唆された。特に，下水処理水量とリン酸塩濃度には有意な負の相関がみられたことから，流域での下水整備率の増加とそれに伴う下水処理水量の増加により浜名湖の水質は改善されていると考えられた。

しかし，アンモニウム塩と TN 濃度が有意に減少しているにも関わらず，浜名湖東部では硝酸塩が増加していた。浜名湖東部は流域の土地利用の大部分が宅地で湖西部に比べ人間活動の影響を強く受けており，相対的に下水処理水の流入量が多くなっている。Azhdarpoor et al. (2016) は一部の硝化-脱窒法による処理方法では，脱窒効率の低下により硝酸塩が増加することを報告している [5]。もしくは，下水処理水と共に流出した硝化細菌により，水域で活発な硝化反応が起こっている可能性もある [6]。その結果，人為的影響をより強く受けている湖東部では TN 負荷量は減っているものの，硝酸塩が増加している可能性が考えられた。

5. 結論

静岡県公共用水域データを用いて，浜名湖の栄養塩長期変動解析を行った。その結果，水域の栄養塩濃度は流域での下水整備率・下水処理水量と相関があることが分かった。しかし，硝酸塩に関しては下水処理効率の低下，もしくは下水処理場からの硝化細菌の流入により増加傾向がみられた。そのため，水域での栄養塩増減傾向を明らかにしていくためには，下水処理水量のみならず，下水処理の各プロセスによる処理効率に着目していく必要がある。

引用文献

[1] Friedl G.: Benthic fluxes of nutrients in the northwestern Black Sea, Marine Chemistry, Vol. 62, pp. 77-88, 1998.

[2] Kubo A. et al.: Long-term variability of nutrient and dissolved organic matter concentrations in Tokyo Bay, Limnology and Oceanography, in press, doi:10.1002/lno.10796.

[3] 安藤ら: 東京湾における底層 DO データの解析, 東京都環境科学研究所年報, Vol. 43, pp. 94-95, 2014.

[4] Yue S. and Wang C.: The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series. Water Resources Management, Vol. 18, pp. 201-218, 2004.

[5] Azhdarpoor A. et al.: Simultaneous removal of nutrients in a novel anaerobic-anoxic/aerobic sequencing reactor: removal of nutrients in a novel reactor. International Journal of Environmental Science and Technology, Vol. 13, pp. 543-550, 2016.

[6] Cebron A. et al.: Nitrification and nitrifying bacteria in the Lower Seine river and estuary (France). Applied and Environmental Microbiology, Vol. 69, pp. 7091-7100, 2003.

P3-19

Sustainable Approach to Conserve an Ancient Water Supply Scheme: Salim Ali Lake at Aurangabad, (MS), India

[1]Kshama Khobragade and [2]Yogita L.Padme

[1]S.B.E.S. College of Science, Aurangabad -(431001), M. S, India.
[2]Dept. of Environmental Science, Dr.Babasaheb Ambedkar Marathwada University, Aurangabad-431001, ,M.S., India

KEYWORDS: Ancient water supply system, Malik Amber, Nahar- E- Ambari, Salim Ali Lake, Water Quality

ABSTRACT

Salim Ali Lake is one of the historical lake in Aurabgabad city of Maharashtra State which was a planed city in midevial period. Priorly known as, 'Khijjar Talao', later on , 'Delhi Gate Talao' and now known as, 'Salim Ali Lake'. This was an excellent example of the ancient water supply system by means of, 'Nahar- E- Ambari', founded nearabout 400 years ago. Originaly the lake area was 54 acres and now reduces to 34 acres placed and is a hub of migratory birds.

The sewage and effluent from residential and industrial areas may responsible for the contamination of surface water reservoirs. The major factors contributing to the pollution of natural reservoirs of the city are; discharge of untreated sewage and effluent, poor sanitation facilities, dumping of municipal solid waste, erosion from the catchment areas, etc. Aurangabad Municipal Corporation had consructed a 5 MLD Sewage Treatment Plant in April 2013 on a lake basin.

In present study the water quality of Lake and outlet of Sewage Treatment Plant, were analyzed. The parameters such as turbidity, Electrical Conductivity, Total Dissolved Solids, DO and Total alkalinity were not compatible with the prescribed standards .

Availability of sewage treatment plant is a crusial problem at highly populated cities. Lake ecosystem and Sewage Treatment Plant should be studied simulteneously for the sake of conservation. There is an urgent need to improve the efficiency of STP so as to conserve such ancient water supply monument. Therby only we can made harmony with the aquatic ecosystem.

1. INTRODUCTION

Aurangabad is located at the latitude of 19.53^0 north and longitude 75.23^o east. Topographically it is located in the valley region between the Chauka Hills on the north and Satara Hills on the south. The total area of the city is about 138.5 sq.km Containing about 9 lacks population as per the 2001 census. The Salim Ali Lake is consisting of rich flora and fauna. The soil along the lake is muddy and rich in algal biomass and microorganisms. This lake is ecologically important as it provide a suitable habitat for birds. Its shape is rectangular and having an area about 54 acres when it was not surrounded by residential area.[1][2]. Aurangabad corporation was constructed a 5MLD Sewage Treatment Plant in 2012 and was started from April 2013.

The domestic effluent generated from the city area accounts for 107000 CMD while that from the councils is 103000 CMD. Untreated or partially treated domestic effluent has been identified as great concern from river water quality point of view. [3]

In present study the physico-chemical parameters of Sewage Treatment Plant outlet situated near Salim Ali Lake and lake water were analyzed.

2. MATERIAL AND METHODS

The analysis of outlet of STP and lake water was carried out monthly for the duration from April 2013 to December 2013. The parameters were analyzed by standard methods [4][5][6]

3. RESULTS

Table no. 2: Physico-chemical analysis of outlet water samples at Sewage Treatment Plant near Salim Ali Lake.

Sr. no.	Parameters	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1	Temp	38.8	42.5	42.5	35	32.5	27.5	26.4	24.3	23.0
2	Turbidity	**98**	**98.4**	**99**	**98.0**	**92.5**	**90.1**	**88.0**	**85.0**	**81.0**
3	TS	748	739	750	696	715	690	748	630.8	730.8
4	TDS	**724**	**716**	**724**	**674**	**693**	**670**	**723**	**615**	**710**
5	TSS	23.4	22.9	25.1	21.7	22	20	25	15.8	20.8
6	EC	**730**	**725**	**730**	**715**	**727**	**710**	**630**	**650**	**720**
7	pH	7.6	7.4	7.2	7.6	7.23	7.6	8.0	8.5	8.5
8	**DO**	**1.0**	**0.98**	**1.1**	**1.4**	**2.0**	**2.1**	**2.3**	**2.4**	**2.4**
9	BOD	12.4	12.5	12.8	12.13	13.2	14.9	20.4	22.8	22.8
10	COD	45	48	50	52	42	54	58	62	65
11	Alkalinity	215	180	182	179	190	195	210	214	215
12	Total Hardness	180	179	181	184	192	197	202	200	209
13	Nitrate	0.090	0.085	0.095	0.092	0.15	0.17	0.16	0.12	0.15
14	Phosphate	0.0070	0.006	0.0078	0.007 5	0.087	0.095	0.09 3	0.080	0.089
15	Sulphate	92.0	92.1	95.7	93.5	91.0	88.0	83.5	80.6	89.1
16	Chlorides	222	225	239	235	245	250	249	252.9	265

{Note: all parameters are in mg/l except Temp (°C), Turbidity (NTU) and EC ($\mu mhos^{-1}$).}

Table no. 2: Average physico-chemical analysis of water samples at Salim Ali Lake from January 2013 to December 2013

Sr. no.	Parameters	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1.	Temp	38.7	39.7	37.5	34.6	32.3	27	26	24.7	22.3
2.	Turbidity	**58.7**	**59.1**	**59.2**	**57.1**	**54.0**	**52.1**	**51.4**	**49.6**	**45.8**
3.	TS	1464	1469	1500	1485	1656	1194	1063	982	1060
4.	TDS	**1006**	**1013**	**1017**	**1045**	**1082**	**828**	**805**	**775**	**820**
5.	TSS	**457**	**455**	**482**	**439**	**573**	**366**	**258**	**207**	**240**
6.	EC	**330**	**330**	**327**	**325**	**346**	**327**	**314**	**338**	**348**
7.	pH	8.0	7.9	7.8	7.9	7.8	7.9	8.0	8.1	8.3
8.	DO	4.2	3.9	4.1	4.3	5.2	5.6	6.2	6.2	6.5
9.	BOD	**32.95**	**30.5**	**35.4**	**34.8**	**34.3**	**34.2**	**30.9**	**27.8**	**27.4**
10.	COD	135	139	142	147	130	153	156	151	160
11.	Alkalinity	283	276	271	247	256	283	291	331	322
12.	Total Hardness	199	195	197	211	233	243	247	242	259
13.	Nitrate	3.3	3.5	3.3	3.3	3.2	3.2	3.1	3.0	3.0
14.	Phosphate	1.3	1.5	1.3	1.2	1.1	1.1	1.1	1.0	1.0
15.	Sulphate	73.5	77	66.7	157	151	146	138	135	146
16.	Chlorides	239	240	236	232	240	249	241	263	272

{Note: all parameters are in mg/l except Temp (°C), Turbidity (NTU) and EC ($\mu mhos^{-1}$

Table no.3: Water Quality Standards.

Sr. No.	Parameters	USPH Standards	ISI Standards for sewage disposal in Inland Surface water	WHO Standards	BIS Standards	MPCB Standards
1	Temp		Shall not exceed 5°C above the Receiving water temperature			
2	pH	6.0-8.5	6.0-9.0	6.5-9.2	-	5.5-9.0
3	EC	300	-	-	-	
4	Turbidity	< 5	-	-	-	
5	TS		-			
6	TDS	500	-	500	-	2100
7	TSS		100			100
8	Alkalinity	-	200	-	-	
9	Total	-	300	-	-	

	Hardness					
10	Chloride	250	600	500	600	600
11	Sulphate	<0.3	-	200-400	1000	
12	DO	4-6	3.0	-	-	4-5
13	BOD	4.0	30	-	-	30
14	COD	4.0	250	-	-	250
15	Phosphate	-	5.0	-	-	5.0
16	Nitrate	-	10	-	-	10

{Note: all parameters are in mg/l except Temp (°C), Turbidity (NTU) and EC ($\mu mhos^{-1}$).}

4. DISCUSSION

In present study, the maximum value of Turbidity was 99 NTU of outlet water sample and 59.2 NTU of lake water sample were observed. Both the values are above the prescribed limit. Turbidity in water may be organic or inorganic origin. Maximum turbidity value was reported during rainy season due to inflow of rain water from surrounding area as well as sewage of city.[6] The maximum TDS was 724.9mg/l in STP outlet and 1082mg/l in lake water. The maximum value of Electrical Conductivity 730 $\mu mhos^{-1}$ in outlet water and 348 $\mu mhos^{-1}$ in lake water were observed. All values and above the prescribed limit. The high value indicating that water is loaded with waste water and domestic sewage from several houses showed maximum levels of conductance in the water the presence of larger amount of salts in the sewage water [7]. The dissolved oxygen value was very much less as compared to the prescribed standards [8]. Low content of DO is sign of organic pollution, is also due to inorganic reductants like ammonia, nitrates, and other such oxidisable substances. The total alkalinity of STP water sample was recorded as 215mg/l and 331 mg/l were observed. Both are above the prescribed standards.

5. CONCLUSION

The present study reveals that the parameters like Turbidity, Total Dissolved Solids and Total Alkalinity are above the standards. Outlets of sewage water containing low DO as compared to standard which is harmful for the aquatic life and is containing more Turbidity, Electrical Conductivity and Total Alkalinity.

STRATEGIES:

- There is an urgent need to increase sewage treatment capacity as well as to improve the functioning of the treatment facilities which they have provided.
- There should be some strategic action plans include identification of projects for improvement of the current situation. Even the policies regarding such issues should be reformed.
- The implementation of effective ecotechnologies such as, Bioremediation Technology, Root zone Technology, Green Bridge Technology, Green Lake Technology, and Stream Eco-System (SES) Technology to restore the quality of Salim Ali Lake.
- There should be the development of models for management of Salim Ali Lake water for sustainable utilization.

REFERENCES

1] Khobragade K. S. 2002): Physico-chemical characteristic of Salim Ali pond in relation to plankton, Ph. D. Thesis, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad.

2] Patil S.S., Auti R.C., Mokashe S.S. (2008) Conservation and management of Salim Ali Lake, Aurangabad. Pp 1614-1622 .In the proceeding of the 12th World Lake Conference

3] Vision 20-20, (2010): Technical Report, Aurangabad district Environmental management, Maharashtra Pollution Control Board, Aurangabad Regional Office

4] APHA (1998): Standard methods for examination of water and wastewater, 20th edition .American Public Health Association, Washington DC.

5] Kodarkar M.S.et al (2006): Methodology for water analysis. Indian Association of Aquatic Biologist (IAAB) Publication, Jambagh, Hydrabad

6] Deshpande S.M. and Aher K.R., (2009): Studies on water quality of lakes around Aurangabad city (M.S.), Bioinfolet 6(3), pp 255-257.

7] Nalawade P.M., Solunke K.R., Late A.M., Patil C.A. and Mule M.B. (2008): dying Lake: a losing habitat of migratory birds- a case study from Aurangabad city, pp.1623-1627.in the 12th World Lake Conference, Jaipur, India.

8] Bhosale P.R., Chavan R.J. and Gaikwad A.M. (2012): Studies on distribution and diversity of Chironiomid larvae (Insecta: Diptera), with respect to water quality in Salim Ali Lake Aurangabad, India. The Bioscan, International Journal of Life Sciences. Vol.7 (2), pp.233-235

P3-20

牛久沼における水質等調査結果について

富永　佳子 [1], 松本　俊一 [1], 中谷　仁崇 [1,2]
[1] 茨城県霞ケ浦環境科学センター, [2] (現)・茨城県霞ケ浦北浦水産事務所

キーワード：富栄養化, 水質管理, 牛久沼, COD

抄録

牛久沼は茨城県南部に位置し，古くから農業用水や漁場として利用されてきたが，流域の開発が進行し1975年頃から水質が悪化した。そのため，県では牛久沼水質保全計画に基づき，湖内及び流入出河川における多地点の水質調査を行っている。その現状を把握するとともに，プランクトン調査，気象情報収集などをも継続的に行い，湖内の汚濁機構の解明の手がかりとした。湖心及び流入河川の水質は，近年(第3期中：2012年～2016年)ではCODが第3期計画目標値(COD：7.2mg/L,TN:1.3mg/L,TP:0.059mg/L)を達成したものの，まだ，最終的な目標の環境基準(湖内でCOD:5mg/L,TN:0.6mg/L,TP:0.05mg/L)に比べて高く，引き続き，調査を継続していく。

1.　はじめに

牛久沼は茨城県南部に位置する湖面積 3.4 km^2，平均水深 1 m の浅い湖沼[1]であり，3 つの肢節部を有する堰止め湖である（図 1)。主に谷田川，西谷田川，稲荷川が牛久沼に流入し，小貝川を経て利根川に流出する。農業用水として利用されるほか，古くから漁場として親しまれる湖沼であるが，その水質は 1975 年代後半から悪化した。流域で様々な排出負荷削減対策が行われているが，COD 等の項目で水質汚濁に係る環境基準を達成していない。そのため，牛久沼における湖内及び流入出河川における水質調査を実施し，その状況を把握するとともに，プランクトン調査，気象情報収集も行い，汚濁機構解明のための基礎資料とする。

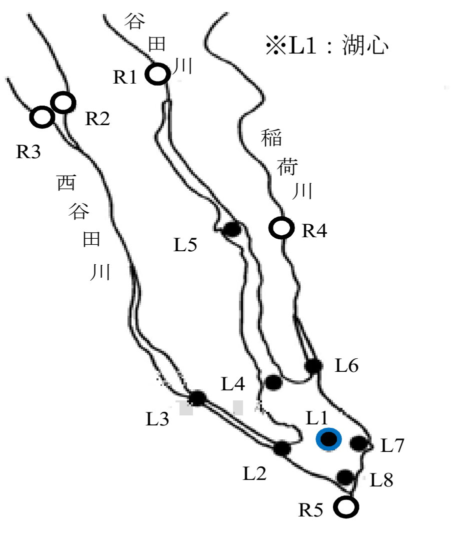


図 1　牛久沼調査地点

2.　調査方法

2.1 水質調査

図 1 に示した地点において，湖内に設定した 8 地点(L1～L8)では上層水(水面下 0.5 m)及び下層水(湖底上 0.5 m)をペリスタルティックポンプにより採水した。流入河川(R1～R4)，流出河川(R5：2007 年より開始)では，表層水をステンレス製バケツで採水した。調査期間は 2002 年 4 月から 2017 年 3 月まで，毎月 1～2 回，行った。現地では水深，透明度，水温，pH，電気伝導率(EC)を測定した。

2.2 分析方法

採取した試料水は当センターに持ち帰り，次の方法で分析した。化学的酸素要求量(COD)については過マンガン酸カリウム(100℃)による方法により分析した。全窒素量(TN，D-TN)及び全リン量(TP，D-TP)については窒素リン自動分析装置（ブランルーベ社製 AUTOANALYZERⅢ)で，各態窒素量(NO_3-N，NO_2-N，NH_4-N)及びリン酸イオン量(PO_4-P)については形態別窒素リン自動分析装置(ブランルーベ社製　AACS-Ⅱ)で分析した。クロロフィル a の測定については，試料水を孔径 1.2 μm のろ紙（Whatman，GF/C）を用いてろ別し，得られたろ紙を凍結した後エタノールで 1 日間抽出し，浮遊物質を遠心分離（3000rpm，10 分）して得られた上澄み液を分析に供した。分析には，吸光光度計（shimadzu 社製，UV-2550）を用いて吸光度を測定し，ユネスコ法の計算式を用いてクロロフィル a 濃度を算出した。pH 及び EC は東亜 DKK 製多項目水質計 WM-32EP を使用した。

2.3 プランクトン調査

図1に示した湖心調査地点（L1）において，植物及び動物プランクトン調査を行った。調査期間は，2005年4月から2017年3月にかけて月に1回～2回の頻度で行った。

植物プランクトンの調査方法を以下に示す。調査地点でペリスタルティックポンプを用いて上層水を400 mL採集し，25%グルタルアルデヒド溶液を終濃度約 4%になるように加えて試料とした。得られた試料についてプランクトン計数板を用いて種ごとの細胞数を測定し，得られた細胞数に1細胞当たりの体積を掛けあわせることで生体積を算出した。

動物プランクトンの調査方法を以下に示す。調査地点において小型プランクトンネット（離合社製，5513，目合い 0.1 mm）を用いて湖底直上 0.5 m から湖水面まで鉛直引きし，得られた湖水試料に 25%グルタルアルデヒド溶液を終濃度が約 4%になるように加えて試料とした。得られた試料について植物プランクトンと同様にプランクトン計数板を用いて個体数密度を測定した。

3. 結果と考察

3.1 水質の経年変化

主要な水質項目の経年変化について，図2～図5（湖内8地点（上層）平均，流入河川4地点平均）に示す。

主要な水質項目（COD，全窒素，全りん，クロロフィルa）をみると，過去5年（2013年～2017年）平均値についてCODは湖内では6.5mg/L～7.4mg/Lの範囲，流入河川では 3.8mg/L～5.2mg/L の範囲で推移し，2017 年は上昇したものの長期的に見ると，低下傾向にあった。全窒素は，湖内では 1.5mg/L～1.8mg/L の範囲であった。長期的に見ると，変動幅が小さくなり横ばいの傾向であった。一方，流入河川では 1.9mg/L～2.5mg/L の範囲で推移し，長期的に見ると低下傾向にあった。全りんについては，湖内では 0.06mg/L～0.08mg/L の範囲,流入河川では 0.06mg/L 前後で推移し，長期的には低下傾向にあったが，2013 年以降は上昇傾向にあった。クロロフィル a については，湖内では 42μg/L～56μg/L の範囲で推移し，2007 年以降に上昇傾向が見られたが，長期的に見ると，2017 年は上昇したものの横ばいで推移した。

流入河川についても 5.6μg/L～13μg/L の範囲で推移し，長期的に見ると，2017 年は上昇したものの横ばいで推移した。

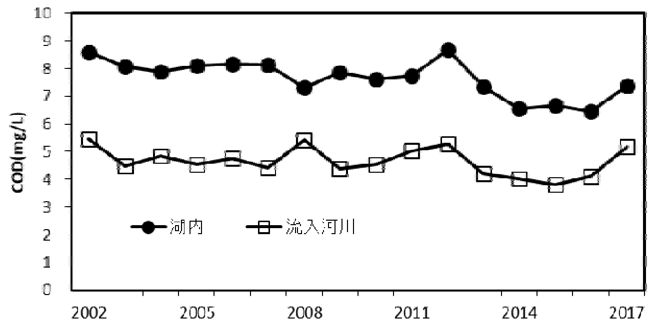


図 2　COD の変化（2002 年～2017 年）

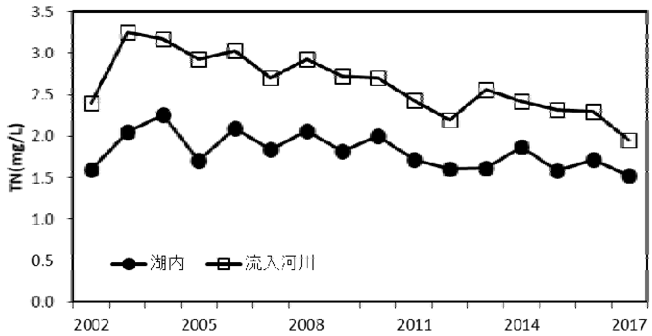


図 3 全窒素の変化（2002 年～2017 年）

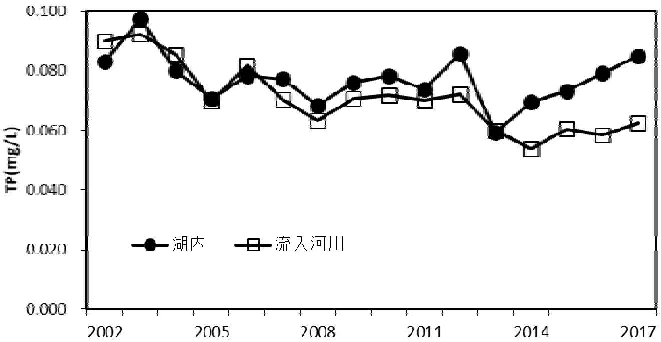


図 4 全りんの変化（2002 年～2017 年）

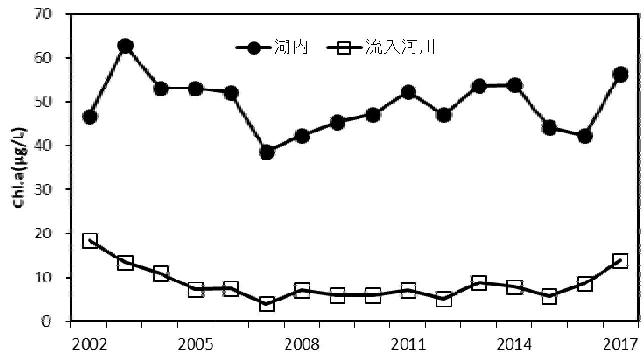


図 5 クロロフィル a の変化（2002 年～2017 年）

3.2 プランクトンの経年変化

プランクトンの経年変化について，図 6～図 7 に示す。牛久沼に出現する植物プランクトンの多くは *Cyclotella* や *Synedra* のような珪藻類である[2]。長期的に見てもその傾向は変わらず，珪藻類（*Aulacoseira* 属）がほぼ優占し，特に春から夏までは群体を作る *Aulacoseira* 属が大きな割合を占めた（図 6）。また，アオコを発生させる *Microcystis* のような水利障害を起こすプランクトンは見られなかった。

動物プランクトンについては，個体数密度で見ると，ワムシ類（*Brachionus*属，*Asplanchna*属）が多く，その他に原生動物やミジンコ類，カイアシ類が見られた（図7）。

4. まとめ

牛久沼の湖内や流入河川の水質の経年変化については COD や窒素については減少傾向であるが，全りんについては上昇傾向であった。また，プランクトンについては，長期的な変動は見られず，水利用障害を起こすプランクトンも発生していない。牛久沼については，環境基準（COD:5mg/L,TN:0.6mg/L,TP:0.05mg/L）に比べて高い状態にあるため，今後とも引き続き調査を継続していく。

引用文献

[1]　日本陸水学会:陸水の辞典，講談社,2006
[2]　漆谷ら：湖沼としての牛久沼の特性．茨城公技研報 11,57～66, 2001

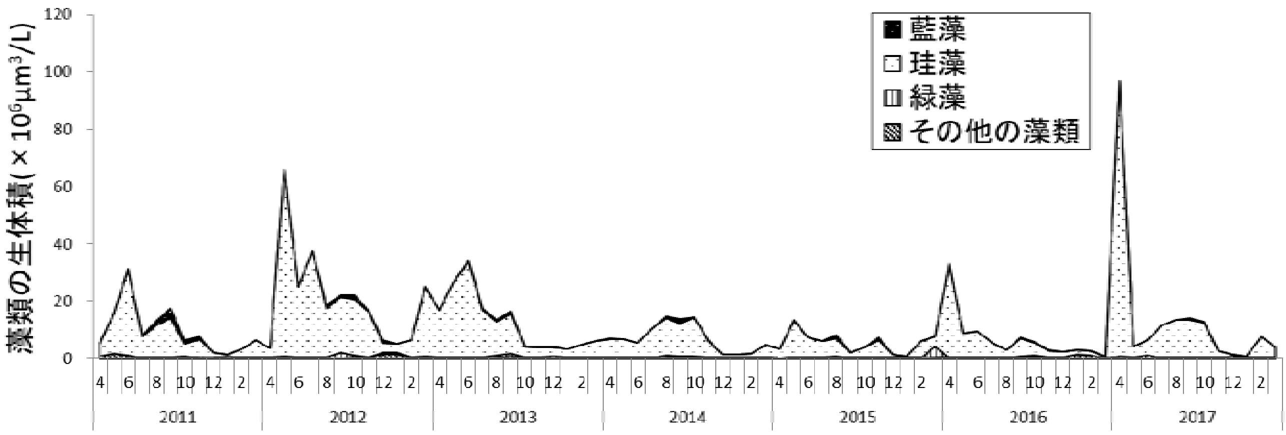


図 6　植物プランクトンの生体積の変化

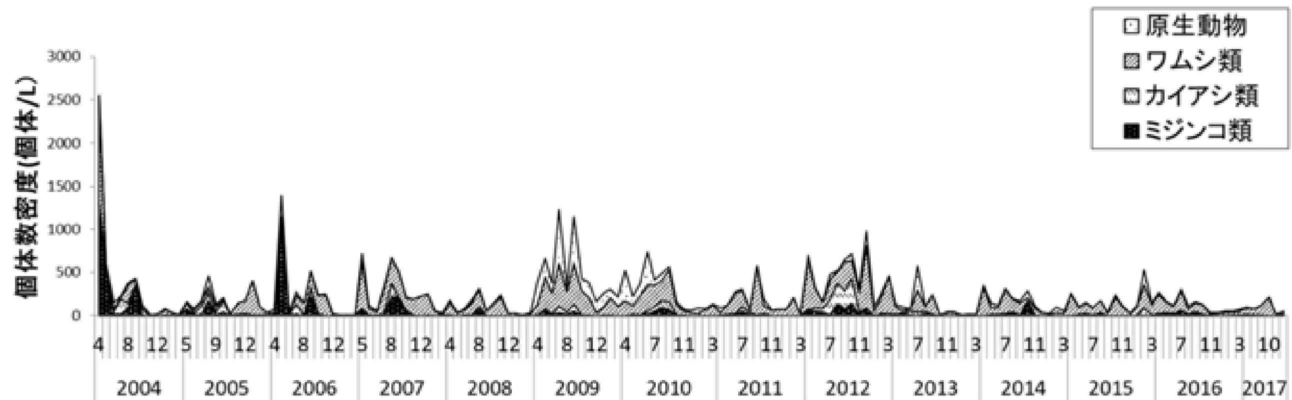


図 7　動物プランクトンの個体数密度の変化

P3-21

Ichtioindicative assessment of Water Quality in Urban Lakes (on the example of Kazan, Russia)

Nail Gosmanovich Nazarov[1], Renat Irekovich Zamaletdinov[1], Lyudmila Yuryevna Balezina[1], Marina Vasilyevna Rubanova[2], Nafisa Mansurovna Mingazova[1]

[1]Kazan Federal University, Kazan, Russia [2]Institute of Ecology of Volga baisin RAS, Togliatti, Russia

Keywords: Ichtyoindicative method, Perccottus glenii , Urban Lakes

ABSTRACT

Fishes react sensitively to changes in environmental conditions, in particular the chemical composition of water, suspended matter and bottom sediments. Also, a relatively high degree of adaptation of fish to changing conditions of their life is known, but it is far from boundless.

In this work we investigated the morphometric, parasitological and biochemical features of the *Perccottus glenii* population of some urban lakes in the city of Kazan. The results of the assessment of the state of the aquatic ecosystems of urban lakes using ichthyoindication methods are presented. It was noted that in the Lake Dryanichnoye *Perccottus glenii* is characterized by the most deviating from the norm values of the liver mass index, biochemical blood indices and parameters of helminth infection.

1. INTRODUCTION

At present, a lot of ichthioindicative methods are used to assess the state of aquatic ecosystems. Fishes react sensitively to changes in environmental conditions, in particular the chemical composition of water, suspended matter and bottom sediments. One of the most interesting examples of biological invasions is the dispersal of Amur sleeper (*Perccottus glenii* Dybowski, 1877). There is a relatively high degree of adaptation of this fish to changing conditions of their life, but it is far from boundless. [1].

The aim of this work is to study the morphological, parasitological and biochemical parameters of the Amur sleeper population in urban lakes in Kazan.

2. METHOD

The material for this work was Amur sleeper's statistical samplings (n = 250) collected in 2017 in four Lakes of the city of Kazan: Marino, Maloe Glubokoe, Maloe Lebyazhye, Dryanichnoe. The collection of the ichthyological material was performed using a grid with a cell size of 1 mm. For morphometric analysis, we measured the mass, length, and height of the body. The measurements of length and height were carried out with an accuracy of ± 0.1 cm. Each fish was weighed on an EK 410i laboratory scale with an accuracy of ± 0.01 g.

The content of helminths in fish tissues was determined in the laboratory conditions. [2]. Cestod was fixed with 70% ethyl alcohol, preparations were made in glycerol-gelatin. Species identification of the parasites was carried out using stereoscopic microscopes MBS-10 and Biolar equipped with a Levenhuk C-Series 5M pixel micro-photon array. As the main characteristics of infection of fish with helminths the parasitological parameters of the extent of invasion (the percentage of infection of the host by one species of parasites), the intensity of infestation (the minimum and maximum number of parasites of one species in the host species), the abundance index (the average number of parasites of one species in the host species).

Samples of blood were collected directly when fish catching. Hematological and biochemical blood tests are performed using a biochemical analyzer "Daytona Randox". During the biochemical analysis of serum samples, the content of glucose, lactic acid, total protein and hemoglobin.

Statistical processing of the material was carried out by standard methods using the Student-coefficient and Spearman rank correlation coefficient.

3. RESULTS

According to the morphometric parameters (mass and body length), the Amur sleeper population from all lakes is not statistically significant. The exponential equation of the Amur sleeper's mass dependence on the body length is $y = 74{,}367e^{0{,}0355x}$ (R^2=0,9).

The values of the fish liver mass index from the Lake Dryanichnoye are statistically significantly different and more than 2 times higher than in other lakes.

The complex of intestinal helminths in the Amur sleeper of reservoirs in Kazan is poorly developed. In all the lakes studied, monoinvasion of fish was detected by a specific cestode *Nippotaenia mogurndae* Yamaguti *et* Miyata, 1940. The highest values of infection rates of rotan N. mogurndae were recorded in Lake Dryanichnoe, where more than 93% of the fish in the samples are infected with a parasite, the intensity of invasion is up to 36 specimens of cestodes in the host. Statistically significant differences in the extent of invasion of rotan *N. mogurndae* were noted for lakes with the maximum and minimum contamination of cestode fish - Lake Dryanichnoe and Glubokoe,

The values of the hematological and biochemical parameters of the Amur sleeper blood in all lakes are within the norm, except the Lake Dryanichnoye. This population is characterized by the smallest concentration of erythrocytes and a low content of hemoglobin and glucose in the blood. On the contrary, there are increased values of leukocyte concentration and a high content of lactic acid in the blood.

4. DISCUSSION

Elevated values of the fish liver mass index may be evidence of high water contamination of Lake Dryanichnoe by toxicants. High values of fish contamination indicators by *N. mogurndae* indicate active feeding of Amur sleeper by the intermediate host of cestoda - a representative of copepods *Mesocyclops leukarti* (Claus, 1857), which has become widespread in many reservoirs of Russia and adjacent territories.

Deviations of biochemical and hematological parameters in the fish from Dryanichnoe lake from the populations of other lakes is an indicator of poor water quality in this reservoir.

5. CONCLUSION

It is noted that in the Lake Dryanichnoye *Perccottus glenii* is characterized by the most deviating from the normative values of the liver mass index, biochemical blood parameters and parameters of helminth infection. In this regard, we can assume that there are unfavorable environmental conditions in this lake due to unsatisfactory water quality.

REFERENCES

[1] P.A. Popov: Estimation of environmental state of waters by methods of ihtioindication, p. 267, 2002.

[2] I.E. Bykhovskaya-Pavlovskaya: Fish parasites, p. 121, 1985.

P3-22

Coniferous forests and lakes: the impact of pine pollen on water quality

Klimaszyk Piotr[1], Rybak Michał[1], Rosińska Joanna[2], Rzymski Piotr[2]

[1]Department of Water Protection, A. Mickiewicz University, Poznań Poland, pklim@amu.edu.pl, [2]Department of Environmental Medicine, Poznań University of Medical Sciences

ABSTRACT

It is believed that in comparison to other types, forest catchments provide smaller quantities of allochthonous matter. Therefore, they seem to be a factor that stabilize functioning of midforest lakes. Some papers point out that forested catchment can provide to the freshwater ecosystems significant amounts of organic matter (humic acids) and trigger lakes humification. We estimated if wind dispersed pine pollen may change water quality and accelerate the increase of fertility of several lakes located in forested areas. We found that pine pollen is rich in nitrogen and phosphorus. Average phosphorus content was about 20 g P kg and nitrogen about 22 g N kg of dry mass of pollen. Based on the field experiment we estimated that during the pollen season (May – June) average pollen deposition is about 12 g d.m. per square meter of the lake. It gives every year provision more than 20 kg of P and over 25 kg of N per one hectare of the lake. According to the laboratory experiment, we provided that pollen fell on the water very quickly release nutrients, and also become a culture for bacteria and fungi. In all investigated lakes we found the increase of concentrations of nitrogen and phosphorus in the littoral zone during pollen season. Certainly these loads of nutrients may stimulate the development of primary producers and FPOM consumers, however this requires further research.

INTRODUCTION

Forested terrestrial ecosystems may strongly affect adjacent freshwater ecosystems. Despite the fact that the most significant loads of nutrients are transported to surface waters from agricultural catchments (Alexakis et al 2013), allochthonous inputs may significantly subsidize midforest lakes (Park et al. 2011). Surface runoff both from deciduous and coniferous forests supply lakes in significant amounts of nitrogen and phosphorus and thus trigger their eutrophication (Klimaszyk et al 2015). Forested catchments can be responsible for the humification of lakes resulting from high quantities of organic matter (humic compounds), transported particularly from the coniferous sites (Steinberg 2003; Klimaszyk and Rzymski 2013). Wind derived forest particles deposited on the lake's surface seems to be less important in lake matter and energy budget, however, we hypothesized that nutrient-rich pollen deposition might accelerate eutrophication of midforest lakes.

MATERIAL AND METHODS

The investigation was carried out in 2017. Six midforest lakes located in the Drawa National Park (North-West Poland) were taken under consideration. The lakes were differentiated according to the morphology (from the small - less than 1 ha to the over 70 ha) and trophic state (from humic to mesotrophic). The common feature of studied lakes was the character of catchment area – 100% overgrown by coniferous pine forest. Several Tauber's traps were installed on the lakes shore during May and June to estimate deposition of pine pollen. Traps were checked every two weeks. The deposited pollens were rinsed with ultrapure water filtered GF/C filter. Filters were inspected with a stereoscope. After that, they were combusted and measured as ash-free dry weight. To determine the impact of pine pollen deposition on lakes chemistry and biocoenoses, samples of water for chemical analyses and samples of phytoplankton were taken. Samples were taken before (early May) in the middle and after pollen season. Electrical conductivity and pH of water were measured in the field using a YSI 556 Multiparameter Instrument. The following parameters were analysed in the laboratory: ammonium ($N\text{-}NH_4$, using the Nessler method), nitrite (NO_2^-, using the sulphonic acid method), nitrate ($N\text{-}NO_3^-$, using the sodium salicylate method), Norg (using the Kjeldahl method), TP (using the molybdate method after mineralization) and orthophosphate (TRP, using the molybdate method) (APHA 2005). Chlorophyll-a was determined after extraction in the ethanol. Samples for the phytoplankton analyses of the qualitative and quantitative composition of phytoplankton were fixed with Lugol's solution. Analyses were done using a Sedgewick-Rafter chamber with a light microscope Olympus CX 21 LED (400x magnification). Pollen was collected from ripe anthers that were harvested from lower canopies of pine trees overgrowing lakes catchments. Anthers we dried at 40ºC put in the bucket and shaken until pollen, and other debris fell into the bottom. Collected mixture was sieved 500 µm mesh size to obtain pure pine pollen. This procedure was also used to collect pine pollen from trees growing near a high trafficked road. Elemental analysis was performed using the inductively coupled plasma optical emission spectrometer Agilent 5100 ICP-OES (Agilent, USA). A total of 67 chemical elements were analyzed. To estimate the nutrients flushing rate from the pollen the experiment was designed. To each conical flask, 1 g of pollen was placed and flooded with a 300 ml of ultrapure water of known parameters. To imitate lake conditions, the flasks were placed in a thermostat (18ºC) and gently shaken. Samples were taken after 1, 3, 6, 9, 12, 15 day of incubation. The pollen residues were filtered with GF/C filter. In obtained water the concentrations of nitrogen, phosphorus, pH, and electrical conductivity were measured according to above-described methods.

RESULTS and DISCUSSION

We found that pine pollen is rich in nitrogen and phosphorus. Average phosphorus content was about 20±2 g kg and nitrogen about 22±3.2 g kg of the dry mass of pollen. We also found that chemical composition of pine pollen depends on environment quality and pollution. Pollen collected near the road contained twice more heavy metals than those from National Park, less polluted area. We also found that during the pollen season (May – June) average pollen deposition is about 12±5 g d.m. per square meter of the lake. It means that pollen deposition provide more than 20 kg of P and over 25 kg of N per one hectare of the lake every year. In all investigated lakes we found the increase of nitrogen and phosphorus concentrations in littoral water. In most of them, the difference of N and P concentration on the beginning and end of pollen period was statistically significant. It confirms earlier observation of Cole et al.(1990) and Graham &Vinebrook (2006), who found that pollen is an important link between coniferous terrestrial and aquatic ecosystems. However, phytoplankton analyses showed that in the most lakes the abundance of phytoplankton decreased during our studies. Total abundance of phytoplankton was the highest before pollen period (early May), and the lowest after pollen period (June). Nevertheless, Chrysophyceae and Chlorophyceae dominated through the whole time. Decreasing phytoplankton abundance may have been caused by the presence of numerous zooplankton, which is often found at the turn of May and June (Lampert et al 1986). Our laboratory experiment confirmed observations made by Lee and Both (2003), who stated rapid decomposition of pollen in water and release of nutrients. We found that maximum release of N and P takes place 3 days after pollen flooding.

REFERENCES

Alexakis D, Kagalou I, Tsakiris G (2013) Assessment of pressuresand impacts on surface water bodies of the Mediterranean.

Case study: Pamvotis Lake, Greece. Environ Earth Sci 70:687–698

Cole JJ, Caraco NF, Likens GE (1990) Short range atmospheric transport. A significant source of phosphorus to oligotrophic lake. Limnol Oceanogr 35:1230–1237

Graham MD, Vinebrook RD, (2006) Coupling of boreal forest and lakes: Effect of conifer pollen on littoral communities. Limnol Oceanog 51:1524–1529

Klimaszyk P, Rzymski P (2013) Catchment vegetation can trigger lake dystrophy through changes in runoff water quality. Ann Limnol – Int J Limnol 41:191–197

Klimaszyk P, Rzymski P (2015) Contribution of surface runoff from forested areas to the chemistry of a through-flow lake. Environ Earth Sci 73:3963–3973

Lampert W, Fleckner W, Rai H, Taylor BE (1986) Phytoplankton control by grazing zooplankton: A study on the spring clear-water phase. Limnol. Oceanogr., 31(3):478-490.

Lee EJ, Booth T (1996) Pollen deposition in the boreal forest of west-central Canada. Can J Bot 74:1265–1272

Park S-R, Lee H-J, Lee S-W, Hwang S-J, Byeon M-S, Joo G-J, Jeong K-S, Kong D-S, Kim M-C (2011) Relationships between land use and multi-dimensional characteristics of streams and rivers at two different scales. Ann Limnol - Int J Limnol 47:107–116

Steinberg CEW (2003) Ecology of Humic Substances in Freshwaters, Springer, Berlin.

P3-23

Contribution of Nitrogen Deposition to Taihu Lake

Xi Chen[1], Chun Ye[2], Hao Yang[1,3] and Yanhua Wang[1,3]

[1]School of Geography Science, Nanjing Normal University, [2]Chinese Research Academy of Environmental Sciences,
[3]Jiangsu Center for Collaborative Innovation in Geographical Information Resource Development and Application

Keywords: nitrogen deposition, water eutrophication, driving force, human activity, Taihu watershed

ABSTRACT

Atmospheric nitrogen (N) deposition represents an important source of reactive nitrogen to ecosystems. However, excessive N inputs could cause adverse ecological effects. In present study, the Taihu basin was taken to explore the characteristics of N deposition and its contribution to water eutrophication. Results show that the annual average of total deposition (TN) and total wet deposition (TN_W) rate were 6154 and 1142 kg km^{-2}, respectively. The TN deposition concentration have a significant negative correlation with the rain intensity ($R=-0.783$, $P<0.01$). The main N pollutants come from domestic sewage (account for 48.88%) and agriculture (account for 28.17%). TN deposition contributed to the lake was 14400 t N a^{-1} and accounted for 12.36% of annual riverine input of TN.

1. INTRODUCTON

Nitrogen (N) deposition mainly originates from the discharge of nitrogen oxides (NO_x), nitrate nitrogen (NO_3^--N), ammonia nitrogen (NH_3) and ammonium nitrogen (NH_4^+-N) with both anthropogenic and natural sources [1, 2]. Excessive N inputs could cause soil acidification, plant biodiversity reduction, and eutrophication in the ecosystems. Many previous studies showed that the concentration of N deposition to water N loads has been increased [2, 3, 4]. Western Europe, China, and India are the three regions with the highest N deposition in the world in recent years. The primary object of this study is to characterize atmospheric N deposition and calculate the N loads from the inflowing rivers.

2. METHOD

2.1. Study area.

Lake Taihu (29°55′~32°19′ N, 118°50′~121°55′ E), one of China's five major freshwater lakes, as an important water source for water quantity regulation, industry, agriculture, and tourism. The lake water was oligotrophic in the 1950s. However, the water environment system has been destroyed quickly in the mid-1980s due to the rapid industrial, agricultural development and excessive population growth. Many policies and foundation item were initiated, for example, "Zero-point Action" and "Standard Discharge", to improve the Lake Taihu water quality. However, The Lake Taihu water quality has not improved remarkably. The natural environment of Lake Taihu has already significantly deteriorated, and water eutrophication has become serious problems.

2.2. Calculation of nitrogen inputs

This present study, we calculated the main pollutant source from agriculture (chemical fertilizer, livestock and aquaculture), domestic sewage (urban domestic sewage and rural-domestic sewage), and industrial effluents in Table 1 by the method of Technical Specification:

$$N_T = N_A * f_A + N_B * f_B + N_C * f_C + N_E * f_E \quad (1)$$

Where N_T (t N a^{-1}) is total N discharged to surface water, N_i (i = A, B, C, and E) is emission coefficient, f_i (i = A, B, C, and E) is the coefficient into water, A is industrial effluents, B is urban sewage domestic sewage, C is rural domestic sewage, E is agricultural pollution.

3. RESULTS

3.1. Spatio-temporal variation of nitrogen deposition

The main N deposition is dry deposition and accounts for 81.40%. The NH_4^+-N/NO_3^--N ratio is 1.4:1. TN and TN_D deposition rate have an apparent seasonal variation features. The high N deposition rate would promote the bloom of cyanobacteria and aggravate the water eutrophication. TN_D deposition rate has increased rapidly in spring while decreased in summer. Because amount of fertilizer and pesticide spraying may enhance the N deposition in spring.

3.2. Comparisons of atmospheric nitrogen deposition rate listed with other domestic areas

The mean annual TIN_w deposition rate in the Taihu watershed, North China plain, Pearl River Delta and Western China were 2736, 2352, 2267, 446 kg km^{-2}, respectively. The N deposition values of Taihu watershed were higher than others area obviously. However, the TN deposition values were increased if the dry deposition rate was considered. Because the rainfall in norther China was less than in south. Obviously, the TN deposition load already exceeds the critical eutrophication load in theory which the allowable TN load was estimated to be only 491 kg km^{-2} a^{-1}.

3.3. Correlation analysis between meteorological conditions and wet nitrogen deposition

A significantly negative correlation was found between the concentration of TN deposition and rainfall ($Y=189.268X^{-0.997}$, $R=-0.999$, $P<0.01$), rainfall frequency ($R=-0.783$, $P<0.01$), and rain intensity ($R=-0.783$, $P<0.01$). This phenomenon indicate that the precipitation can clean N nutrients and the light rain clean better than heavy rain. The significant correlation between the meteorological conditions and TN deposition load indicate that high load N deposition would aggravate the water eutrophication.

4. DISCUSSION

To better understand the spatial-temporal distribution characteristics of N deposition and its estimated contributions to water eutrophication. The N deposition of simulated data in the Taihu watershed was investigated. Based on the EQ. (1), the main N pollutants come from domestic sewage (account for 48.88%) and agriculture (account for 28.17%). Compared to the previous studies from 2007 to 2015, the contribution of N deposition to the Lake Taihu has an increasing trend. Obviously, the TN deposition load already exceeds the eutrophication critical load in theory. This phenomenon may potentially accelerate the eutrophication process of the Lake Taihu.

5. CONCLUSION

1) The TN and TN_D deposition have a significant temporal and spatial distribution features.
2) The concentration of TN deposition has a significant negative correlation with meteorological conditions and significant positive correlation with N deposition rate.
3) Total amounts of TN deposition loads contributed to the Lake Taihu accounted for approximately 12.36% of total annual N input via inflow rivers.

REFERENCES

[1] K.M. Russell, J.N. Galloway, S.A. Macko, J. L. Moody and J.R. Scudlark: “Sources of nitrogen in wet deposition to the Chesapeake-bay region,” Atmospheric Environment, vol. 32, no. 14, pp. 3923-3927, 1998.

[2] J.N. Galloway, F.J. Dentener, D.G. Capone et al: “Nitrogen cycle: past, present and future,” Biogeochemistry. Vol. 70, no. 2, pp. 153-226, 2004.

[3] Y.H. Zhao, L. Zhang, Y.F. Chen et al: “Atmospheric nitrogen deposition to China: A model analysis on nitrogen budget and critical load exceedance,” Atmospheric Environment, vol. 153, pp. 32-40, 2017.

[4] Y.X. Xie, Z.Q. Xiong, G.X. Xing, X.Y. Yan and S.L. Shi: “Source of nitrogen in wet deposition to a rice agroecosystem at Tai lake region,” Atmospheric Environment, vol. 42, no. 21. Pp. 5182–5192, 2008.

P3-24

Sustainable Utilization of a Crater Lake by Riparian Communities: The Quality of the waters of Lake Bosomtwe in the Ashanti Region of Ghana

Akrong M. O[1] and Ampofo. J. A[1]

[1]CSIR, Water Research Institute, Ghana

Keywords: Lake Bosomtwe, Water Quality, Seasonal Changes, Ecosystem, Water pollution

ABSTRACT

Water has vital role in all aspects of life with its significance visible in its sustenance to the environment, local economies, food security, ecosystem productivity, and health. The importance of freshwater throughout human history has been seen in its interrelationship with man. The importance of Lake Bosomtwe has been considered in relation to its quality and the services this resource provides, considering the inability of humans to survive without it. The study involved twenty-six (26) riparian communities surrounding the largest Crater Lake in Africa, the Lake Bosomtwe. Water sources such as lake, streams and boreholes used as drinking water sources were collected quarterly for a period of two years. These were analysed bacteriologically for the determination of total and faecal coliform, *E. coli, Aeromonas sp. Enterococcus sp. Salmonella sp*, *Pseudomonas sp* and total heterotrophic bacteria (THB) using Membrane filtration and pour plate. The results showed variation of bacteria counts in all the water sources. The highest *E. coli* counts of *$2.9x10^3$ cfu/100ml* was recorded in the lake and the least in the borehole *$2.1x10^1$ cfu/100ml.* The difference between the total coliform, faecal coliform and *E. coli* counts and the water sources was significant ($p<0.05$). Bacteria in the different water sources had higher bacteria counts during the dry season than the wet season which are statistically significant ($p<0.05$). Drinking these waters without any form of treatments could pose health risk to consumers because of the presence of bacteria from water pollution. These water sources can however be used for domestic purposes.

1. INTRODUCTION

Water is essential for life and the well-being of all people as well as an important natural resource useful for domestic and developmental purposes. The quality of the water sources greatly impacts on the health status of the consumers. Untreated surface and underground water are still commonly used for domestic purposes in many areas in developing countries[1]. This has a true reflection in areas such as communities surrounding the rim of lake Bosomtwe in the Ashanti Region of Ghana. This is a meteoritic impacted lake which is filled by rain and surface runoffs but has no outlet.

This study aims to determine the sustainable utilization of lake Bosomtwe in relation to the bacteriological quality of the water sources (lake, stream and boreholes) used by communities surrounding the rim of the lake as well as establishing the effect of seasonal climate changes on the quality of the water sources.

2. METHOD

This research was carried out within lake Bosomtwe and surrounding communities in the Ashanti Region of Ghana (Fig. 1). A total of 222 water samples were collected from three water sources (lake, streams and boreholes).

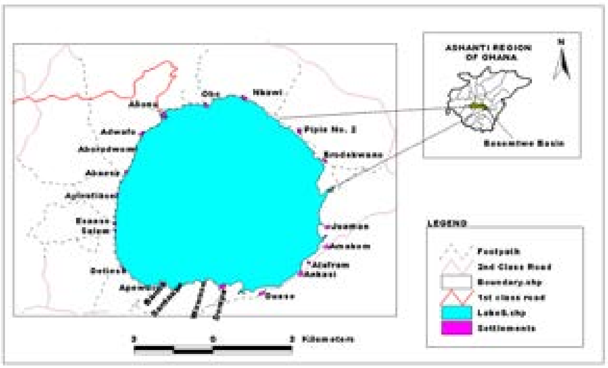


Fig. 1 Map of Study site [2]

Water samples were analysed for the presence and enumeration of total and faecal coliform, *E. coli, Aeromonas sp. Enterococcus sp. Salmonella sp, Pseudomonas sp* and total heterotrophic bacteria (THB). All analyses were carried out aseptically using membrane filtration and pour plate techniques. Results were expressed in colony forming unit (cfu) per 100ml and 1ml of analysed sample. The standard procedures for bacteriological analysis of water [3] were followed.

3. RESULTS

All the water sources were contaminated with bacteria in varying colony counts.

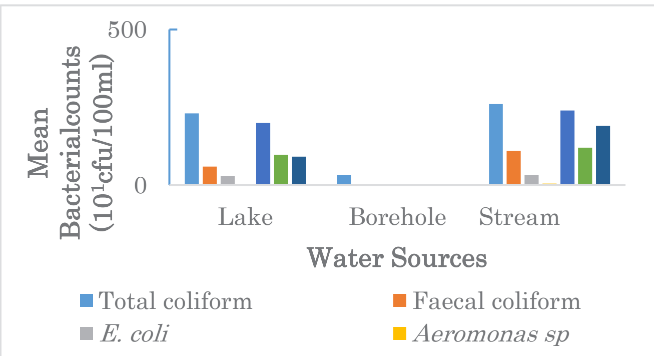


Fig. 2 Bacterial contamination in water sources

The highest mean total coliform counts was recorded in the stream samples (2.6×10^3 cfu/100ml) whiles the least count occurred in the borehole samples (3.2×10^2 cfu/100ml) Fig 2. The *E. coli* count recorded in the lake ranged from 0 - 5.4×10^3 cfu/100ml with a mean value of 2.9×10^3 cfu/100ml whiles in the borehole, it ranged from 0 – 6×10^1 cfu/100ml with a mean value of 2.1×10^1 cfu/100ml. Stream samples ranged from 2×10^3 - 4.2×10^3 cfu/100ml with a mean value of 1.1×10^3 cfu/100ml.

Generally, the bacteria counts recorded in the borehole source were higher during the dry season than the wet season and vice versa for the lake and streams.

4. DISCUSSION

The presence of faecal coliform bacteria and *E. coli* in water gives an indication of faecal contamination by warm-blooded animals. Their occurrence may indicate the presence of other pathogens responsible for infectious diseases such as cholera, gastroenteritis, dysentery, and typhoid fever after ingestion of contaminated water. The high bacteria counts in the lake during the wet season could be attributed to its large surface and its function as a sink, collecting pollutants and therefore exposing it to contamination through runoffs, anthropogenic activities such as swimming, washing of clothes, fishing net and cooking utensils. Also, concentration of piggeries, free range chickens and dogs close to the lake may also account for the high bacteria count in the lake. Run offs from uphill into the streams could account for the high bacteria counts during the wet season.

5. CONCLUSION

Generally, the mean bacteria count in lake, stream and borehole water samples assessed during the study period were bacteriologically unsafe to be used as a drinking water source without any treatment. Bacterial counts recorded do not conform to WHO guidelines and Ghana Standards recommended for drinking purposes. This implies that consumers of these water sources are at risk since the presence of these bacteria could pose health threats such as cholera, gastroenteritis, dysentery, and typhoid fever after ingestion of these contaminated water.

REFERENCES

[1] WHO (World Health Organization) The world health Report 2002: Reducing Risks, Promoting Health Life. Geneva, Switzerland.

[2] Amu-Mensah, M.A., Amu-Mensah, F.K., Akrong, M.O., Darko, H. and Addico, G. (2017) Significance of Lake Bosomtwe as a freshwater resource in Ghana; communities' perception. International Journal of Development and Sustainability. Vol. 6 No. 10 (2017): 1305 – 1318.

[3] APHA, AWWA, WEF. (2012) Standard Methods for examination of water and wastewater. 22nd ed. Washington: American Public Health Association; 2012,1360 pp. ISBN 978-087553-013-0.

P3-25

汽水湖中海における無機態窒素の挙動に関する研究

加藤 季晋[1], 管原 庄吾[2], 江川 美千子[2], 吉原 司[1], 長岡 克朗[1], 神門 利之[1], 神谷 宏[1], 清家 泰[2]
[1] 島根県保健環境科学研究所, [2] 島根大学

キーワード：栄養塩動態，貧酸素，汽水湖，亜硝酸，ヒドロキシルアミン

抄録

窒素化学種は自然環境中で微生物などに利用され、形態を変えながら循環している。これまでに私たちは、硝化や脱窒、アナモックス反応の中間体として知られている NH_2OH と N_2H_4 の新規の定量方法を開発した。本研究では、汽水湖中海における NH_2OH と N_2H_4 を含めた無機窒素化学種の挙動から窒素循環のメカニズムを解明することを目的とし、中海全域を対象とした調査を行った。中海は日本海と境水道でつながっており、潮汐の影響を受けて物質交換が起こる。また、日本海から塩分を含んだ密度の高い海水が入ってくる。流入してくる海水には溶存酸素が含まれており、底層への溶存酸素の供給がある。これによって中海の底層は微好気的環境であり、中海の南部では硝化の中間体である NO_2^- や NH_2OH が比較的高濃度で検出された。この結果から、中海では日本海からの海水の流入による酸素供給が硝化や脱窒などの窒素循環に大きな影響を与えていることが示唆された。

1. はじめに

窒素は生物にとって必須の元素であり、様々な形態をとる。有機態窒素はバクテリアによって分解され NH_4^+ となる。NH_4^+ は硝化細菌によりヒドロキシルアミン（NH_2OH）、NO_2^- を経て、NO_3^- になる。NO_3^- は湖沼の溶存酸素がほとんどなくなると、脱窒細菌の働きにより、亜酸化窒素（N_2O）を経て分子状窒素（N_2）になる。脱窒過程の中間体である N_2O は温暖化ガスの一つとしても知られている。

また、近年注目されているアナモックス反応は、NH_4^+ を NO_2^- により還元し、N_2 ガスを生成する反応である。アナモックス反応では中間体として NH_2OH とヒドラジン（N_2H_4）が生成される。そこで私たちは、既存の方法を改良することで、新規の NH_2OH と N_2H_4 の定量法[1] [2]を開発した。本研究では、この新規定量法を用いて、中海における NH_2OH, N_2O 及び N_2H_4 の挙動を把握し、汽水湖中海における窒素循環について解明することを目的とした。

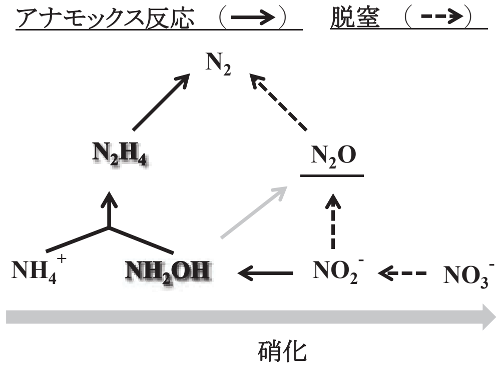


Fig. 1 アナモックス反応のプロセス

2. 調査地点及び調査方法

2017 年 9 月 13 日、島根県の東部に位置する中海の 11 地点（Fig. 2）の底層（湖底上 1 m）において調査、サンプリングを行った。

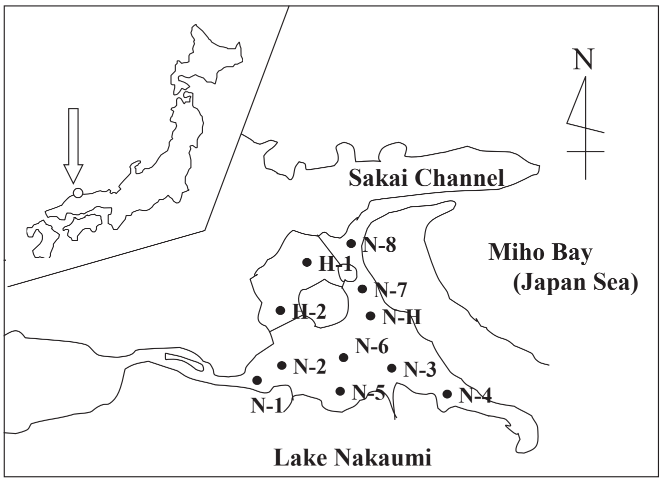


Fig. 2 調査地点

NH_2OH, N_2O は、試料をバイアル瓶に分取し、NH_2OH 測定用試料水には NaClO 溶液を、N_2O 測定用試料水にはホルマリンをそれぞれ添加後、実験室に持ち帰り、N_2 ガスを入れ、気相を ECD 付きガスクロマトグラフ(Shimazu GC－14)を用いて測定した（Fig. 3）。

N_2H_4 は、試料をろ過して発色試薬を添加後、Sep-Pak C18 カードリッジに通水・吸着させて持ち帰り、塩酸・エタノール混合溶液で溶離し、分光光度計(ShimazuUV-1800)で吸光度を測定した（Fig. 4）。

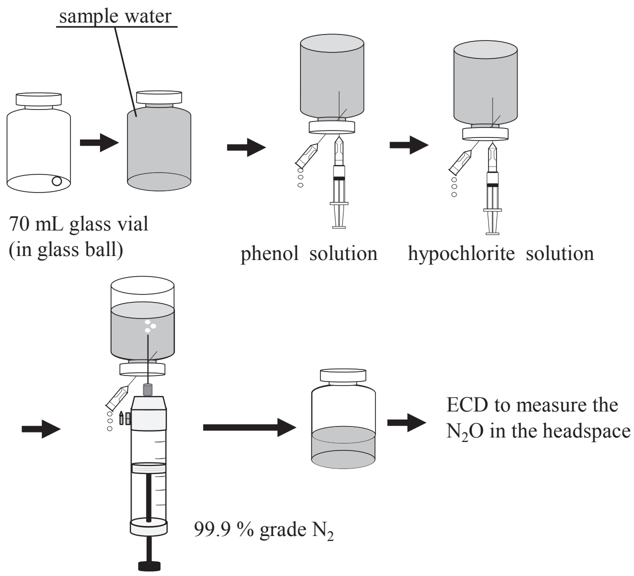


Fig. 3 NH_2OH の新規定量法

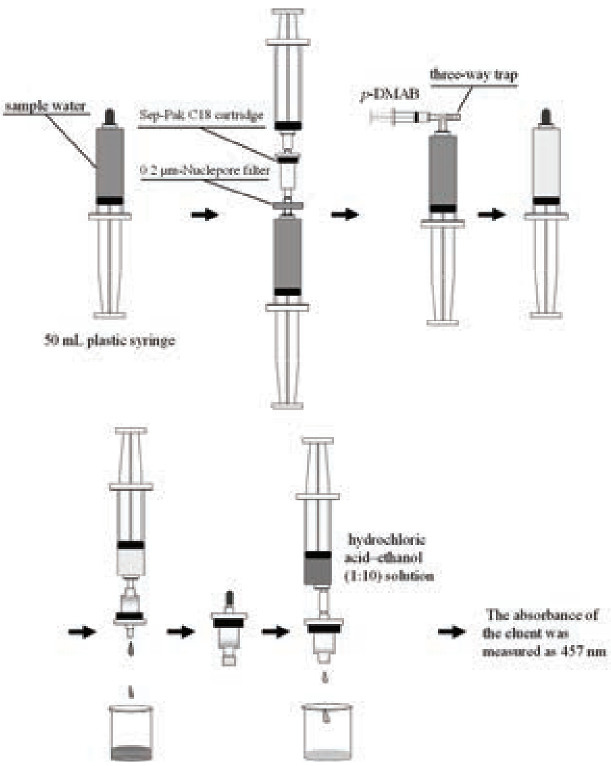


Fig. 4 N_2H_4 の新規定量法

NH_4^+、NO_2^-、NO_3^-は、採水して持ち帰った試料をろ過し、連続流れ分析装置（QuAAtro 39）で測定した。

水中の水温、塩分、溶存酸素は、現場で多項目水質計(RINKO-Profiler) を用いて測定した。

3. 結果と考察

まず、中海底層の溶存酸素の結果を Fig. 5 に示す。中海は日本海と境水道でつながっており、潮汐の影響を受けて物質交換が起こる。また、中海では日本海から塩分を含んだ密度の高い海水が入ってくる。流入してくる海水には溶存酸素が含まれており、底層の貧酸素への溶存酸素の供給がある。今回、境水道に近い N-8 や N-7 は底層でも溶存酸素は豊富に存在していたが、境水道から離れた N-3 や N-4 では貧酸素になっていた。

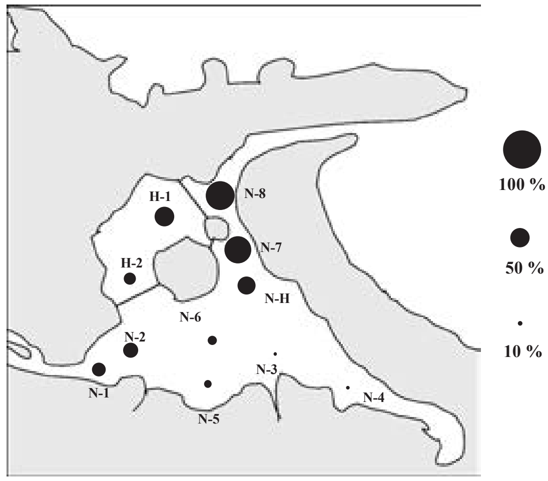


Fig. 5 中海底層（湖底上 1 m）の溶存酸素

次に、溶存無機態窒素の測定結果を Fig. 6 に示す。中海の底層では地点ごとに無機態窒素の濃度に差異があった。これまでに中海では、水深 7 m の底層は光が届くぎりぎりの深度であり、硝化のうち $NO_2^- \rightarrow NO_3^-$のパスが光阻害され NO_2^-が蓄積されることが知られている[3]。今回、N-4 や N-H では NH_2OH が高濃度で存在していた。NH_2OH は酸素の少ない微好気的な環境で生成されることから、わずかながら酸素が供給され、硝化が生じていると考えられる。中海南東部や南西部の（N-3 や N-4）では NH_4^+が比較的高い濃度で検出された。これは、溶存酸素を含んだ海水の流入がこれらの地点まで届いていないためと考えられる。

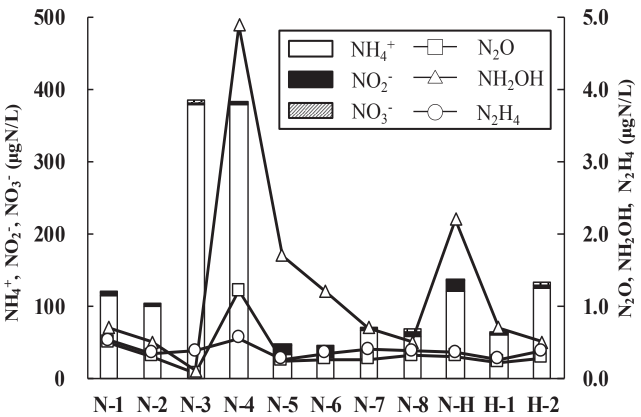


Fig. 6 中海底層（湖底上 1 m）の溶存無機態窒素

4. 結論

汽水湖中海において、新規で開発した NH_2OH と N_2H_4 の定量方法を適用することで窒素循環の解明を試みた。その結果、中海においては、この時期の日本海からの海水の流入による酸素供給が硝化や脱窒などの窒素循環に大きな影響を与えていることが示唆された。また、酸素供給が少ない中海の湖心や南部では、硝化の中間体である NO_2^- や NH_2OH が高濃度で蓄積することが分かった。

引用文献

[1] Kato T, Sugahara S, Murakami M, Senga Y, Egawa M, Kamiya H, Omata K, and Seike Y (2017) Sensitive Method for the Oxidation-determination of Trace Hydroxylamine in Environmental Water Using Hypochlorite Followed by Gas Chromatography. Analytical Sciences, 33, 691-695.

[2] Kato T, Sugahara S, Kajitani T, Senga Y, Egawa M, Kamiya H, and Seike Y (2017) Determination of Trace Hydrazine in Environmental Water Samples by in situ Solid Phase Extraction. Analytical Sciences, 33, 487-491.

[3] 清家 泰, 奥村 稔, 藤永 薫, 黒住 誠司 (1997) 汽水湖中海における貧酸素水塊形成時の硝化・脱窒. 沿岸海洋研究, 35, 27-33

P3-26

Nutrient Dynamics and Trophic State of Lake Tempe in South Sulawesi, Indonesia

Yustiawati Yustiawati[1], Rosidah[1], M. Suhaemi Syawal[1]
[1]Research Center for Limnology, Indonesian Institute of Sciences

Keywords: nutrient, trophic state, total nitrogen, total phosphorus, floodplain lake

ABSTRACT

Lake Tempe is a floodplain lake that located in South Sulawesi province, Indonesia. Since many years ago, Lake Tempe have been providing great benefit for local people in daily activity and economically. This lake is as great fishery resources, and as nutrient deposition especially in dry season. However, in recent years, some problems occurred in this lake, such as environmental degradation and decreasing fishery production. High sedimentation rate and aquatic plants blooming have degraded environment lake. The local government plan to revitalize this lake by dredging some area of Lake Tempe. However as floodplain lake, there are some zones that have ecological function for fishery as breeding zone and feeding zone. Base on this background, the aim of study is to reveal nutrient dynamic in permanent and nonpermanent zone of the lake. That information will be used to determine the important zone for fishery or agriculture related to the nutrient rich or trophic level of this lake. The results indicated that concentration of dissolved total nitrogen (diss-TN) in nonpermanent inundation zone (zone 1, 2, 3, 4, 5) increased significantly when water level increased (July 2017). The decomposed aquatic plants and residue fertilizer are supposed contribute to increase concentration diss-TN in nonpermanent inundated zone. The concentration of diss-TN was 421 to 996 mg/m^3, it is categorized eutrophic to super trophic state. The concentration of Dissolved Total Phosphorus (diss-TP) was increasing during medium water level, the concentration was higher than 96 mg/m^3, it is categorized hypertrophic state.

1. INTRODUCTION

Lake Tempe is a floodplain lake that located in Wajo, Sidrap and Sopeng regency of South Sulawesi province, Indonesia. The floodplain inundation is very dynamics related to rainy season and dry season. There are permanent zone and nonpermanent zone (temporary zone) In rainy season the temporary inundation zone is very wide, but in dry season the inundation zone is getting smaller then remain permanent zone. When water level increase, the grass and aquatic plants will be sunken, died and decayed. After flood, dissolved inorganic nitrogen (DIN) increased [4]. Finally, this process release nitrate, nitrite, ammonia, phosphate, etc. These nutrients will be used for phytoplankton, zooplankton, aquatic plants, invertebrate organism and small fishes. After flooded, nutrient deposition in nonpermanent inundation zone (temporary zone). This area (lentic) is important site in floodplain lake as ecological function to support sustainability of fishery. High sedimentation rate and blooming aquatic plant blooming have degraded the lake environment. The government plan to revitalize this lake by dredging some area of Lake Tempe.

Base on this background, the aim of the study is to reveal the pattern of nutrient distribution in permanent and nonpermanent zone and to reveal trophic state of Lake Tempe. Trophic status could not be evaluated by examining one or two parameters [5]. In aquatic environment of waterbody, four types of trophic statues can be distinguished: oligotrophic, mesotrophic, eutrophic and dystrophic.

2. METHOD

The study was conducted in Lake Tempe, South Sulawesi Province, Indonesia. Sampling was done in March, May and July 2017. Water samples have been collected from six zones, that representative of permanent inundation zone (zone 6) and nonpermanent inundation zone (zone 1, 2, 3, 4, 5) as shown in figure 1.

Parameter TN, TP, ammonium, chlorophyll-a were analyzed according to Standard Method APHA-AWWA (Anonim, 2015), water samples for TN, TP and ammonia were filtered by membrane filter 0.45 µm. Transparency was measured by Sechi disk. *In situ* measurement was carried out for pH, temperature, DO, TDS, conductivity, ORP by Horiba U-51 Water Quality Checker. Total Suspended Solid was measured by gravimetry method.

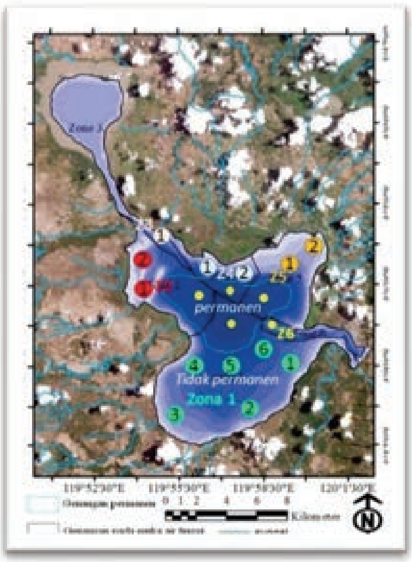


Fig. 1. Sampling sites in Lake Tempe [6]

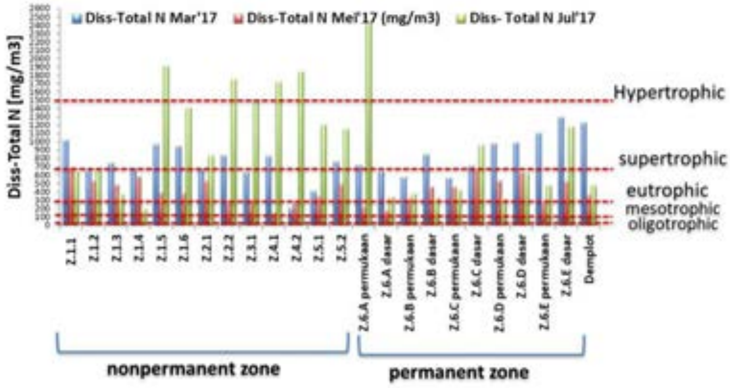


Figure. 2. Trophic state of Lake Tempe with variable Total Nitrogen (TN) concentration

3. RESULTS AND DISCUSSION

Many methods can be used to assess water quality of the lake. One of assessment methods is evaluating the trophic state. Some parameter such as TN, TP, ammonia, transparency (Sechi depth) and TDS can be used to determine trophic state. Generally, nitrogen and phosphor in aquatic environment origin from agriculture residue and organic materials from domestic wastes. Trophic level also can be observed through algae population or algae density. Concentration of chlorophyll-a in the water also can be used as an indicator to evaluate trophic level. In Lake Tempe, aquatic plants grow well, it is also similar with algae population, therefore by analyzing chlorophyll-a concentration in the water, we can evaluate trophic level of Lake Tempe.

Concentration of dissolved Total Nitrogen (diss-TN) in Lake Tempe was in the range 208 -2445 mg/m^3, it is categorized mesotrophic to supertrophic level [1]. In July 2017, water level was getting high, it was followed by increasing diss-TN concentration in nonpermanent zones (zone 1, 2, 3, 4, 5) as shown in figure.2. The decomposed aquatic plants and fertilizer residue are supposed contribute to increase concentration diss-TN in nonpermanent inundated zone.

Distribution of dissolved Total Phosphorus (diss-TP) is shown in figure.3. Concentration of dissolved Total Phosphorus (diss-TP) in permanent inundation zone and nonpermanent inundation zone was higher than 97 mg/m^3, it indicated Lake Tempe was in hypertrophic category. Concentration diss-TP increased when water level in medium level, especially in nonpermanent inundation zones.

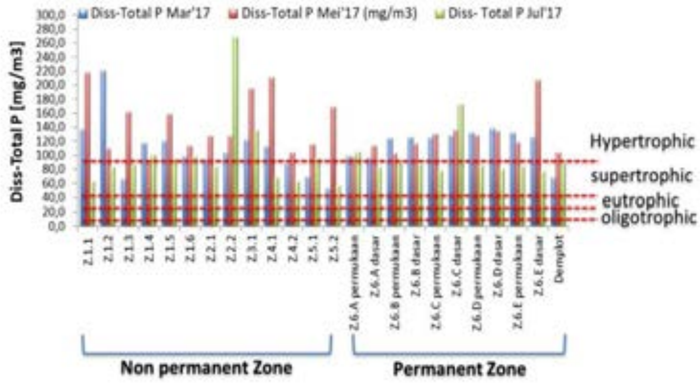


Figure 3. Trophic state of Lake Tempe with variable dissolved Total Phosphorus.

Distribution of concentration chlorophyll-a is shown in figure.4. Concentration of chlorophyll-a in permanent and nonpermanent inundation zone was in the range 1.639 – 26.109 mg/m3. According to Pavluk and Vaate [1], this value is categorized in mesotrophic to hypertrophic level. Comparing the pattern of dissolved TP and chlorophyll-a in permanent and nonpermanent inundation zone (figure 3 and 4.) showed similar pattern, it indicated source of dissolved TP originated from aquatic plants and algae in Lake Tempe.

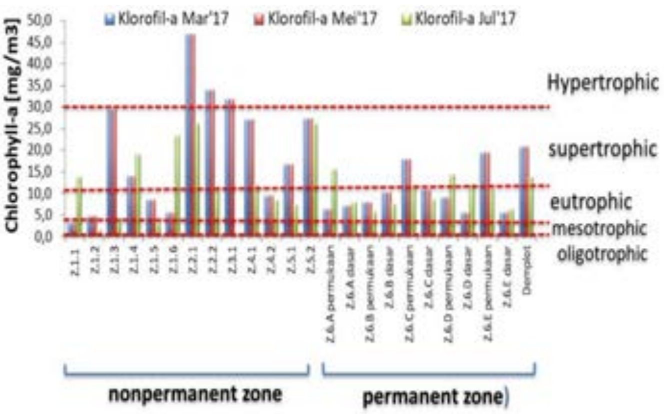


Figure. 4. Trophic state of Lake Tempe with variable Chlorophyll-a

In Lake Tempe, ammonia could be sourced from fishes excretion or aquatic plant degradation. Through mineralization process from those nitrogen sources and resuspension from sediment to the water, ammonia will be formed about 45.34 mg/mg/m^2/day and resuspension to the water about 1.29 mg/mg/m^2/day, and nitrification is about 39.72 mg/mg/m^2/day [3]. High concentration of ammonia was found in March 2017, in zone 6 (permanent inundation zone) as shown in figure. 5.

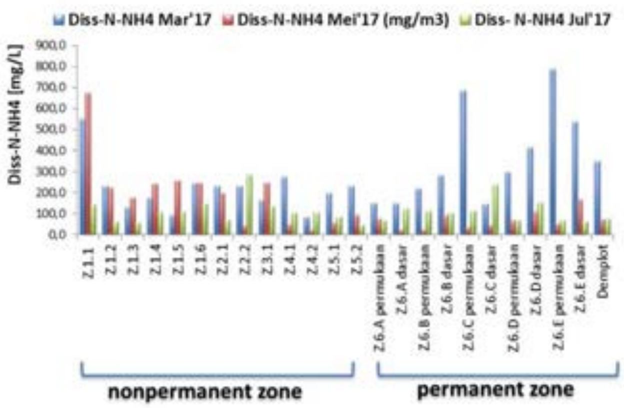


Figure. 5. Concentration of dissolved N-NH$_4$ in nonpermanent and permanent zone of Lake Tempe

Beside nutrients parameters, transparency (sechi depth) also could be an indicator for trophic state. Transparency in Lake Tempe was in the range 9 to 103 cm, it was categorized hypertrophic to supertrophic, according to Pavluk and Vaate [1]. Increasing suspended solid, aquatic plants and algae blooming could decrease transparency of water.

Based on the pattern of nutrient distribution and transparency as discussed above, Lake Tempe could be categorized in eutrophic to hypertrophic state, related to seasonally change.

4. CONCLUSION

Lake Tempe as a floodplain lake has high nutrient deposition. Lake Tempe could be categorized eutrophic to hypertrophic state. This trophic state could not be said good or poor water quality, it depends on the utilization of the water. This information can be useful for management of Lake Tempe. When Lake Tempe will be utilized for fishery and agriculture, the existing of the nonpermanent inundation zone should be maintained because here is valuable zone for fishery as breeding and feeding zone, also for agriculture as paddy field.

REFERENCES

[1] Pavluk, Timur and Vaate, Abraham Bij de. Trophic Index and Efficiency. Reference Module in Earth Systems and Environmental Sciences. Elsevier Inc. 2017.

[2] Anonim. Standard Method for water and waste water. APHA-AWWA Publisher. 2015.

[3] James, RT., J. Martin.T, T. Wool dan P.F. Wang. A sediment resuspension and water quality Model of Lake Okeechobee. J. American Water Res. Ass. 3 (33): 661-680. 1997.

[4] Carignan, R., J.J. Neiff. Nutrient dynamics in the floodplain ponds of the Parana River (Argentina) dominated by the water hyacinth *Eichhornia crassipes*.J. Biogeochemistry. 17: 85-121. 1992.

[5] Carlson, R.E. A trophic state index for lakes. J. Limnology and Oceanography. March, V. 22 (2): 361- 369. 1977.

[6] Harsono, E. Laporan Teknis SBK. Pusat Penelitian Limnologi-LIPI. 2017, (Indonesian)

P3-27

Paper title：Study on the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* with different organic phosphorus sources

Yuping Su[1,2];Lixiang Zhang[1];Yangfeng Chen[1];Helong Li[1];Chenxing She[1];Xinyin Zhang[1]
1Environmental Science and Engineering College, Fujian Normal University, Fuzhou 350007, P.R. China
2. Fujian Key Laboratory of Pollution Control and Resource Recycling, Fuzhou, 350007

Key words: organic phosphorus; triethyl phosphate; *Peridinium umbonatum*; *Scenedesmus bijuga*

ABSTRACT

Phosphorus plays a vital role in algal growth, and organic phosphorus is an important part of it. It is of significance to study the growth and competition by different forms of phosphorus for better understanding of the difference. From the aspect of organic phosphorus, the PM4A plate (61 forms of P) was used as experimental P sources in this research. We use the PM4A to cultivate *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* and Distinguish the growth of algal and competition by different forms of organic phosphorus. In the mono-cultures, there were 12 forms and 21 forms of organic P could promote the growth of Peridinium umbonatum var. Inaequale and Scenedesmus bijuga,respectively.Besides,Pyrophosphate,Thiophosphate,Dithiophosphate,O-Phospho-D-Serine,O-Phosphoryl-Ethanolamine and Thymidine- 5'- monophosphate can promote the growth of two algae. The utilization of some organic phosphorus (Triethyl Phosphate, O-Phospho-D-Serine) by two algae were obviously higher than some inorganic phosphorus (Tripoly-phosphate, Pyrophosphate). In the co-cultures, those who could encourage the growth earlier still showed an acceleration. Compared with mono-culture, the promotion was more significant. For *Peridinium umbonatum var. Inaequale,* the promotion was further enhanced. The effective organic phosphorus promote the growth of *Scenedesmus bijuga* up to 40 forms. In a word, both of the two algae have a selectivity to utilize different organic phosphorus in the mono-culture and the co-culture. *Peridinium umbonatum var. Inaequale* has a better utilization on nucleotide phosphate and glucose phosphate. While *Scenedesmus bijuga* has a better utilization on nucleotide phosphate, amino acid phosphate and phosphoGlyceric acid. Two algae have a higher bioavailability to organic phosphorus bond C–O–P than C–P. The most significant organic phosphorus source for the promotion of *Peridinium umbonatum var. Inaequale* was triethyl phosphate.

1. INTRODUCTION

Inorganic phosphorus and organic phosphorus are the main types in aquatic ecosystems, organic phosphorus is an important component of total phosphorus which exists in the sediments. Generally, inorganic phosphorus can be directly utilized by most algae, which is the predominant bioavailable phosphorus fraction for the growth of algal[6]. Researches showed that alkaline phosphatase hydrolyze some organic phosphorus, which can be directly used by algal. Some of algae even had a better utilization than IP[7]. Those who can use OP effectively would became the dominant algae species when P is scare[8].

There were differences in phosphorus content in water areas. And the proportion of organic phosphorus is also different, then influenced the phytoplankton community succession. In order to research the growth and competitiveness of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*, the PM4A plate was used as experimental P source. At the beginning, we used this biolog technology to cultivate the two kinds algae separately, and then mixed them together in laboratory. In the end, the mechanism and effect of algal growth will be identified. And the results may explain the influence by different forms of organic P. What's more, our study may provide a basis to control and predict the blooms when a dominant species in eutrophical water.

2. METHOD

2.1 Algal strains and cultivation

Peridinium umbonatum var. Inaequale and Scenedesmus bijuga were obatained from Freshwater Algae Culture Collection of the Institute of Hydrobi-ology, Chinese Academy of Sciences (FACHB). *Peridinium umbonatum var. Inaequale*（FACHB-329）and *Scenedesmus bijuga*（FACHB-76）were cultured in self-made 119 and SE medium（Appendix 1）, respectively. The algal biomass was kept at 25 °C with a light intensity of 2000 Lux under a 12/12 h light/dark cycle in an light incubator until reach the exponential growth phase.

2.2 Algae cultivation and experimental design

Different sources of phosphorus were purchased from PM4A plate, including 61 kinds of phosphorus sources (four kinds of DIP). In super clean bench, adding 200 uL sterile water into PM4A plate's micropores to dissolve all kinds of phosphorus resources as the mother liquor. Then pack into 0.5mL centrifuge tube, kept at low temperature after sterilization. *Peridinium umbonatum var. Inaequale* was added in the culture media, which inorganic phosphorus was not added for 2 days. Shake it well, and then equal amonts of 150 uL inoculum were added to biolog plate. After that, 50 uL of different phosphorus sources was added on each hole and cultured in the medium for 20 days. At this time, each biolog plate have 200 uL solution. The biomass density is 1.13×107 cells/L. Detectiving biomass per day by Microplate reader（Perlong DNM-9602）.*Scenedesmus bijuga* 's inoculation and operation is similar. The initial biomass is 4.45×109 cells/L. All mediums were kept at 25 °C with a light intensity of 2000 Lux under a 12/12 h light/dark cycle for 20 days. In order to prevent the evaporation from the biolog plate, two PM4A plates were put on transparent zip-lock bag and opened in a UV sterilization stage. The competitive effects of the two species of algae were made by co-culture experiments.

The cell ratio of two kinds of algae is approximately 50:1, the well density ratio is 1:50. The cell density was determined using a light microscope, then follow the concentration ratio to inoculate *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga.* After shaking well, we added different phosphorus sources on each hole, which concentration is same as PM4A plate. Other conditions were the same as mono-cultures. There are three groups in this study. The experimental period is 18 d and each group has a parallel sample and samples were collected each 6 days. We used 0.5mL solution and added in centrifuge tube. Algal cells were fixatived in Lugol's solution and counted by microscope.(400× magnification, Motic, BM-1000, Guangzhou).

2.3 Statistical analysis

SPSS 19.0 was used to investigate the variance and correlation analyses.

3. Results

3.1 Growth curve of algal strains under different organic phosphorus sources

The biomass density of two algal species varied greatly after 20 days with different organic P. List of phosphorus sources that promote algal growth are shown in Fig.1 indicates that the final result of proliferation. There are 22 forms P sources could promote the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*. At the end of experiment, *S. bijuga* has higer biomass. The maximum biomass by Cytidine-3'-monophosphate is 3.05×10^{10} cells/L.

As for *Peridinium umbonatum var. Inaequale*, there are 12 forms of P sources, which obviously stimulated the proliferation. In the mixed cultures of *P. Inaequale* and *S. bijuga* (purple parts in Fig.2), *Scenedesmus bijuga* has more forms of effective IP than *Peridinium umbonatum var. Inaequale*. Phosphorus source growth factors (GF for short) niche of two algal strains of were obtained after dealing with proliferation treatment. Gf reflects the phosphorus sources that promote the growth of algae, in which has 17 forms and 6 forms of phosphorus sources that enhance the growth of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga*, respectively. Besides, there are 6 forms of P sources stimulate them both.

Compared with inorganic phosphorus, organic phosphorus had a significant promotion on algal growth. And the effect of *P. Inaequale* is more remarkable. The results showed that there are 19 forms of organic P that have promotion on *Peridinium umbonatum var. Inaequale* . Including Nucleotide, Glucose, etc.. The most effective types of OP for *Peridinium umbonatum var. Inaequale* promotion are Triethyl Phosphate(gf=3.038). Although there are few organic phosphorus species promoting *Scenedesmus bijuga* growth, the growth promotion was obvious, which confirmed that *Peridinium umbonatum var. Inaequal* could boom in P-limited environments.

Figure 1. Growth dynamics of *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* with different phosphorus sources.

On the left side of the graph for different organic phosphorus source list, and the green background was the organic phosphorus that can significantly promote *Scenedesmus bijuga* growth, orange background represents the organic phosphorus can significantly promote the *Peridinium umbonatum var. Inaequale* growth, purple for organic phosphorus two taxa algae can effectively utilized , frame bar color depth reflect the different periods of algae cells density.

3.2 Competitive growth of two strains

In the mixed cultures, in the first 6 days of mixed cultures, *Peridinium umbonatum var. Inaequale* had utilized 23 forms of P sources to promote its growth, which is more 6 kinds than mono-cultures. There are 22 forms of P sources that boost its growth, which is more 1 kind than mono-cultures. There were 8 kinds of phosphorus sources which promoted the growth of two algae, which is 2 kinds more than mono-cultures. In mono-culture experiment, phosphorus sources have a significant promotion on *Peridinium umbonatum var. Inaequale*. And the effect is remarkable than *Scenedesmus bijuga*. Similar result was also found in co-cultures. On day 12 in the mixed cultures, for *P. Inaequale*, the cell density stared to decrease compare with the previously. The biomass density of *S. bijuga* greatly increased. The results suggested that *Scenedesmus bijuga* could grow in their available phosphorus source. In the meantime, it also showed that those Phosphorus sources stimulated *Peridinium umbonatum var. Inaequale* growth. In view of the algal growth, it is clear that IP promotion growth of *Peridinium umbonatum var. Inaequale* . On day 18 in the mixed cultures (Fig.4c), *Peridinium umbonatum var. Inaequale* had just 27 forms of effective P. But the forms of P sources to promote *P. Inaequale* growth have increased by 10 than mono-cultures. The forms of valid P for *Scenedesmus bijuga* had risen to 40. A greater cause for two algae is that the increase of P sources. For instance, there are 22 forms of P sources stimulatory effects on two kinds of algal growth, which has almost quadrupled than mono-culture. As the culture continues, significant difference was showed in algal growth between different forms of P source. For example, *Scenedesmus bijuga* had declined in Triethyl Phosphate'culture, whereas *P. Inaequale* was promoted. Meanwhile, the growth of *S. bijuga* was promoted whereas *P. Inaequale* growth was depressed in β-Glycerol Phosphate（gf=1.50）.

5. Conclusions

In this study, *Peridinium umbonatum var. Inaequale* and *Scenedesmus bijuga* were cultured alone and mixing together with different organic phosphorus, the following results are obtained:

In the mono-cultures, both P*eridinium umbonatum var. Inaequale and Scenedesmus bijuga* could utilize organic P for their growth. Moreover, they show a different P selectively on different P substrates. There are 12 forms of DIP and 21 forms organic P could promote the growth of *Peridinium umbonatum var. Inaequale and Scenedesmus bijuga,* respectively. Among them, five of which could promote the effective growth of the two algae. Our results showed that the utilization of some organic P by two species of algae was obviously higher than some inorganic P .

In the co-cultures, the promotion effect of different organic phosphorus on the two algae was more significant. For *Peridinium umbonatum var. Inaequale*, the promotion was enhanced, while increasing the effective types of organic phosphorus on *Scenedesmus bijuga*'s growth. *Peridinium umbonatum var. Inaequale* has a better utilization on nucleotide phosphate and glucose phosphate. Two forms of algae have a higher bioavailability to organic phosphorus bond C–O–P than C–P. The most significant organic phosphorus source for the promotion of *Peridinium umbonatum var. Inaequale* was Triethyl Phosphate, which indicates that *Peridinium umbonatum var. Inaequale* has a specificity of utilizing triethyl Phosphate.

P3-28

諏訪湖における藻類群集に及ぼす栄養塩組成の影響

横内 雅大[1], 宮原 裕一[2]
[1]信州大学大学院総合理工学研究科, [2]信州大学山岳科学研究所

キーワード:栄養塩動態, 一次生産, 生態系機能

抄録

本研究では諏訪湖における栄養塩組成と植物プランクトンの関係を明らかにするため，湖水中の窒素，リン，シリカと植物プランクトン細胞数の季節変動を観察した．諏訪湖の湖心および流入･流出河川において採水し，水中の窒素，リン，シリカ濃度を測定した．また，湖水中のクロロフィル濃度の測定と藻類細胞数を計数した．1979 年・2016 年・2017 年には DIN 制限が認められた．また，1979 年・2017 年には DSi 制限が認められた．1979 年・2016 年・2017 年ともに各栄養塩制限の影響と考えられる藻類組成の変化が確認された．また，経年的な湖水中の栄養塩比の変化は下水道の整備による浄化が進んだことや，増殖した珪藻によるシリカの取り込みによって引き起こされていると考えられ，それらによって夏期に優占する藻類の組成が変化したと考えられた．

1. はじめに

長野県中央部に位置する諏訪湖では，2007 年までは主にミクロキスティスを主とした藍藻が夏期の植物プランクトン種であった（花里・朴，2008）[1]．現在では藍藻とともに珪藻も主要な植物プランクトン種であることが確認され，近年夏期の主要な植物プランクトン種の組成は大きく変化している．一般に，植物プランクトンの種組成は水温や栄養塩（窒素・リン・シリカ）濃度のほかに，栄養塩組成の影響も受け，富栄養化が進むと相対的に溶存態シリカが不足し，非珪藻類が優占すると言われている（原島，2005）[2]．

諏訪湖では，湖水中窒素・リン濃度は 1970 年代から長期間計測されており，それらは減少傾向にあることが知られている（宮原，2013，2018）[3, 4]．一方，湖水中シリカ濃度は 1971 年から 1972 年（倉沢，1973）[5]・1977 年から 1978 年（沖野ほか，1978）[6]以外，通年では測定されていないため，現在，諏訪湖水中の窒素・リン・シリカはどのような組成か不明である．そこで，本研究では諏訪湖における栄養塩と植物プランクトンの関係を明らかにするために，窒素・リン・シリカ濃度と植物プランクトンの季節変動について観察を行った．

2. 方法

2015 年 7 月から 2017 年 12 月において，諏訪湖湖心（36°02’50”N，138°05’14”E）でカラム型採水器を用いて採水した．また，同期間において，諏訪湖の流入・流出河川の河川水も各河川の河口に近い橋の上から，ロープをつけたバケツを用いて採水した．これら試水は，いずれも孔径 0.45 μmのメンブレンフィルターでろ過した．また，植物プランクトンの計数のため，湖水を中性ホルマリン（1.5%）で固定した．

測定対象とした試水中の各形態の栄養塩濃度およびクロロフィル（Chl.a）濃度や藻類細胞数を図 1 に示した．

全窒素，溶存態全窒素はアルカリ性過硫酸カリ加圧分解法に基づいて分析した．硝酸態窒素，亜硝酸態窒素およびアンモニア態窒素はイオンクロマトグラフを用いて測定した．溶存態無機窒素（DIN）はイオンクロマトグラフで測定した硝酸態窒素，亜硝酸態窒素およびアンモニア態窒素を合算し算出した．生物態窒素（BN）は全窒素から溶存態全窒素を差し引いた懸濁態窒素の値とした．

全リン，溶存態全リンは，それぞれ試水原液およびろ液を，ペルオキソ二硫酸カリウム溶液を用いてリン酸態リン（PO_4-P）に分解し，下記の PO_4-P と同様の方法で測定した．PO_4-P はモリブデンブルー法に基づいて分析した．生物態リン（BP）は全リンから溶存態全リンを差し引いた懸濁態リンの値とした．

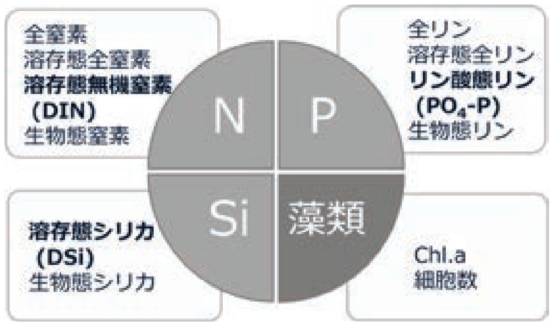


図１．測定項目

溶存態シリカ（DSi）はモリブデンイエロー法に基づいて分析した．生物態シリカはろ過に用いたメンブレンフィルターをアルカリ抽出する（中嶋さやかほか，2006）[7]ことで溶存態シリカと同様の方法で測定した．

クロロフィル(Chl.a)濃度はユネスコ法で測定した．試水を GF/C でろ過し，その GF/C をアルコール抽出した抽出液の吸光度からクロロフィル濃度を算出した．

植物プランクトンの組成は試水に含まれる藻類細胞を光学顕微鏡下で同定したのち計数することで求めた．

諏訪湖におけるシリカの収支を推定するにあたって，流入・流出河川のシリカの年間移動量は流量に濃度を乗じて算出した．湖内でのシリカの沈降量は，諏訪湖湖心にセディメントトラップを水深 5m に一昼夜設置し，得られた沈殿物を凍結乾燥し，分析に供した．底泥からのシリカの溶出量は，ポリエチレンビンの中に諏訪湖の底質と全層水ろ液を入れ，15℃，pH7-8 でコントロールしながら実験室内で 30 日間静置し，水中の溶存態シリカ濃度の変化を観測することで求めた．

3. 結果および考察

植物プランクトンにとって，最適な水中の栄養塩比は植物プランクトン自身の体組成比と考えた．そこで，諏訪湖における植物プランクトンの体組成比を調べると，窒素:リン:シリカのモル比は，18.8：1：92.6（平均）であった．この諏訪湖の植物プランクトン体組成比は，海洋の植物プランクトンを構成する栄養塩の平均組成であるレッドフィールド比（N：P：Si＝16：1：15）に比べシリカの比率が大きい．陸水におけるシリカの起源はケイ酸質岩石からの溶け出しと言われており，この結果は淡水湖沼の特徴を反映してると言える．この比と湖水中の溶存態栄養塩比を比較することで栄養塩の欠乏状況の評価を行った．

2016 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 2 に示した．2016 年 4 月から 8 月の湖水中の DIN/PO_4-P 比や DIN/DSi 比は上記の植物プランクトンの体組成比よりも低く，この間の諏訪湖は DIN 制限にあったと考えられた（図 2）．また，2016 年 4 月から 5 月にかけて，Chl.a 濃度および植物プランクトン細胞数の減少から植物プランクトン量の減少が確認された．さらに，同年 4 月には見られなかった窒素固定型の藍藻である *Anabaena* が 8 月と 9 月に確認された．これらの藻類の量や組成の変化は DIN 制限の影響と考えられた．

一方，2017 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 3 に示した．2017 年の栄養塩

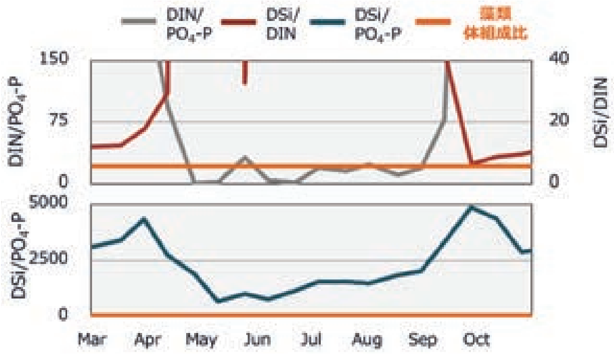


図 2 ． 諏訪湖栄養塩比（2016 年）

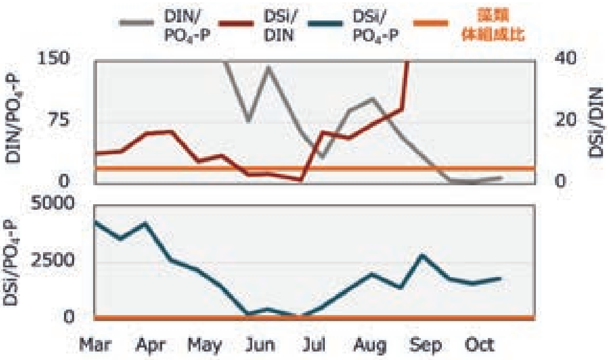


図 3 ． 諏訪湖栄養塩比（2017 年）

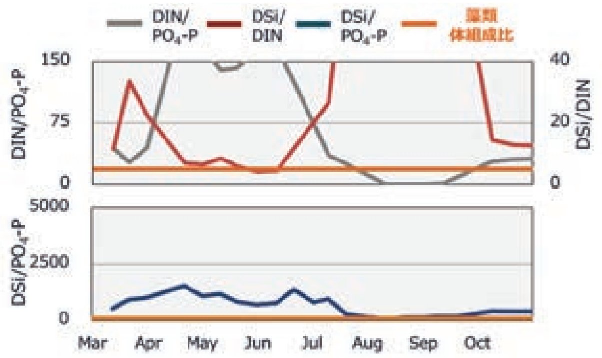


図 4 ． 諏訪湖栄養塩比
（1977 年（沖野ほか，1978 より））

濃度は 2016 年と同様の季節変動を見せたが，この湖水中の栄養塩比を植物プランクトンの体組成比と比べてみると，2017 年の 5 月から 6 月は DSi 制限，9 月から 10 月は DIN 制限にあったと考えられた．同年 5 月から 7 月にかけて，珪藻類の細胞数は減少した．この珪藻類の量の変化は DSi 制限の影響とも考えられた．

これら 2016 年，2017 年の栄養塩比から，DIN 制限は諏訪湖の特徴であり，DSi 制限は 2017 年の特徴であると言える．2017 年の DSi 制限は，DSi 濃度の減少によるものであるが，その時期の流入河川の DSi 濃度に大きな減少は認められなかった．2017 年 4 月から 6 月では，2016 年 4 月から 6 月に比べ珪藻細胞数が多かった．2017 年の DSi 制限は，2016 年に比べ何らかの理由でより増殖した珪藻による，シリカの取り込み量の増加が原因と考えられた．

現状を過去と比較するために，1977 年の栄養塩比（沖野ほか，1978）も同様の方法で評価した．1977 年の諏訪湖の溶存態栄養塩比と植物プランクトンの体組成比を図 4 に示した．1979 年は 2016 年・2017 年と同じく DIN 制限が見られたが，2016 比べ制限がかかる時期が遅く，その期間が短かった（図 4）．また，DSi 制限となる期間も見られた．そこで，1977 年から 1978 年と 2016 年の湖水全層水中の各溶存態栄養塩平均濃度を比較するとと，DIN は 35%，PO_4-P は 11%，DSi は 62%に減少していた．DSi 濃度も減少していたが，DIN・PO_4-P のほうがより大きく減少していた．これによって，1977 年よりも 2016 年の方が DIN 不足の期間は長くなり，1977 年に見られたシリカ不足は 2016 年には生じなかったと考えられた．以上から，下水道の整備による浄化が進んだことで湖水中の窒素・リン濃度が減少し，栄養塩比が変化したことによって，夏期に優占する藻類が藍藻のみであった状態から，近年では藍藻に珪藻が加わったと考えられた．

浄化対策が進んだ諏訪湖では，今後，水中の窒素・リン濃度は横ばいか微減と予想される．対してシリカ濃度は 1979 年以降通年では測定されていないため，その予測が難しい．そこで，湖水中シリカ濃度の増減を推定するため，諏訪湖における 2016 年から 2017 年のシリカの収支を推定し，図 5 に示した．

諏訪湖の湖水中シリカ濃度を増加させる要因を加算すると，23.2 × 10^3 ton SiO_2 / 年であった（内訳：21.84 + 0.995 + 0.382 ）．一方，シリカ濃度を減少させる要因を加算すると， 23.3 × 10^3 ton SiO_2 / 年であった（内訳：17.16 + 2.35 + 3.79 ）（図 5）．この差分を諏訪湖の湖水量で除すると，シリカ濃度の変化量は 0.002 mg-SiO_2 / L / 年と推定され，現在の諏訪湖のシリカの収支は，± 0 と評価された．ここから，降水量や河川水中シリカ濃度や水温などが大きく変化しなければ，諏訪湖のシリカの濃度も今後大きく変化することはないと予想される．

4. 結論

諏訪湖の植物プランクトンを構成する栄養塩の組成（窒素:リン:シリカのモル比）は 18.8：1：92.6（平均）であった．この比を湖水中の栄養塩比と比較することで栄養塩の欠乏状況の評価を行った．1979 年・2016 年・2017 年は DIN 制限が見られた．1979 年・2017 年は DSi 制限が見られた．2016 年・2017 年では各栄養塩制限の影響と考えられる藻類組成の変化が確認された．また，下水道の整備による浄化が進んだことで湖水中の窒素・リン濃度が減少し，栄養塩比の変化することによって，夏期に優占する藻類が藍藻のみであった状態から，近年では藍藻とともに珪藻も加わったと考えられた．何らかの理由で珪藻が増殖すると，そのシリカの取り込みによって，シリカ制限となることも示唆された．

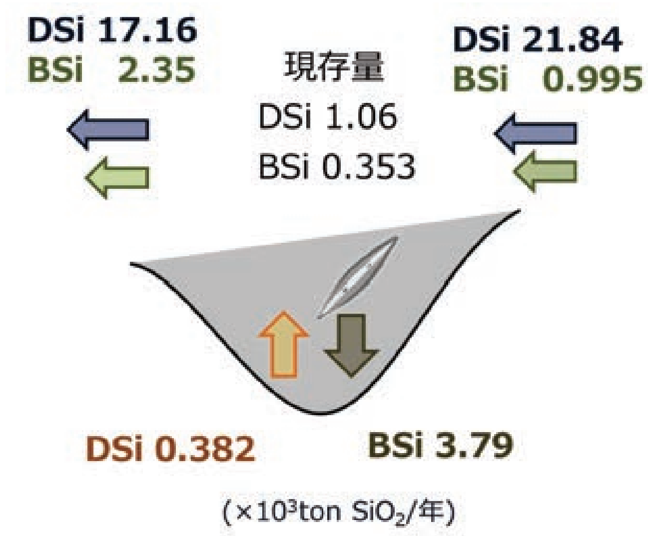


図 5 ． 諏訪湖のシリカ収支（2016 年から 2017 年）
青色が河川による溶存態シリカ移動量，緑色が河川による生物体シリカ移動量，土色が珪藻によるシリカ堆積量，橙色が底質からのシリカ溶出量を表す．

将来のシリカ濃度の推定のために，シリカの収支を算出した．シリカの収支は，±0と推定され，今後，諏訪湖のシリカ濃度および溶存態栄養塩比は大きく変化することはないと予想された．

引用文献

[1] 花里孝幸・朴虎東，2008，諏訪湖におけるラン藻の長期変動と生態系構造の変化，日本プランクトン学会報，**55**（**1**），48-54.

[2] 原島省，2005，フェリーモニタリングに基づいたシリカ欠損仮説の検証，沿岸海洋研究，**43**（**1**），39-44.

[3] 宮原裕一，2013，諏訪湖定期調査（2007～2011）の結果，信州大学山地水環境教育研究センター研究報告，**9**，1-214.

[4] 宮原裕一，2018，諏訪湖定期調査（2012～2016）の結果，信州大学山地水環境教育研究センター研究報告，**11**，1-236.

[5] 倉沢秀夫，1973，諏訪湖小坂沖定点における基礎生産，二次生産，分解，栄養塩類の季節変化に関する研究，諏訪湖生物群集の生産力に関する研究，5，20-40.

[6] 沖野外輝夫・山本雅道，1978，１９７７－１９７８年の諏訪湖の水質（電気伝導度、SiO_2、Cl^-、Ca^{++}、Mg^{++}、NH_4-N、COD），諏訪湖定期観測資料集　No.1，27-36.

[7] 中嶋さやか・井関和夫，2006，沿岸域における生物起源ケイ素の分析手法の検討と春季周防灘における分布，Hirosima Univ., **45**，21-29.

P3-29

Water Quality Assessment and Trophic Status Determination of Lake Lanao, Mindanao Island, Philippines

Carmelita G. Hansel[1] and Misael M. Sanguila[2]

[1]College of Natural Sciences and Mathematics, [2]College of Fisheries, Mindanao State University, Marawi City, Lanao del Sur, Philippines

Keywords: water quality, primary production, eutrophication

ABSTRACT

Lake Lanao is the second largest lake in the Philippines, and is of great biological, ecological, economic and social importance. Since the first studies by Frey and Lewis in early 70s , various changes have occurred. Thus, this study sought to assess the water quality and make a determination of the trophic status of Lake Lanao during the period June 2016 – February 2017. An offshore station was chosen to represent the lake. The Secchi disk depth was taken while measurements made for conductivity, dissolved oxygen, pH, and temperature. Water samples were collected, kept in a cooler, and analyzed in lab for nutrients (nitrate-N, ammonia-N, total phosphorus), alkalinity and chlorophyll-a. Dissolved oxygen value showed no lack of oxygen for use of the lake organisms. The values for the other parameters showed good water quality and were in the range for that of a healthy lake. Based on the table prepared by Brown and Simpson, and trophic status index (TSI) based on the equations formulated by Carlson gave values equivalent to an oligotrophic-mesotrophic lake. Lake Lanao is trending towards eutrophication, which is a natural process in many freshwater ecosystems as they age. However, since human-caused nutrient loading can accelerate this process, cultural eutrophication can be controlled by community and management practices in the catchment basin that will restrict the input of pollutants into the lake.

1. INTRODUCTION

Lake Lanao is the second largest lake in the Philippines and is wholly located within the province of Lanao del Sur. It has great biological, ecological, economic and social importance – as the seat of evolution of an endemic species flock of cyprinids, as a sizable contributor to the local hydrologic cycle, as the source of water supply driving the Agus hydropower plants, and as the center of life and culture of its native inhabitants - the Maranaos who call themselves the “People of the Lake.” The first extensive limnological study of Lake Lanao was done by Frey[3]. This was continued by Lewis with his more in-depth field work performed in 1970-71[6]. Since these first studies, various changes have occurred such as that affecting the natural variation in the outflow of Lake Lanao due to the construction of a hydropower plant near the mouth of Agus River, its single outlet, which started operation in 1992. Some unusual phenomena, such as the occurrence of a fish kill, diagnosed as epizootic ulcerative syndrome, occurred in 1997[2] and an unusual greening occurred in September 2006[4]. These unusual occurrences point out the need for a regular periodic assessment of the water quality of the lake. Thus, this study sought to assess the current status of the usual water quality parameters and determination of the trophic status of Lake Lanao.

2. METHODOLOGY

A sampling station was selected offshore at a deeper part of the lake which alternated between three locations in order to represent the lake. See Figure 1. Field measurements and collection of water samples were done five times over the period from June 2016 through February 2017. Field measurements were done for Secchi disk depth, conductivity, dissolved oxygen, pH, and temperature[5]. At the same time, water samples were collected for laboratory analyses of nutrients (nitrate-N, ammonia-N, total phosphorus), alkalinity and chlorophyll-a.

3. RESULTS

All values are mean of measurements from the top 5 m, unless otherwise indicated.

Table 1. Secchi disk depth, temperature, and chemical factors in Lake Lanao.

Physical factor/ Chemic	27 June 2016	14 Sep 2016	15 Nov 2016	19 Dec 2016	26 Feb 2017

al factor	Tugaya Offshore	Tugaya Offshore	Taraka Offshore	Taraka Offshore	Masiu Offshore
Secchi depth, m	4.5	5.2	6.0	6.6	3.5
Temperature, ^{0}C Mean, top 5 m	28.0	27.6	27.7	26.4	25.6
Mean, 28-32 m	27.7	27.5	27.2		
Dissolved oxygen, ppm Mean, Top 5 m			7.3	7.7	6.4 (Surface only)
Mean, 28-32 m			7.6		
NO3-N, ppm	0.0257	0.0257	0.017	0.021	0.029
NH3-N, ppm	0.0673	0.0947	0.0933	0.0883	0.0883
Total P, ppm	0.0377	0.035	0.0303	0.0323	0.0197
Chl-a, mg/m^3	1.3937	0.8136	0.565	0.678	N.d.
pH	8.4	8.6	9.0	8.0	7.9 (surface)
Alkalinity, ppm CaCO3	497	500	680	623	600
EC, mS/cm	0.102	0.114	0.078	0.108	0.130

1 ppm = 1 mg/L = 1000 μg/L = 1000 mg/m^3

Table 2. Comparison of Lake Lanao values with Brown and Simpson[1] to give lake classification.

Variable	Lake Lanao values	From Brown and Simpson, Table 1
Secchi depth, m Mean Range	 5.14 3.5 – 6.6	 4.2 1.5 – 8.1; Mesotrophic
Total Nitrogen, μg/L Mean Range	(Nitrate- + Ammonia-N) 110 93 – 120.4	 660 310-11600; Oligotrophic
Total Phosphorus, μg/L Mean Range	 31 19.7 – 37.7	 27 11 – 96; Mesotrophic
Chlorophyll-a, μg/L Mean Range	 0.8626 0.565 – 1.3937	 1.7 0.3 – 4.5; Oligotrophic

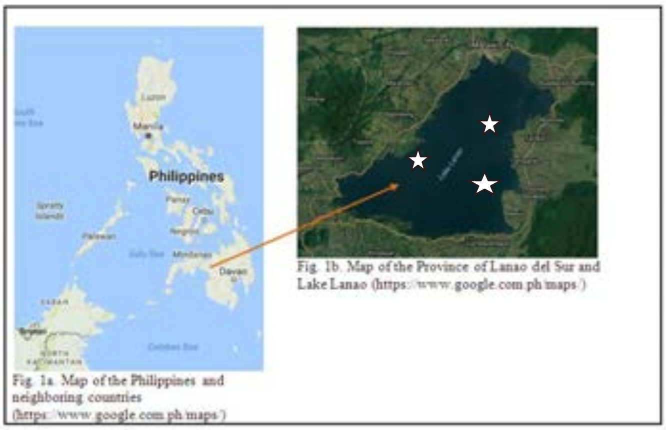


Figure 1. A map of the Philippines to show the location of Lake Lanao and a map to show the three locations of the sampling station.

4. DISCUSSION

The values of various physical and chemical parameters of Lake Lanao follow those quantities usually obtaining in most nonpolluted lakes. Secchi depth ranged from 3.5 m to 6.6 m. Dissolved oxygen at the top 5 m was nearly saturated, indicating that there was no lack of oxygen for organisms in the littoral and limnetic zone. Similar to the pH of most natural waters that is between 6.5 and 9.0, Lake Lanao pH ranged from 7.4 to 9.0. Conductivity generally ranges between 10 and 1,000 µS/cm in most rivers or lakes that have outflows, such as Lake Lanao. Alkalinity values reflect a good buffering capacity of Lake Lanao. Comparing the inorganic nitrogen and total phosphorus levels in the lake show a nitrogen limitation for algal growth. The trophic state of a lake describes its productivity, i.e., how much algal biomass it contains, and consists of three categories as the lake becomes greener or more productive: oligotrophic, mesotrophic, eutrophic. Referring to the table prepared by Brown and Simpson, Lake Lanao is oligotrophic-mesotrophic. The trophic state index based on the equations formulated by Carlson[7] further affirm the trophic status of Lake Lanao as oligotrophic-mesotrophic.

5. CONCLUSION

The values for various physical and chemical parameters of Lake Lanao showed good water quality and were in the range for that of a healthy lake. It is nevertheless trending towards eutrophication, which is a natural process in many freshwater ecosystems as they age. However, since human-caused nutrient loading can accelerate this process, cultural eutrophication can be controlled by community and management practices in the catchment basin that will restrict the input of pollutants into the lake.

ACKNOWLEDGMENT

This study (NRCP Proj. E-228) was funded by National Research Council of the Philippines, under a research program, Comprehensive Studies on Lake Lanao for Sustainable Development, implemented by Mindanao State University-Iligan Institute of Technology.

REFERENCES

[1.] Brown, Ted and Jon Simpson. I. Determining the trophic state of your lake. Accessed at www.obvcapitale.org/.../Determining-the-trophic-state-of-your-**lake**.pdf on 2 March 2015.

[2.] Escudero, Pedro, Carmelita G. Hansel, et al. First report of EUS (epizootic ulcerative syndrome) occurrence in Lake Lanao, Lanao del Sur, Philippines. Paper presented at the FIMFS 30th Annual Convention at University of Eastern Philippines, Catarman, Northern Samar on December 9-11, 1998.

[3.] Frey, David G. 1969. A limnological reconnaissance of Lake Lanao. Verh. Internat. Verein Limnol. 17. (Reprinted with author’s permission in Mindanao Journal. 1974. 1(1):81-101.)

[4.] Lagmay, Juliet P., Carmelita G. Hansel, et al. 2006. Hydrobiological assessment of Lake Lanao subsequent to its unusual greening in 2006. Mindanao Journal 29:85-100.

[5.] Lind, O.T. 1985. Handbook of common methods in limnology. 2nd ed. Kendall/Hunt Publishing Company, Dubuque, Iowa.

[6.] Lewis, William M., Jr. 1973. The thermal regime of Lake Lanao (Philippines) and its theoretical implications for tropical lakes. Limnology and Oceanography 18(2):200-217. (Reprinted with author’s permission in Mindanao Journal. 1974. 1(1):102-130.)

[7.] Michaud, Joy P. 1991. A Citizen’s guide to understanding and monitoring lakes and streams. Available at http://www.ecy.wa.gov/programs/wq/plants/management/joysmanual/index.html.

P3-30

WATER QUALITY CHANGES AND EFFECTS OF POLLUTION IN KISUMU BAY WATERS OF LAKE VICTORIA

[1]Rolin Nzomo Mwiva

[1]Lake Basin Development Authority

Keywords: Transparency, phytoplankton, eutrophication, sustainable water quality monitoring, and pollution control.

ABSTRACT

The study was undertaken in Kisumu bay, Lake Victoria with objectives to determine water quality status, pollution levels and impacts on lake waters. Parameters were analyzed using APHA method. Relationship between phytoplankton counts, nutrients and physicochemical parameters was statistically determined.

River Kisat depicted poor water quality with mean DO 1.4 mg/l, Conductivity 844 μscm^{-1} and BOD 228 mg/l. Nutrients were high with mean TN ranging 0.807 ± 0.170 mg/l to 5.390 ± 0.413 mg/l, while mean TP ranged 0.088 ± 0.010 to 0.317 ± 0.039 mg/l. Mean (NO_3-N) and (PO_4-P) was 0.055 ± 0.048 mg/l and 0.054 ± 0.042 mg/l respectively. Phytoplankton taxa, Cyanophyta, Chlorophyta, Bacillariophyta and Pyrrophyta were identified, with 20 identified algae species. Chlorophyll "a" concentration was high 0.308 ± 0.085 mg/ l. Positive correlation was observed on nutrients and phytoplankton densities with significant ($r = 0.918$) between phytoplankton counts and TP. TN: TP > 12, indicating that P was the nutrient limiting factor. Transparency was low 0.47 ± 0.09 m. T P and TN mean values 0.188 and 2.946 mg/l were beyond upper limits given by OECD of 0.02 mg/l and 0.2 mg/l.

Therefore, as a result of pollution from River Kisat, the elevated nutrients, low transparency, increased blue green algae and water hyacinth in Kisumu bay is a sign of water quality deterioration and a water mass undergoing eutrophication. Mitigations recommended included rehabilitation of Kisumu Municipal waste treatment plant, effecting sustainable water quality monitoring programme and enforcement of existing pollution control laws.

INTRODUCTION

Eutrophication is the biological response to excess nutrients input to a lake. It refers to nutrients enrichment and is associated with increased primary productivity. The term is synonymous with increased proliferation of phytoplankton in the lake. Warm tropical lakes are more severely affected than colder water counterparts in temperate regions, because of high temperatures accelerating growth of phytoplankton (Jorgensen and Vollenweider, 1989).

According to LBDA (1997), Lake Victoria which is the second largest fresh water lake in the world with a surface area of 68,800km^2 contribute significantly towards ecological, biophysical and socio economic development along its shoreline, within its basin as well as the livelihood of communities far and beyond its catchment area. It is lifeline to the riparian for food, hydropower generation, transport, tourism, water supply for domestic, agricultural and industrial use, waste water disposal, recreation, and biodiversity conservation.

There has been momentous rise in human population and industrial development in major urban centres near the lake including Kisumu town. Rapid industrialization and urbanization with overstretched sewage system has greatly contributed to the lake pollution.

Study area :Kisumu bay which lies in longitudes - 33° 20' East and 35° 20' East, latitude - 0° 20' South and 0°50' south is within Winam Gulf of Lake Victoria. The study area is within Kisumu town with a population of about 500,000 people. Kisumu is the biggest urban centre in western Kenya with commercial enterprises, industrial area and urban estates. River Kisat which flows into Kisumu bay receives effluents from Kisumu Municipal convectional treatment plant & industrial area and slum area at its upstream.

Overall project objective: To determine water quality status, and effects of pollution on Kisumu bay waters.

Specific Objectives

i. To determine water quality of river Kisat.
ii. Determine physical parameters and nutrients levels, their relationships with phytoplankton population and impacts on Kisumu bay waters.
iii. Compare water quality with other parts of the lake and recommend abatement measures on pollution control.

PROJECT RESEARCH METHOD.

Lake sampling stations were accessed by use of boat. A line transect was used to provide for systematic random sampling, where GPS was used to mark sampling stations. The 6 sampling stations were 1.2 km apart covering total distance of 6 km along the bay from Kisat river mouth. Samples were collected for five consecutive months – Jan, Feb, Mar, Apr, and May 2009.The hydro lab surveyor machine was used in measuring physico – chemical parameters in situ. Nutrients were analyzed in the laboratory using procedures by APHA (1992).

Data was subjected to statistical analysis for and trends and distributions were presented, in form of tables, histograms, graphs and pie charts. Regression analysis was done to determine correlations between different variables

RESULTS AND DISCUSSION

Secchi depth, PH & DO showed increased values from station A to F- while TDS, TURB, TP, TN, NO_3 - N, NO_2-N, NH_4-N and Chl "a" depicted reducing trend from station A to F. Except for PH of 7.9, most parameters in River Kisat didn't meet national standards, WHO and conditions of aquatic life. There was low D.O 1.4 mg/l and high BOD_5 of 228mg/l measured, reason being poor state of Kisumu Sewage Treatment Plant.

Mean values of physical chemical parameters in Kisat river

Parameter	Cond(μscm^{-1})	TDS(mg/l)	TUR(NTU)
Mean	844	418	23.4

Out of the 20 phytoplankton species identified, 4 taxa were established namely,Cyanophyta with 10 species, Chlorophyta 5 species, Bacillariophyta 4 species and Dinoflagellates 2 species .

All nutrients portrayed the same trend, of general decrease in concentration, from station A to F. Concentrations of chlorophyll 'a' decreased from 0.471 mg/l at station A to 0.228 mg/l at station F. The levels of NO_3-N and PO_4-P were relatively high at station A, 0.158±0-026 mg/l and 0.147±0-057 mg/l respectively. These concentrations dropped drastically at station F, 6 km away. The mean value of TN was 2.946 ± 1.769mg/l, while TP was 0.188 ± 0.085mg/l. The mean values of ammonia, ammonium and nitrite concentrations were 0.025 ± 0.019 mg/l, 0.178 ± 0.032mg/l and 0.007 ± 0.004mg/l respectively. Nitrite levels were found to be very low compared to nitrate within the study area. Regression between chlorophyll "a" and other variables was carried out and showed, PO_4-P ($r = 0.948$), TP ($r = 0.929$), TN ($r = 0.912$) and phytoplankton counts ($r = 0.422$). Chl "a" was negatively correlated with secchi depth ($r = -0.838$) and DO ($r = -0.951$).

Transparency mean value was 0.47m. Njuru &Hecky (2005) observed 0.7m in Winam Gulf and 2.3m in the open lake. Transparency is influenced by suspended matter, silt, clay & plankton. Sedimentation and reduced phytoplankton densities caused increased transparency as flow moves towards open lake. Njuguna (1985) and Lung'ayia *et al* (2000) observed declining transparency in the lake. Average DO was 5.83 mg/l. Low conc. in station A (river mouth) was due to organic matter decomposition &

biodegradation. As DO usage decline due to biodegradation, DO measurements improve. Upwelling help in oxygenation hence increased DO. at station F. DO conc. below 2 mg/l may lead to fish death (UNESCO / WHO 1992).

High PO_4-P and TP at station A was due to high phosphorous loading from river Kisat. High TP could be caused by external loading, internal loading from bottom sediments, waste water from nearby beach hotels & vehicle washing. Upwelling makes PO_4-P available at hypolimnion for use by phytoplankton (Tilzer 1990). Njuru & Hecky (2005) noted same range of PO_4-P & TP as study found. Chl "a" mean levels was 0.308 mg/l mainly caused by elevated nutrients and high illumination. Positive correlation between chl "a" and other key nutrients supports hypothesis that nutrient enrichment is synonymous with increased biota. Obtained values compares well with LVEMP (2000) findings for Mwanza bay (0.172mg/l) and Murchison bay (0.300mg/l). Chl "a" conc. and increased biomass in tropical lakes is fanned by high temp, abundant light & high photosynthesis.

TN:TP mean ratio of 13.15 was beyond Meybeck *et al* (1989) ratio of 7:1 typical of organic matters in aquatic plants thus if N:P>7, P is limiting factor while if N:P< 7, N is limiting factor. Results concur wilt Forsberg (1978), that if N:P>12 then P is the limiting factor. Reason for P being limiting factor is, naturally occurring in low quantities, readily uptake by phytoplankton, and being held by bottom sediments. TN and TP exceeded boundary values for eutrophication by OECD (1987) of 0.2mg/l and 0.02mg/l and Volleinweider (1968) of 1.5mg/l and 0.1mg/l respectively, strengthening the position that the lake is eutrophic.

The above findings mirror on previous studies which revealed elevated sediment loads, nutrients, biomass, algal blooms, and proliferation of the water hyacinth. These are indicators and manifestation of water quality deterioration and a water mass undergoing eutrophication (Talling 1966, Njuguna 1984, Mavuti 1987, Calamari *et al* 1995 and Njuru and Hecky 2005). Studies have also shown water quality changes as a contributing factor behind fisheries biodiversity and stock decline. These changes are profound in Winam Gulf which is a recipient of high loads of river, industrial and urban pollutants.

CONCLUSION & RECOMMENDATIONS

Study concluded that pollution and eutrophication are a major threat to Kisumu Bay waters. Pollution is as a result of effluent, laden with nutrients, organic and to some extent sediment pollution loads. Nutrient and algal biomass are predicted to increase with time and aggravate the situation. It is envisaged that eutrophic waters will impact negatively on the lake ecosystem, utilization potential and the livelihood of the basin communities.

Recommendations: There is need to support and effect a multi institutional water quality surveillance programme as a tool for water quality and environmental management. The Kisumu Municipal conventional waste treatment plant be rehabilitated and maintained in working conditions and regulatory authorities NEMA and WRMA ascertain that effluent released comply with stipulated discharge standards. Comprehensive studies be undertaken on nutrient budget modeling to assess and quantify nutrient inputs into the bay, investigate internal nutrient loading; estimate amounts taken up by plankton and quantities settling in bottom sediments.

REFERENCES

APHA. (1992). Standard methods for examination of water and waste water (16th ed) APHA, AWWA and WEF. Washington. 1266 pp.

LBDA (1987). Integrated Regional development Master plan for Lake Basin Development Area

Meybeck M. Chapman D. and Helmer R. (1989). Global fresh water quality. A first assessment Blackwell reference Oxford 306 pp

Njuru P. G and Hecky R. E. (2005). Nutrient Concentrations in Nyanza Gulf, Lake Victoria Kenya: Light Limits algal Demand and Abundance. Hydrobiologia (2005) 534: 131 – 140.

P3-31

C3 および C4 植物を構成する有機物の河川への流入と変化

瀬川 秀平[1], 長山 美紗紀, 山根 美幸[1], 中國 正寿[1], 山本 修一[1]
[1]創価大学 大学院 工学研究科 環境共生工学専攻

キーワード:C3・C4 植物、表流水と地下水、土壌、生分解、炭素安定同位体比

抄録

有機地球化学ではリグニンフェノールや炭素安定同位体比(δ^{13}C)といった植物由来の有機物に関する指標が用いられ、古植生情報の復元などが行われている。しかし、これら有機物は、生分解や物理的、化学的分解により変化することが考えられる。したがって、有機物の変化による、指標となる値の変化を把握することは重要である。本研究では植物由来の有機物が土壌や河川へ流入する際にどのような変化を受けているのか検討した。試料は C3 植物のアシ、C4 植物のススキを選定し、これらの群生地において、植物の他、土壌、堆積物、周辺河川水（POM、DOM）を採取した。これらの有機物と炭素安定同位体比を測定した結果、植物の δ^{13}C 値は土壌や堆積物中有機物の値によく反映されているが、次第に大きい値になること、またリグニンフェノールの酸/アルデヒド比は、落葉し、土壌、堆積物、また水中へと分解が進むなかで、大きな値になっていくことがわかった。

1. はじめに

堆積物や土壌に含まれるリグニンフェノールなどの植物由来のバイオマーカーや炭素安定同位体比(δ^{13}C)は、それぞれの時代の周辺植生を反映しているとの仮定のもと、過去の植生変化が解析されている[1, 2]。植物を構成する葉や小枝は、季節・気象変化などにより脱離し、昆虫や微生物による分解を経て、土壌中有機物になり、やがて河川や大気による輸送過程を経て湖沼や海洋へ堆積していくと考えられる。植物を構成する有機物や炭素安定同位体比は、このようなプロセスを経る中でどのような変化を受けるのかを理解することは、古植生情報の復元にとって重要であるが、未だ十分な理解がなされているとは言いがたい。

これらの変化は、主に生物分解や無機的な環境、あるいは時間の経過などの影響により、生物的、物理的、化学的に起こると考えられており、この変化を初期続成変化という。この初期続成変化により構成する有機物の組成が変化し、またその際に起こる同位体分別作用により炭素安定同位体比に変化が生じる。したがって、元の生物における指標が生物的、物理的、化学的な作用により、どのような方向に変化するのかを把握しておくことは、指標を使用するうえで重要になる。

陸生植物を構成する有機物のほとんどは最終的に真菌類やバクテリアによって無機化され、わずかな残留物が土壌や腐葉土中に保存されることや、真菌類は好気性であるため嫌気的環境下では保存されやすいことが知られている[3]。また、主に木質部を構成するリグニンやセルロース、ヘミセルロースでは、水中などの嫌気条件下においてはセルロースやヘミセルロースなど炭水化物が優先的に分解されることが知られているが、十分な研究がされているわけではない。

一方、河川流域研究に関する研究において、炭素安定同位体比の値から有機物の起源の推定等が行われている。陸上高等植物には光合成経路の違いから C3 植物と C4 植物がある。C3 植物の平均的な δ^{13}C 値は -27 ‰程度であるが、C4 植物では-10～-14 ‰と大きな違いがある[4]。

本研究では、C3 植物と C4 植物が異なる炭素安定同位体比をとることに着目し、これらを構成する有機物が落葉後、土壌、また河川に至る過程でどのような変化をするのかを検討した。使用した植物は C3 植物としてアシ、また C4 植物としてススキの草本類である。

2. 方法

サンプリングを検討する際には、有機物の変化過程を追跡しやすくするためにできるだけ単純な植生の場の選択が重要と考えられたことから、C3 草本植物として神奈川県芦ノ湖の湖尻水門のアシを、また C4 草本植物として神奈川県箱根仙石原のススキを選択し(Fig.1)、それぞれの場にて植物、土壌、堆積物および河川水を

試料として採取した。

植物試料は、枝切りバサミを用いて生体から直接採取し、これらをジップロックに密閉し処理まで冷凍保存した。土壌試料は、陸土壌は表面の落ち葉や腐葉土を除去した後、表層(～5 cm) を、スコップを用いて採取しアイボーイ(Agilent Technologies 社, 広口びん 100 mL)にいれ処理まで冷凍保存した。植物および土壌は冷凍保存したのち約 24～48 時間かけて凍結乾燥した。植物試料は粉砕器にて粉末状にし、土壌試料は植物片や砂など粒径の大きいものは除去し、瑪瑙乳鉢ですりつぶした後、100 μm のふるいで分画したものを分析用試料とした。

河川水は、バケツにて表層水（～50 cm）を約 20~40 L 採水し、ポリタンクに保存した。これを静置したのち、グラスファイバーフィルター(GF/F)を用いて吸引ろ過し懸濁態有機物を分離した。それらフィルターから無機炭素を除去するため塩酸処理した後 milli-Q にて洗浄した。その後、凍結乾燥し、ろ紙上のものを回収し、乳鉢にて均一にしたものを POM (Particulate Organic Matter)試料とした。減圧濾過の際に得られたろ液については、12 M 塩酸で pH 2 に調整した後、圧力ポンプ（Pump Modules C-601, Pomp Controller C-610：日本ビュッヒ株式会社）を用いて、流速 20 mL min-1 で DAX8-樹脂に通水して有機物を捕集した。その後、樹脂に吸着した有機物をメタノール約 100 mL で溶離し、エバポレーターにて濃縮したものを DOM(Dissolved Organic Matter)試料とした。

これらの試料において有機物分析と、炭素安定同位体比分析を行った。

有機物分析に関しては Online-TMAH-GC/MS 法にて以下の手順で行った。まず、加熱温度が 315℃のパイロホイルに試料（DOM:約 0.1～0.5 mg, POM: 約 3.0～5.0 mg, 植物: 約 1.0 mg, 土壌: 5.0~10 mg）をとり、25% TMAH（Tetramethyl-ammonium hydroxide）試薬 20～30 mL と内部標準試料（Nonadecanoic-d37 acid）2 mL を加えて減圧乾燥させた。その後、熱分解装置（JHP3 型 Curie Point Pyrolyzer: 日本分析工業社）を連結させたガスクロマトグラフィー質量分析計（GC/MS 装置 6850 GC/5975C MS, Agilent Technologies 社）にて分析を行った。

元素組成および炭素安定同位体比は、元素分析器 FlashEA 1112 Series CHN 分析計（Thermo Scientific 社）と Delta Advantage IRMS(Thermo Scientific 社)をオンラインで繋いだ連続フロータイプの測定機器である EA/IRMS（Elemental Analyzer-Isotopic Ratio Mass Spectrometer）にて測定した。なお、試料中の全炭素量は標準物質（Acetanilide Standard: C8H9N10）を用いた検量線法で定量した。

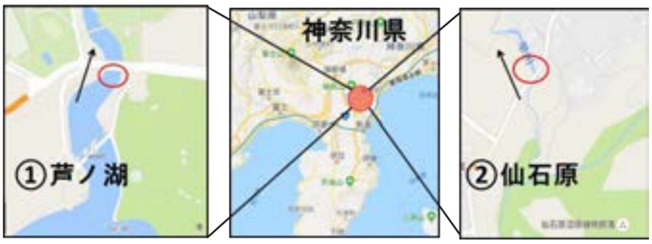


Fig.1 サンプリング地点

（矢印は河川の流れる方向を示す）

3. 結果

芦ノ湖のアシに関連した試料の炭素安定同位体比（δ^{13}C）の値(Fig.2)をみると、いずれの試料においても大きな違いはないが、堆積物中有機物、POM および DOM の δ^{13}C 値はアシの δ^{13}C 値よりもやや大きい（重い）値であった。

仙石原のススキに関連した試料の δ^{13}C 値にでは、ススキおよび土壌中有機物の δ^{13}C 値と河川水中の POM および DOM の δ^{13}C 値はかなり異なっていた。すなわち、土壌中有機物の δ^{13}C 値はススキの δ^{13}C よりやや小さい（軽い）値になった一方で、POM や DOM など河川水中有機物の δ^{13}C 値はかなり軽い値になった。

また、リグニンを構成するバニリルフェノールのバニリン酸/バニリン比(Ad/Al)v は、糸状菌による酸化的分解の程度を表す指標であり[5]、値が高いほど酸化的分解の程度が大きいことを示す。 Fig.3 に示した結果をみると、両地点の試料ともに、起源である植物と POM の (Ad/Al)v が近い値をとり、その一方で土壌中有機物や堆積物中有機物と DOM の(Ad/Al)v 値は起源である植物の値よりもかなり大きい値をとることを示している。

4. 考察

アシの δ^{13}C 値は、対応する堆積物中有機物、DOM および POM の δ^{13}C 値と近い値をとっていることから、アシの δ^{13}C 値は堆積物中有機物や付近の河川水中有機物(POM や DOM)にも良く反映されていることを示している。さらに詳細に検討すると、微生物分解を受けると、軽い炭素が CO_2 として放出されると考えられることから、残存する有機物の δ^{13}C 値は大きくなると予想される。その意味では、芦ノ湖のアシに関連した試料では

土壌、POMおよびDOMへと分解が進んでいることを示唆している。このことはリグニンの(Ad/Al)v比の変化にも現れており、起源であるアシの(Ad/Al)v 比よりも糸状菌などによる分解作用などをうけた有機物は大きい(Ad/Al)v比になることを示している。また、POMとDOMの(Ad/Al)v 比を比べると、DOM の値が大きいことから、有機物の分解が進んだものが DOM に分化している可能性がある。

一方、ススキに関連した試料の場合、(Ad/Al)v 比の値は、アシと同様に、土壌やPOMおよびDOMの値はかなり大きく、分解が進んでいることを示唆しているが、ススキのδ^{13}C 値は水中の POM や DOM のδ^{13}C 値と比べて、かなり軽い値になっていることから、付近に存在する C3 植物に由来する有機物が混入している可能性がある。

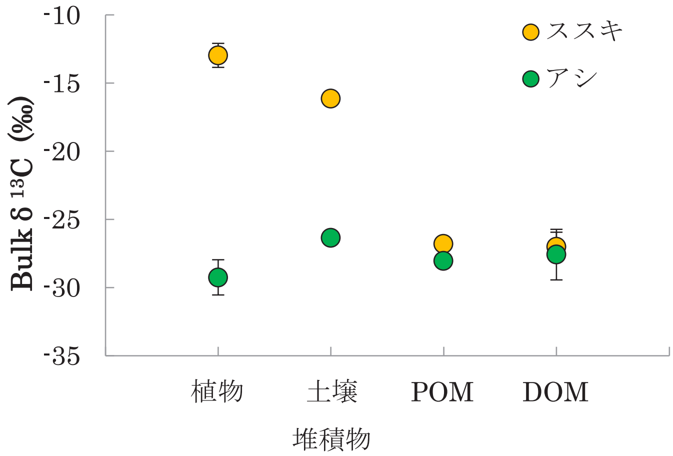
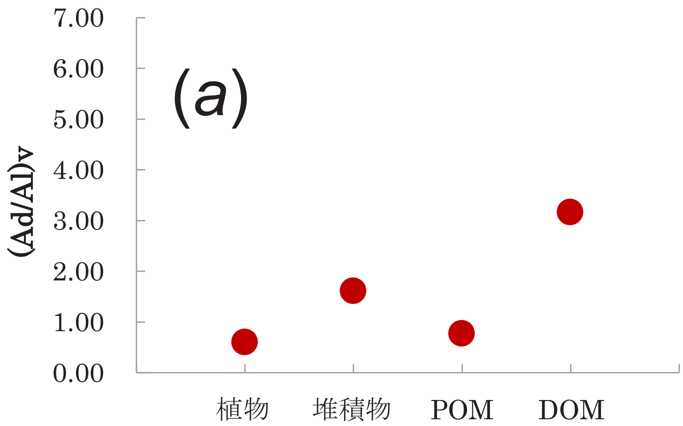


Fig.2 各試料における全炭素安定同位体比
(Bulk δ ^{13}C 値)

5. 結論

土壌、POM、DOMのリグニンの組成変化、δ^{13}C 値の変化、また(Ad/Al)v 比の変化は、概ね植物、土壌、POM、さらにDOMの順に 進んでいることを示唆しており、河川水中の溶存態有機物は土壌からの流入に影響を受けていることが示唆された。ただし、仙石原の試料(特に POM)にはススキ以外の有機物に由来するものが含まれている可能性がある。



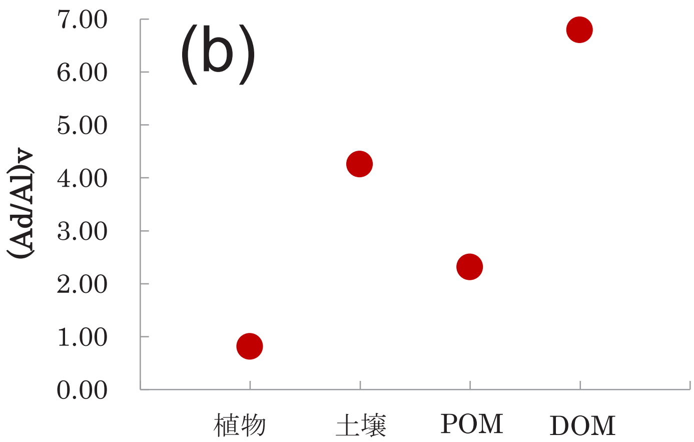


Fig.3 各地点における試料中リグニンの(Ad/Al)v 比
: (a)アシ、(b)ススキ

引用文献

[1] P. A. Meyers and R. Ishiwatari: Org. Geochem., Vol. 20, pp. 867-900, 1993.

[2] R. Ishiwatari et al.: Org. Geochem., Vol. 37, pp. 1787-1802, 2006.

[3] J. I. Hedges et al.: Geochim, Cosmochim. Acta., Vol. 52, pp. 2717-2726, 1988.

[4] B.N. Smith and S. Epstein: Plant Physiology., Vol. 47, pp. 380-384, 1971.

[5] J.I. Hedges et al.: Geochim. Cosmochim. Acta., Vol. 46, pp.1869-1877, 1982.

P3-32

Paper title：Lessons learned from Management of West Lake (Ho Tay) in Hanoi Capital of Vietnam after a haft century

Hoang Van Thang[1], Mai Dinh Yen[2], Bui Thi Ha Ly[1]

[1]Central Institute for Natural Resources and Environmental Studies, Vietnam National University,
[2]Vietnam Ecological Association

Keywords: West Lake (Ho Tay), Management, Lesson learned, Biodiversity, Water pollution

ABSTRACT

Ho Tay (West Lake), a more than 500 hectares natural lake is located in the Western of Hanoi Capital, Vietnam. The lake has played very important role in ecosystem services for the city in the past, present as well as in the future.
After over a half century, flowing with the history of Vietnam, the management of West Lake could be divided into 3 periods: 1) from 1954 – 1975: war for reunification of the country; 2) 1975 - 1986: socio-economic development after the war and; 3) 1986 – up to date (2017): "Open the door" or "Renovation" which lead to rapid urbanization of Hanoi Capital. Despite of many efforts in management have been undertaken, in comparison with the 1st period, our research analysis showed that in the 3rd period, water quality has been polluted, and biodiversity has been degraded seriously. Two hundreds of tons of fishes and aquatic animals were died suddenly in October 2016!
This paper will touch upon the experiences and lessons learned after a half century in management of West Lake toward a better conservation and management of West Lake.

1. INTRODUCTION

West Lake (Ho Tay) with a surface area of over 500ha is one of four important natural lakes in Vietnam. West Lake is located in the center of Western part of Hanoi city. The lake contributes many important ecosystem services for the city in the past, present and future (Mai & Mai, 2014).

Limnology aspects was studied in 1961. Since then, there have been many surveys on water qualities, aquatic biodiversity and management carried out regularly in the West Lake.

After a half century of management, the lake has been greatly impacted by nature as well as people. Nevertheless, lessons learned on management and conservation means for the lake, as well as the status of water qualities, biodiversity, legislation and ecosystem services (ES) of West Lake, have not been overviewed and analyzed.

2. RESEARCH METHODS

This scientific paper overviews and synthesizes related scientific papers from our and colleagues studies.

3. RESULTS

3.1. West Lake ecosystem services play different important roles in over 50 years

West Lake is located at 21°04'N and 105°05'E on an elevation of less than 10m a.s.l. The catchment has an area of 9,3km^2 (Bui, 2014). The surface area of the lake is 519.75 hectares (2014) which formed as horseshoe shape and is one of the largest natural lakes in the Red River Delta. The lake originated as a segment of the Red river but not connected with the river by any canal presently (Tay Ho DPC & WMA, Survey, assess water quality, ecosystem and propose wise used methods of West Lake, 2012) .

West Lake receives the water from precipitation (around 2000mm/year) within its catchment and waste water from surrounding human settlement (Tay Ho DPC & WMA, Survey, assess water quality, ecosystem and propose wise used methods of West Lake, 2012) . The lake is connected to the neighboring Truc Bach Lake (which is 20ha in surface water). Lake water level changes are correlated with the fluctuation of Red River but amplitudes are small.

Over a half century, flowing with the history of Vietnam, which can be divided into 3 periods:

- From 1954 to 1975: War for reunification of the country;
- From 1975 to 1986: Socio-Economic development after war; and
- From 1986 to 2017: "Open the door", "Renovation", "Socialist-oriented market economy". This period is marked as "rapid urbanization". At present, Hanoi has approximately 9 million of habitants.

The West Lake has been contributing to the development of the city through its ES. However, the ESs play different role in each periods, particularly for the 1st and the 3rd ones. In the 1st period, the provisioning and regulating and supporting services were the main contribution to Hanoi. At that time, the lake provided fishes, shrimps, water snails, clean and fresh water and regulating flood water for

Hanoi. In the 3rd period, due to the lack of management and failed utilization, the provisioning and regulating services were decreased. The quantity and quality of food productions had been significant reduced, the water was contaminated, the surrounding environment was polluted; flood control function was decreased due to the depth of sedimentation increased year by year. In the third period, the culture and supporting services of West Lake are raising due to high demand from human and nature. West Lake become the destination for many local communities and visitors from the capital city and other provinces, especially during the hot summer days as well as holidays.

3.2. Current status of water qualities, biodiversity, legislative aspects of West Lake

- *Water qualities*: The water quality is being decreased through the years (Table 1). In 1961, the Dissolved Oxygen (DO) was 5,15mg/l, but in 1995 and 2012 it decreased to 4 and 3,1 mg/l respectively. The amount of Ammonium was raising from trace to 2 mg/l during 1961 to 2012. Two other parameters like Biochemical Oxygen Demand (BOD_5) and Chemical Oxygen Demand (COD) which illustrated the contaminated of the water were increased from 21,19 to 187mg/l (BOD_5) and from 10,1 - 370 mg/l (COD).

Table 1. Water quality of West Lake in 1961, 1995, 2012

Parameter	1961	1995	2012
pH	7,4 - 8,0	6,5 - 8,5	6,9 - 9,8
DO (mg/l)	5,15	4	3,1
Cl^- (mg/l)	49,5	42 - 63	-
NH_4^+(mg/l)	trace	0,37 - 0,8	0,5 - 2
PO_4^{3-} (mg/l)	0,71	0,5 - 3,0	0,67 - 1,04
BOD_5 (mg/l)	21,19	39 - 48	16-187
COD (mg/l)	-	10,1 - 40	29 - 370
SS (mg/l)	60 - 130	75 - 225	8,6-147,3

Source: (Mai, Dang, Pham, & Dao, 1961), (Mai, 1995), (Tay Ho DPC & WMA, 2012) (Le, Mai, & Trinh, 1995). Note: - no information

- *Water depth and sediment depth*: After a half century, the West Lake's water level getting shallower. In 1961, the deepest point was 3,5 meters but in 2012 it was only 2,5 meters, the depth of sludge/ sediment was raised from 0,5 meter in 1961 to 1,5 meter in 2012. It is because of a large amount rubbishes and untreated sewage, surface run-off pouring into the lake in decades.

- *Heavy metals chemical composition of mud layer*: The heavy metals in the sludge layer and water will be accumulated into zoobenthos, mollusks, water snails, clams, fishes in the lake while many kind of fishes, clams have been harvested for food. The amount of heavy metals in table 2, shows that sediment parameters increase from 1,37 up to 30 times.

Table 2. Sediment Chemistry of West Lake in 2001 and 2014

Sediment parameter	2001	2014
As (ppm)	17	5,21 - 23,44
Cd (ppm)	0,7	1,53 - 5,72
Hg (ppm)	0,12	1 - 3,6
Cu (ppm)	6	46 - 128,8
Pb (ppm)	22	40 - 204,35
Zn (ppm)	38	100,59 - 503,33

Sources: (Wong, Le, Tran, Nguyen, & Easton, 2001), (Bui, 2014).

- *Aquatic biodiversity*: Almost aquatic plant species were removed from the lake. As to algae, the number of Bacillariophyta division is decrease, whilst Euglenophyta and Cyanobacteria are increase in number, which indicate the water become eutrophicated. Fish species was increasing in number, however, almost of them are invasive alien species (which due to intensive aquaculture practices in 2nd and 3rd period) and become dominated in the fish group of the lake presently (Table 3).

Table 3. Number of fish species in 1961 and 2017

No.	Fish family	1961	2017
		22 species	47 species
1.	Engraulidae	-	1
2.	Cyprinidae	14	26
3.	Cobitidae	1	1
4.	Bagridae	-	1
5.	Loricariidae	-	1
6.	Siluridae	-	1
7.	Clariidae	2	2
8.	Adrianichthyidae	-	1
9.	Hemiramphidae	-	1
10.	Synbranchidae	1	1
11.	Mastacembelidae	-	1
12.	Cichlidae	-	2
13.	Eleotridae	-	1
14.	Gobiidae	1	3
15.	Anabantidae	1	1
16.	Belontidae	-	1
17.	Channidae	2	2

Source: (Mai, Dang, Pham, & Dao, 1961), (Tay Ho DPC, 2017)

- *Legal management documents and activities*: the city authorities deliberated many decrees as well as activities aim to conserve biodiversity, control water quality, and protect natural environment of the lake. However as assessed, there are still many limitation and challenges. The local communities have not been involved much in lake management and conservation activities. Street vendors, visitors are still pouring waste water, throw rubbish on the lake shore and in to the lake. Consequently, water quality is getting worse and worse, natural species was decreased in number, habitat for native and migratory species, including birds was degraded. An example for that is over 200 tons of fish was died out from October 1 - 4, 2016 due to water pollution.

3.3. Lessons learned from management of West Lake: Science -Technology and Policy – Legislation aspects

Science – Technology

- Rubbishes and untreated sewage, sediment from surface run-off caused the raising of sludge and fill up West Lake in decades.
- Development of intensive aquaculture lead negative impacts to the native aquatic biodiversity. Introduction, dominating of many invasive alien fish species increases the competition with the native species.
- Remove almost of the aquatic plant species reduced the capacity in natural purification of the lake and facilitate the development of phytoplankton.
- Overexploitation and over harvesting threaten many native commercial fish and invertebrate species (shrimps, clams, snails).
- Habitat for native and migratory bird was destroyed due to lack of appropriate management means and activities.

Policy – Legislation

- Deliberate too many legal documents, but rather weak in implementation and enforcement.
- Lack of cross-sectional responsibilities and resources.
- Community participation and involvement are still minor.
- In order to maintain the ecosystem services and wise uses of the West Lake, comprehensive and ecosystem-based approaches need to be considered and applied to avoid the above lessons in restoration and better management of the West Lake.

4. CONCLUSION

West Lake is one of the largest natural lake in Hanoi capital city, Vietnam. In ecosystem services, the lake plays important and different roles in the development and resilience of the city.

Although a number of means and activities have been applied and conducted, water quality of the lake is still polluted, biodiversity is decreased.

Though experiences and lesson learned in management and conservation during the past decades, comprehensive and ecosystem-based approaches are recommended to apply for the conservation and management of West Lake (Ho Tay).

ACKNOWLEGEMENT

We would like to express our appreciation to Vietnam National University who support us to complete this paper.

REFERENCES

1. Bui, D. L. (2014). Conservation, utility and propose methods to promote the values of West Lake. *Conservation, development and promoting the values of West Lake - Vietnam National landscape* (pp. 135 - 139). Hanoi: Hanoi Union of Science and Technology Associations.
2. Le, T. H., Mai, D. Y., & Trinh, T. T. (1995). Analysis and assess water quality of some lakes in Hanoi. *Biology Magazine 3 - 1995*, 14 - 18.
3. Mai, D. Y. (1995). Some important natural freshwater lake of Vietnam and the protection of their biodiversity. *6th International Conference on the Conservation and Management of lakes* . Kasumigaura.
4. Mai, D. Y., & Mai, D. H. (2014). Preliminary analysis the impact of climate change and propose methods to response for the West Lake ecosystem. *Conservation, development and promoting the values of West Lake - Vietnam National landscape* (pp. 152-158). Hanoi: Hanoi Union of Science and Technology Associations.
5. Mai, D. Y., Dang, N. T., Pham, V. H., & Dao, V. T. (1961). *Preliminary assessment of species and aquatic resources of West Lake (Hanoi)* . Hanoi: Agriculture Department of Hanoi.
6. Tay Ho DPC, T. H., & planning, V. I. (2017). *synthesis report of The project Assess fish stock and propose measures to preserve and develop the aquatic resources of West lake.* Hanoi: Tay Ho District People's Committee.
7. Tay Ho DPC, T. H., & WMA, W. L. (2012). *Survey, assess water quality, ecosystem and propose wise used methods of West Lake.* Hanoi: Tay Ho District Peoples's Committee.
8. Wong, M. L., Le, Q. H., Tran, T. K., Nguyen, T. P., & Easton, B. (2001). Participatory Environmental Assessment of aquatic resources, West Lake, Hanoi, Vietnam. *International Workshop on Biology*, (pp. 257 - 279). Hanoi.

P3-33

気候変動が琵琶湖の水温･DOに及ぼす影響とそのメカニズム

多鍋 耀介[1], 中谷 祐介[1], 西田 修三[1]

[1] 大阪大学 大学院工学研究科地球総合工学専攻（〒565-0871 大阪府吹田市山田丘2-1）

キーワード: 気候変動, 溶存酸素濃度, 琵琶湖, 数値シミュレーション

抄録

IPCC 第 5 次評価報告書によると，世界的な温暖化は明らかであり，温暖化は人為的な温室効果ガスの増加による可能性が非常に高いと結論づけられた．温暖化は猛暑や豪雨といった異常気象の発生頻度や強度を変化させると予測されており，湖沼生態系にも少なからず影響を及ぼすものと考えられる．そこで，本研究では琵琶湖を対象に，高解像度の GCM の気象出力データを用いた三次元流動水質シミュレーションを行い，気候変動による琵琶湖の水温・DO に及ぼす影響を解析した．その結果，琵琶湖では，将来の気温は年間を通して上昇し，豪雨の発生頻度が増加することが示された．将来は全層で水温が約 1.5℃上昇することが示された．また，底層 DO は約 2 mg/L の減少を示し，気候変動は琵琶湖底層の貧酸素化を助長させることが示唆された．その中でも，水表面での熱交換量の変化が琵琶湖の水質変化に最も支配的であることが示唆された．

1. はじめに

IPCC第5次評価報告書によると，世界的な温暖化は明らかであり，温暖化は人為的な温室効果ガスの増加による可能性が非常に高いと結論づけられた．温暖化は猛暑や豪雨といった異常気象の発生頻度や強度を変化させると予測されており，湖沼生態系にも少なからず影響を及ぼすものと考えられる．

本研究で対象とする琵琶湖は湖面積672km^{2}の日本最大の淡水湖であり，琵琶湖においても，気候変動の影響予測に関する研究が多くなされてきた．例えば, 環境省[1]は全球気候モデルGCM（Global Climate Model）の出力を用いて2015～2039年を対象に琵琶湖水質の将来予測を行い, 表層水温が0.9～1.7℃上昇すること，全循環が弱まる時期が発生すること，それに伴い下層のDO濃度の減少やリン濃度が増加することを指摘した．しかしながら，そのメカニズムは明らかになっておらず，効果的な適応策を講じるにはメカニズムを知る必要がある．

本研究では，まず高解像GCMの気象出力データを用いて将来の琵琶湖における気候変動を明らかにする．そしてそのデータを境界条件に用いた三次元流動水質シミュレーションを行い，気候変動が湖内の水質に及ぼす影響を評価し，そのメカニズムを明らかにする．

2. GCMデータの解析

(1) 手法

一般にGCM出力値にはバイアスが含まれているため，利用する際にはバイアス補正を行う必要があり，本研究では猪俣ら[2]により開発された手法によりバイアス補正を行った．この方法では極値（全体上位0.5%）については通年で補正を行う一方，その他のデータセットについては月別に補正を行うため, 極端現象を考慮することができる．本研究では1979～2003年と2075～2099年の各25年間をそれぞれ現在および将来の参照期間とした．GCM出力値には，気象庁気象研究所の大気大循環モデルGCM20によるSRESのA1Bシナリオにおける計算結果を使用した．GCM20は水平格子サイズが20kmと他のGCMと比べて空間解像度が高く, また1時間間隔の出力値が利用可能という特徴を有している．観測値にはアメダス彦根の毎時データを使用した．ただし，短波放射量は観測項目に含まれていないため，全天日射量で代替した．

(2) 解析結果

図-1に現在期間と将来期間におけるバイアス補正後の気温・短波放射量・風速の旬平均を示す．現在気候値を将来気候値と比較したところ，平均気温は年間を通して約3℃上昇するものの, 各期間の標準偏

差はともに約1.2℃であり大きな差異はみられなかった．平均短波放射量は4月から8月にかけて約1.5MJ/m^2の上昇を示したが，標準偏差に大きな差異はみられなかった．平均風速は1月から4月にかけて若干の増加を示したがそれらを除いた期間では減少する傾向を示した．標準偏差に大きな差異はみられなかった．表-1に1時間降水量の頻度を示す．現況と将来を比較すると10 mm以上の1時間降水量の頻度が増加しており，将来は短時間豪雨の発生回数が増加すると考えられる．

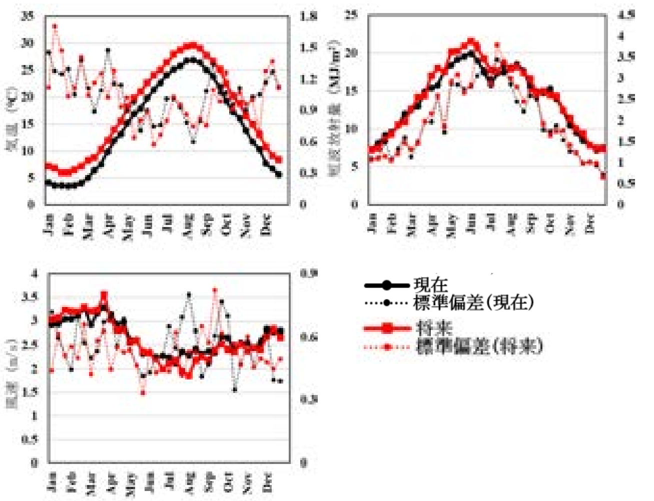


図-1　バイアス補正後の GCM 出力値

表-1　1 時間降水量の頻度

1時間降水量	現在	将来
0 mm	204055	204031
0-1 mm	3788	3102
1-10 mm	10876	11504
10-20 mm	335	403
20-30 mm	49	56
30-50 mm	16	20
50-80 mm	1	4

3. 数値シミュレーション

(1) 手法

数値モデルは準三次元バロクリニック流動水質モデル[3)]を使用した．紙面の都合により，モデルの詳細については既往研究[例えば, 3)]に譲り，ここでは概要のみを以下に示す．デカルト座標系を採用し，計算格子にはスタッガード格子を用いている．水平方向には1km辺長の正方格子によって40×65個のグリッドに分割した．鉛直方向には50層に分割し，層厚は最表層と水深10m以深では2m，表層第2層から水深10mまでは1mとした．

(3) モデルの再現性

2013年3月1日から2年間の助走計算を行い，2015年3月1日～2016年2月28日の計算結果を基に再現性の検証を行った．モデルの再現性は，今津沖中央における水温，DOの鉛直分布の時系列について，計算結果を観測結果と比較することで評価した．気象条件には彦根における毎時観測値を与えた．ただし，風場については，湖岸5地点における地上観測値を基に，逆距離荷重法で補間して求めた空間分布を与えた．流入河川としては主要河川である姉川，安曇川，愛知川，日野川，野洲川を考慮した．これらの河川は観測データが不足しているため，西田ら[4)]においても用いられている分布型流出モデルを用いて流量・水温を算定した．水質濃度は月1回の頻度で実施された平水時観測の結果[5)]を基に与えた．図-2に今津沖中央における水温とDOの時系列について，観測結果と計算結果の比較を示す．観測結果に比べると下層への熱伝播がやや過大評価されているが，4月中旬から1月中旬において，水表面が過熱されることで水温成層が形成されている様子が計算結果でも再現されている．DOについてみると，成層期には底泥による酸素消費の影響を受けて底層濃度が徐々に低下し，全循環によって急激に回復する様子が再現されている．以上より，一部改善の余地は残されているものの，本モデルは琵琶湖北湖における水温・DOの季節変動特性を良好に再現しており，本モデルを用いて気候変動の影響を解析することは可能であると判断した．

(4) ケーススタディの計算条件

前述のバイアス補正を施したGCM出力値を用いて，表-2に示す5種類の計算を行った．計算期間は，それぞれ助走計算の2年間を含む3年間とした．Case-1,2は，現在および将来の計算とし，Case-3,4,5については各要素を将来のGCM出力値に置き換えた計算とした．流入河川の流量・水温については，再現計算と同様に分布型流出モデルを用いて与えた．

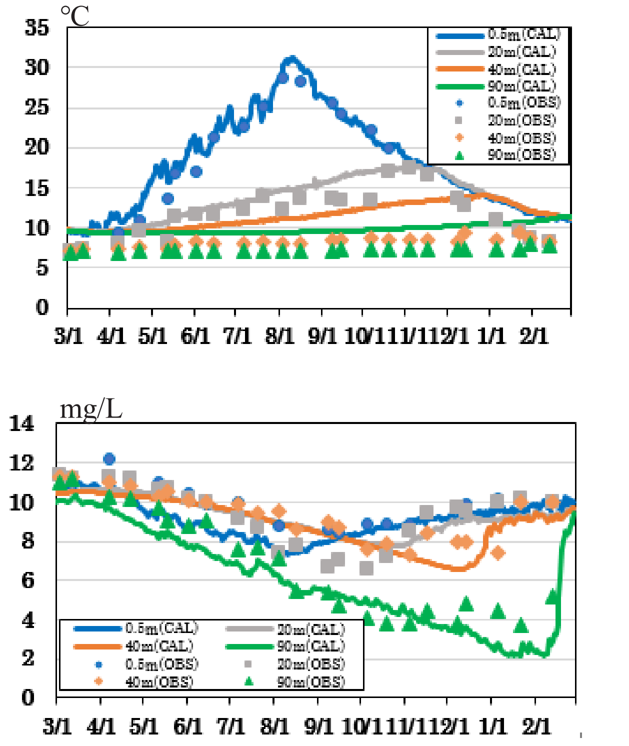


図-2　水温と DO における観測値と計算値の比較

表-2　Case 設定の内容

No.	内容
Case-1	1979 年—1982 年の計算
Case-2	2075 年—2078 年の計算
Case-3	気温･短波放射量を変化させた計算
Case-4	流入河川の流量･水温を変化させた計算
Case-5	風向･風速を変化させた計算

(5) ケーススタディの計算結果

図-3に今津沖中央における水温とDOのCase-1からの変化量の鉛直分布時系列を示す．水温については，Case-2,3の場合は年間を通して全層で約1.5 ℃程の上昇を示したが，Case-4,5の場合は大きな変化はみられなかった．DOについては，Case-4,5の場合では，大きな変化はみられなかったが，Case-2,3においては成層期の中層から底層のDOは約2 mg/L程の減少を示した．熱フラックスが変化することで琵琶湖へと供給される熱量が増加し，底層においても水温が上昇したことで底泥の酸素消費量が増加したことが底層のDOの減少の原因と考えられる．さらに，Case-1とCase-2,3,4,5を比較することで将来は貧酸素化が進行し，将来の変化要因の中でも気温・短波放射量の変化がDOに寄与する割合が大きく，熱フラックスの変化がさらなる貧酸素化を助長することが示唆された．

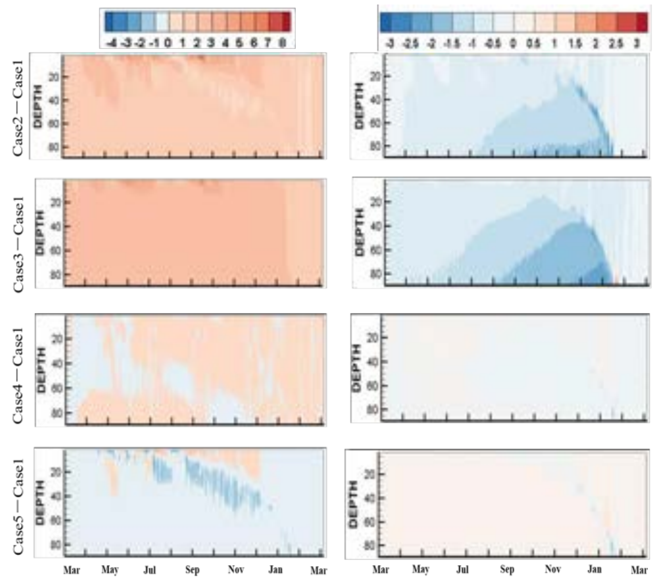


図-3　水温と DO の変化量の鉛直分布時系列

4. 結論

本研究では，気候変動が湖内の水質に及ぼす影響を評価し，そのメカニズムを明らかにした．その結果，将来は全層で水温が1.5℃程の上昇を示した．また，底層の溶存酸素濃度は約2 mg/L減少し，気候変動は琵琶湖底層の貧酸素化を助長させることが示唆された．その中でも，水表面での熱交換の変化が琵琶湖の水質変化に最も支配的であることが示唆された．

謝辞: 本研究を進めるにあたり，気象庁気象研究所にはGCMデータをご提供頂きました．ここに記し深く感謝の意を表します

引用文献

[1]　環境省水・大気環境局水環境課: 気候変動による水質等への影響解明調査，2013.

[2]　猪俣広典，竹内邦良，深見和彦: GCM 降水量データの正手法開発，土木技術資料，51-10，2009.

[3]　中辻啓二，許再寧，室田明: 三次元表層密度流の数値実験，土木学会論文集，第 432/ II-15，pp.214-218，1991.

[4　西田修三，北畠大督，入江政安: 淀川流域圏の水環境と大阪湾への影響解析，水工学論文集，第 51 巻，2007.

[5]　滋賀県: 環境白書資料編 平成 25-28 年度版，2013-2016.

P3-34

バイカル湖堆積物に記録された植生変動の解析

竹原 景子[1], 中國 正寿[1], 山本 修一[1]
[1]創価大学大学院 工学研究科 環境共生工学専攻

キーワード：バイカル湖，リグニンフェノール，TMAH、植生解析

抄録

過去の気候や植生環境を知ることは、近未来に起こり得る急激な気候変動に対する対策を講じることに繋がる。本研究では、北半球高緯度域に位置するバイカル湖の堆積物試料中に含まれている陸上起源有機物を、過去の周辺の植生やそれらの流入環境を知るための指標として用い、バイカル湖周辺の古環境変動の解析を試みた。バイカル湖堆積物試料からは、リグニンや長鎖の脂肪酸、クチン酸などの陸上植物に特徴的な有機物が検出された。これら有機物は、いずれも堆積物試料の 36–50 cm で最も高い傾向を示し、この時代に、大きな植物の流入があったことを示した。さらに、リグニンを用いた植生指標は、この時に、草本植物と分解物の高い寄与があったことを示した。これらの植生の特徴は、現在のバイカル湖の西岸と類似しており、西岸から来る強い風がこれらの有機物を運び込んだと考えられた。

1. はじめに

湖沼環境は，豊かな生態系を支える場であるとともに，河川の流入，周辺の植生や土地利用など，さまざまな影響を受ける。近年，温暖化に伴う気候変動は，自然環境に大きな影響を与えると，懸念されており，これは，湖沼環境も例外ではない。その環境変化が与える影響を予測するために，さまざまな「指標」を用いて過去の環境変動の復元から将来を予測する古環境解析は，その一つの方法として有用である。

沿岸域や湖沼などの水圏堆積物中の有機物は，陸上から河川や大気を通して供給された陸起源有機物と，水中で生産された有機物で構成されている。これらの有機物の内，生分解作用を受けにくい難分解性有機物や，貧酸素環境下に置かれた有機物は、堆積物中に長期的に保存される。そのため，堆積物中の有機物は，当時の地球環境に関する情報を与えるものとして非常に重要であり、それらは過去の気候変動を知るための「指標」として用いられてきた。その中でも，植物由来の有機物は，植物種によって特徴的な有機組成を有しており，過去の周辺の植生やそれらの流入環境をとらえることができる。例えば、維管束植物の主要な有機物組成であるリグニンは、針葉樹がグアイアシルリグニンによって構成されているのに対して、広葉樹はグアイアシルリグニンとシリンギルリグニンで、草本類はそれらに加えシンナミルリグニンで構成されており、その組成は植物間で大きく異なっている。

ACIA（Arctic Climate Impact Assesment：北極圏気候影響評価）によると、地球気候変動モデルによって推定された温暖化は、北半球の高緯度域でもっともその影響が強く出ると予想している[1]。そのため、長期的な気候変動に伴う環境変化を見るには、北半球の高緯度域の研究が重要となる。北半球のシベリア地域に位置するバイカル湖（図1）は，冬は高気圧，夏は低気圧という季節によって気圧配置が大きく異なる環境下にある。そのため，気候変動に伴う長期的な気圧の変動は，過去の周辺の植生やそれらの流入環境に影響を与えたことが考えられる。

そこで、本研究では、バイカル湖堆積物中の有機物（とりわけ陸上植物の指標であるリグニンフェノールやクチン酸）の分析を行い、バイカル湖周辺の植生およびそれらの流入環境解析を行うことを目的とする。

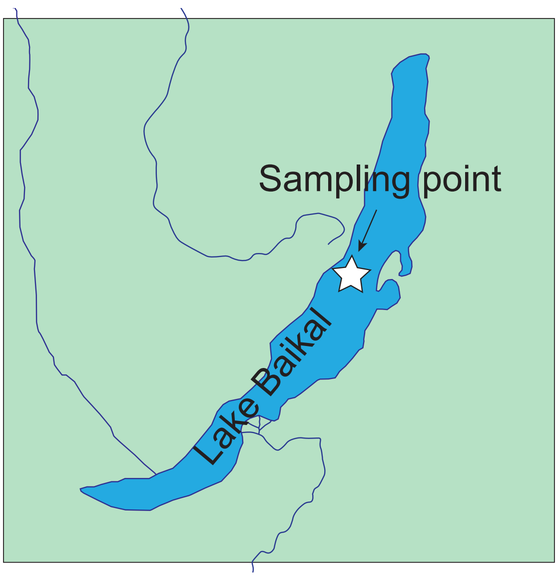


図 1. バイカル湖と堆積物試料採取地点

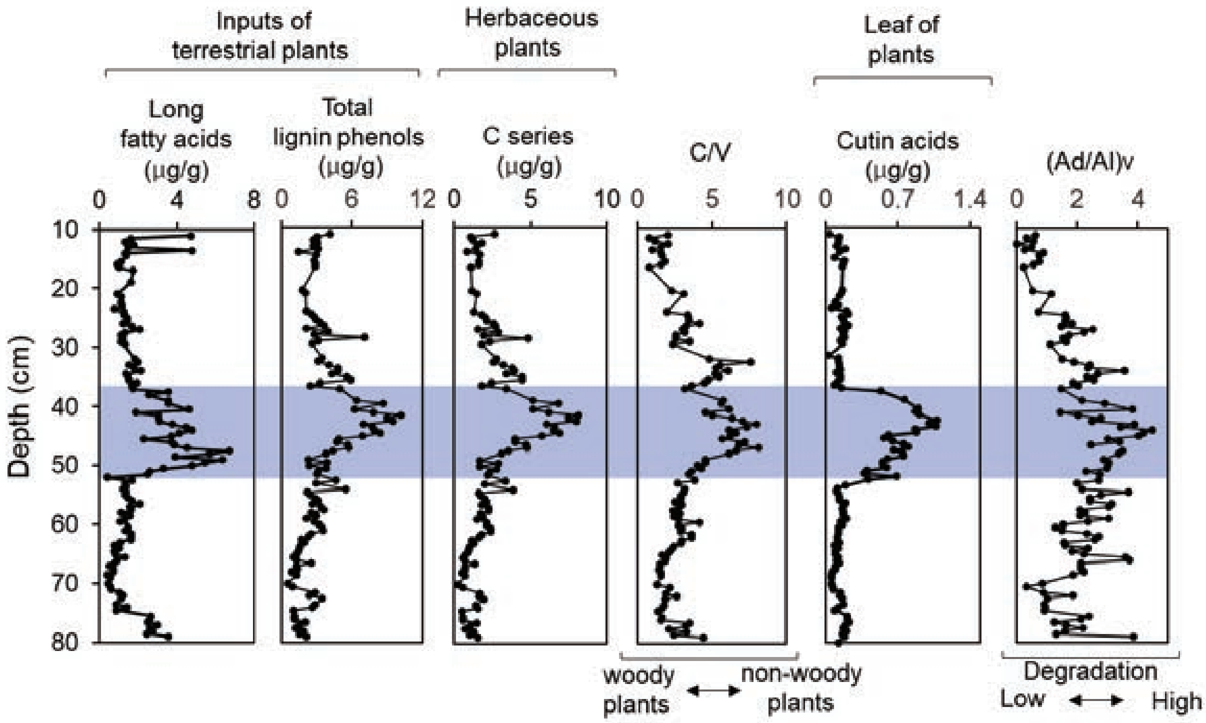


図 2. ver98-1 st.5 PA コア中の有機物指標の深度分布. 長鎖脂肪酸 (C_{24}–C_{32}) および総リグニン量は，陸上植物に由来し，これらの増加は植物の寄与が高いことを示す．リグニンの C シリーズは，草本植物に特徴的なリグニンであり，リグニンフェノールの C/V 比は，草本の寄与が高い時に高い値を示す．クチン酸は，植物の葉のクチクラ層を構成する有機物である．(Ad/Al)v 比は，リグニンフェノールのバニリル類の中でアルデヒド類 (Al) に対する酸類 (Ad) の比であり，リグニンが糸状菌などによって酸化的に分解されると，高い(Ad/Al)v 比を示す．クチン酸は 8,16-/9,16-/10,16-dihydroxyhexadecanoic acid の総和を示す.

2. 方法

本研究では、バイカル湖アカデミシャンリッジ (53°44'33" N, 108°24'35"E, 水深 325 m)で採取した ver.98-1 st-5 パイロットコア PA (試料長 996 mm)を用いた。

堆積物試料の有機物分析は先行研究[3-5]と同様に、Off-line TMAH GC–MS 法により行った。乾燥試料約 300 mg を 10 ml ガラスアンプル管に量り取り、25% TMAH (Tetramethylammonium hydroxide: 97%, SIGMA-ALDRCHI 社)-メタノール(特級, 和光純薬)溶液 150 μL, Nonadecanoic-d37 acid-メタノール(特級, 和光純薬)溶液(100 ng/μL)を内部標準試薬として 50 μL を添加した。その後、減圧デシケーターおよび窒素気流下の 40℃ホットプレートで乾燥させ、減圧状態にして封管した。そして電気炉にて 300℃で 30 分間熱反応を行った。反応後、300 μl の酢酸エチルで 3 回抽出を行い、減圧デシケーターで乾燥させた。その後、酢酸エチル 25 μl でメスアップを行い、2 μl を GC–MS [6890N GC 5973 MS (Agilent Technologies)]にて分析を行った。

3. 結果

ver.98-1 st-5 PA コアから検出された、長鎖脂肪酸量、総リグニン量 (バニリル類 [V]+シリンギル類 [S]+シンナミル類 [C]), C リグニン, リグニンの C/V 比, (Ad/Al)v 比およびクチン酸の深度分布を図 2 に示す。長鎖脂肪酸、リグニン及びクチン酸は、陸上植物の指標として用いられている。深度約 36–50 cm にかけて高い値を示し、湖環境に陸上植物の大きな流入があったことを示している。C リグニンは、草本植物が多く持つリグニン類である。C/V 比は、リグニンのバニリル類に対するシンナミル類の比で、値が高くなるほど草本植物の寄与が高いことを示す。いずれも、植物の流入の指標と同様に、36–50 cm にかけて高い値を示しており、この時の陸上植物は、草本植物によって主に構成されていることを示している。(Ad/Al)v 比は、リグニンのアルデヒド類に対する酸類の比で、値が高くなるほど分解物の寄与が高いことを示す。この比も同様に、深度約 36–50 cm にかけて高い値を示し、この時期に分解物の寄与も高くなったことを示唆している。

4. 考察

陸上植物の指標からみた傾向から、深度約 36–50 cm にかけての陸上植物の大きな流入は、分解物を含み、

草本に富んだ植物片であることが示された。現代のバイカル湖の東西の植生環境は大きく異なっている。西岸は、草本や針葉樹、分解物を含む砂礫から、構成されているのに対して、東岸は、多様な木本植物から成る[7]。草本と分解物で構成されていた堆積物指標に記録された大きな植物の湖への流入時期（深度約 36–50 cm）は、現代の植生分布と比較すると、西岸の植生環境と一致している。

現在のバイカル湖の西岸部の森林環境は、バイカル湖周辺に吹き付ける風の影響が大きいことが知られている[7]。この風は、3000mの山脈から吹き付ける強風で、低温かつ乾燥している特徴を有する。この風が吹き付ける場では、立木をなぎ倒し、乾燥が進み草原化させる。風の向きは、北と南からと、西から東に向かって吹く。そして、この風は、特に、寒気に強くなる傾向がある。したがって、西岸からの植物片の流入の増加と考えられる深度約 36–50 cm での結果は、この風が、過去のバイカル湖気候で、現代よりも長期的な期間で強化されたために得られた記録ではないかと考えられる。実際に、現代よりも寒冷だった時代は、過去の地球史で何度も繰り返し生じてきた。残念ながら、本コアにおける正確な年代測定との比較は、まだ行っていないが、これらの結果は、確かに湖底の堆積物が周りの植生およびそれらの流入史を記録していることを示していると言える。

5. 結論

陸上植物の指標からみた傾向から、深度約 36–50 cmにかけて、分解物と草本に富んだ植物片の流入が起きたことが明らかになった。現代のバイカル湖に吹く、西から東への風は、バイカル湖西岸を乾燥化させ、草原化させている。この風は寒気に強く吹く特徴を有していることから、深度約 36–50 cm における過去のバイカル湖気候で、現代よりも長期的な期間で風が強化されたために、草原化が進み、堆積していた分解物と共に湖内へ流入したことで得られた記録ではないかと考えられた。

引用文献

[1] Arctic Climate Impact Assessment (ACIA): Impacts of a Warming Arctic: Arctic Climate Impact Assessment, Cambridge University Press, 2014.

[2] E. Bezrukova, E.V. Bezrukova, A.V. Belov and L.A. Orlova: Holocene vegetation and climate variability in North Pre-Baikal region, East Siberia, Russia, Quaternary International, Vol. 237, pp. 74-82, 2011.

[3] M. Nakakuni, C. Dairiki, G. Kaur and S. Yamamoto: Stanol to sterol ratios in late Quaternary sediments from southern California: An indicator for continuous variability of the oxygen minimum zone. Organic Geochemistry, Vol. 111, pp. 126-135, 2017.

[4] M. Nakakuni, K. Takehara, N. Nakatomi, J. Higuchi, M. Yamane and S. Yamamoto: Sterol and stanol compositions in sediments from the Bungaku-no-ike pond, Tokyo, Japan: Examination of stanol sources. Researches in Organic Geochemistry, Vol. 33, pp. 15-24, 2017.

[5] M. Nakakuni, J. Kitano, H. Uemura and S. Yamamoto: Modern sediment records of stanol to sterol ratios in Lake Suigetsu, Japan: An indicator of variable lacustrine redox conditions. Organic Geochemistry, Vol. 119, pp. 59-71, 2018.

[6] 森野浩, 宮崎信之:バイカル湖 古代湖のフィールドサイエンス, 東京大学出版会, 1994.