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The Dynamic of Phytoplankton Community Structure in Face of Warming Climate in A Tropical Man-Made Lake

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Abstract

In freshwater ecosystems, water temperature plays as an environmental factor that regulates its structure and function. A research on the impacts of changes in temperature to the dynamics of the Phytoplankton community structure has been done. Data from nineteen-year period (1995 to 2013) were collected from Cirata Reservoir as an example of artificial tropical lake in Indonesia. The research aimed to determine the changes of water temperature as the impact of climate warming on the dynamics of phytoplankton community structure. Different measures such as species richness, diversity index, and abundance were measured in order to understand the changes of phytoplankton community structure. Trend analysis, linear regression, and correlation were applied to achieve our objective. The study revealed that changes in water temperature have affected the species richness, but not the diversity index and abundance of the phytoplankton. Bacilariophyceae and Cyanophyceae were found as two predominant phytoplankton classes in the lake with percentage of 48,45 and 41,43 respectively, assuming their capacity to adapt the new environment. This study suggests that climate warming implies changes of the freshwater ecosystems.

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INTRODUCTION

Freshwater ecosystem is a vital component not only for human being but also for other creatures. Many freshwater services are openly available like habitat for plants and animals, recreation, transportation, flood control, and purification of human and industrial wastes (Baron & Poff, 2004; Karabulut et al., 2016). But lately as human population grow and uncontrolled landscape changing happened, threats to freshwater in the matter of quality and quantity reach its critical point. Water pollution and water scarcity is reported excessively occurred in several places. This freshwater problem hits not only the developing countries but also the developed countries (Brown & Matlock, 2011).

The global mean surface of air temperature has risen about 0.7± 0.2 °C during the 20th century (IPCC, 2007). Since 1990 a report has mentioned that an escalation in mean and maximum temperatures of lakes at temperate area was a repercussion of an increase of annual air temperatures in those lakes over the past 20 years (Thorp, 1996). Changing in water temperature therefore may affect the freshwater condition as it links directly to water cycle. The effects of climate warming on freshwater ecosystems become very crucial and need an urgent solution. That is not only due to its direct need for living things but also because it will dynamically modify to maintain its resilience. Exacerbated eutrophication may occur as general effect of climate change in freshwater lentic system which then alter food webs, change habitat availability and quality (Ficke et al., 2007).

Due to phytoplankton ability to perform photosynthesis in the base of aquatic food chain, changes of its composition will influence significantly the higher trophic levels (Cellamare et al., 2011). Phytoplankton dynamics are linked to annual fluctuations of temperature (Cloern et al., 2014; Aryawati et al., 2016), shifting temperature will affect the producers directly through physiology and indirectly by changing water column stratification and resource availability, mainly nutrients and light, or intensified grazing by heterotrophs (Winder & Sommer, 2012). Changes in phytoplankton can have far-reaching consequences for ecosystem structure and functioning.

Studies on dynamics of phytoplankton communities under climate warming in subtropical reservoirs have been extensively done. In contrast, their variability and dynamics in tropical lakes remain poorly explored. Furthermore, the complex community interactions of phytoplankton also depend on its original community composition, as well as the intensity and frequency of disturbances (Soares, 2013). This paper aims to describe the dynamics of phytoplankton community structure in Cirata Reservoir, a tropical man-made lake in Indonesia. A long-term analysis on the phyoplankton dynamic in face of climate warming enable us understand how tropical freshwater acosystems evolve toward new stability.

METHODS

Cirata Reservoir is one of cascade lakes in Citarum River which is located within three regencies in West Java Indonesia: Cianjur, Purwakarta, and Bandung Barat Regency. Built in 1988, Cirata Reservoir along with Saguling Reservoir was established to maintain energy security in Java and Bali Islands. With the catchment area of 603.200 Ha and mean depth of 34.9 m, Cirata is the biggest hydroelectric power in Southeast Asia that is able to produce 1,428 GWh per year (Figure 1).

Citarum, as one of the biggest river in West Java, supplies about two thirds of Cirata water. The river plays an important role for people living not only in West Java but also Jakarta Province. Based on the report collected by Institute of Ecology (IoE) Universitas Padjadjaran, the current water quality in most of stations of upper Citarum Watershed is poor, and the pollution has gone beyond the maximum of allowable levels. Over-exploitation and habitat or land use change are past major anthropogenic pressures towards the river environment. With the total length of 350 km, lately this river is categorized as the notorious polluted sites around the world (Sunardi, et al., 2012) and become one of the dirtiest rivers in the world (Cavelle, 2013). The Citarum River directly affects the water quality of Cirata Reservoir as proved by its eutrophic state for the past few years (IoE, 2015). The other catchments, like Cisokan, Cikundul and smaller catchments, also contribute in watering Cirata.

Temperature data and Phytoplankton sample collection

Long-term water quality monitoring (1995-2013) of Cirata Reservoir have been done by Institute of Ecology Universitas Padjadjaran, Bandung Institute of Technology, and Public Work Agency of Bandung City. About 30-L water sample from each sampling site were collected using plankton net no. 25 with diameter of 30 cm. All the samples were taken from 20 cm water

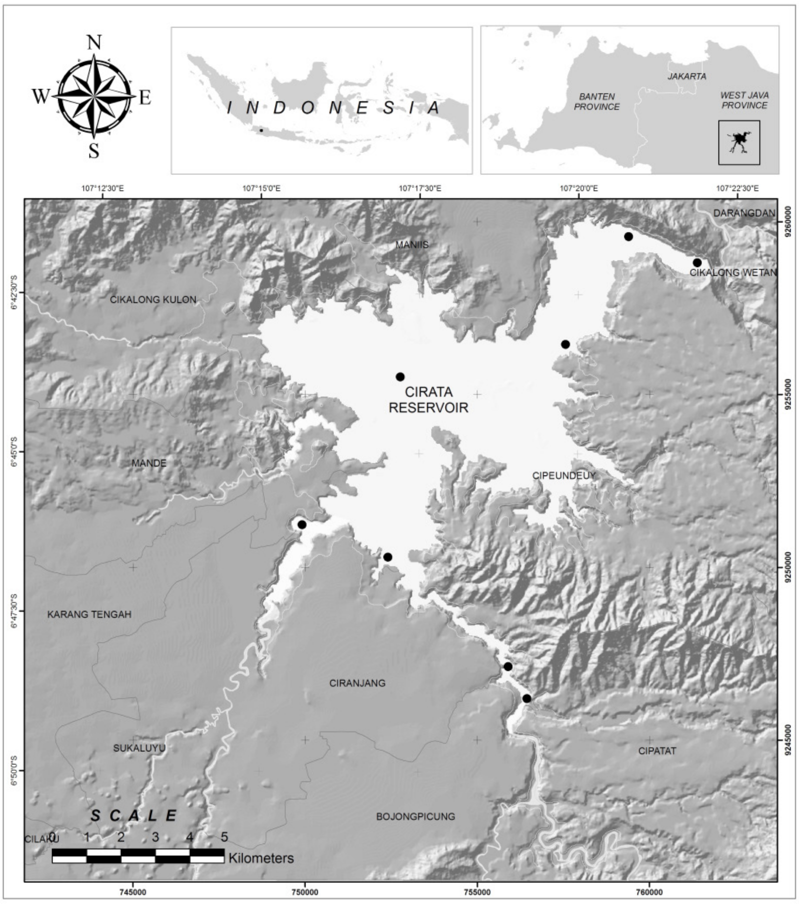

Figure 1. Study Location: Cirata Reservoir (Dots denote the sampling stations).

depth. The samples were then preserved in 4% formaldehyde and taken to the laboratory for microscopic identification. Samplings normally started from about 11.00 AM and finished at 14.00 PM. The water temperature and transparency were measured on-site using an Hg thermometer and a Secchi-disk, respectively (APHA, 1989). Other water samples were collected for other physicochemical analysis. Figure 2 presents the situation and sampling activities in Cirata Reservoir.

Parameters for community structure and statistical analysis

To evaluate the community structure of phytoplankton, three parameters were counted: species richness, diversity index, and abundance *(N)* of phytoplankton. Species richness of the phytoplankton was obtained by calculate the total number of species in each of the water sample. As for diversity index, it was calculated using Shanon-Wiener equation:

$$H' = -\sum_{i-1}^{s}\left(\frac{ni}{N}\right) ln\left(\frac{ni}{N}\right)$$

Where H' = Shanon-Wiener Diversity Index, ni = total number of plankton and species identified, and N = total number of plankton. Diversity index (H') was categorized as "low" if the result below 1 (< 1), and "middle" if the number laid between 1 and 3 ($1 < H' < 3$), or "high" when above 3 (> 3).

While the abundance of phytoplankton was calculaed using formula:

$$N = \left(\frac{Vk}{Vp}\right) x \left(\frac{1}{Vs}\right) x \left(n\right)$$

Where N = total number of plankton per liter (ind/L), Vs = total volume of filtered water, Vk = total volume of concentrated water, Vp = total volume of analyzed of water, and n = number of species identified.

Data analysis

Trend analysis, simple linear regression and correlation were used for statistical analysis purposes. Trend analysis was employed to understand the long-term tendency of changes in temperature and water transparency, aw well as the phytoplankton community structure in Cirata during 1995-2013. As for linear regression, ana-

Figure 2. The situation and sampling activities in Cirata Reservoir

lysis was made to determine the relationship between phytoplankton community structures and the changes in temperature. While the correlation analysis was done to identify the strength of such relationship.

RESULTS AND DISCUSSION

Water temperature

The result showed that the average water temperature of Cirata lake fluctuated; no generic pattern of temperature was seen. The range of water temperature was 26.50 – 30.86°C with the highest temperature in 2003, and the lowest in 2005 (Figure 3). The result indicated that the temperature has increased up to 0.54°C during the period, or equal to about 0.029°C annually.

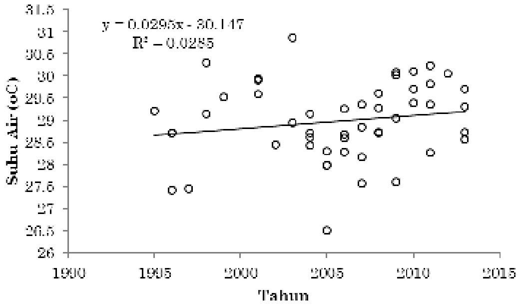

Figure 3. Trend of water temperature in Cirata Lake over the period of 1995-2013.

Species richness, diversity index, and abundance

A total of 40 species belongs to 15 classes were identified in Cirata Lake in the period of 19 years. The result shows that the species richness of phytoplankton tended to increase along with the year (Figure 4-A), and the statistical analysis shows that the richness increment was determined by the increased temperature (Table 1). The study has revealed that the phytoplankton diversity index tended to decrease (Figure 4-B). The lowest number of diversity index was 0.14 in 2004, while the highest was 2.52 in 2007. However, the warming water did not indicate a significant effect on the decrease in phytoplankton diversity index (see Table 1). During 19-year period, the results indicated that the phytoplankton abundance decreased up to 21,157 cells/L per year (Figure 4-C). The study showed that within 3°C temperature shift, approximately a number of 75,432 cells/L phytoplankton declined; nonetheless the statistical significance of the relationship was not significant (as indicated by the number of R2 (0.0007) and p-value (0.8569), Table 1).

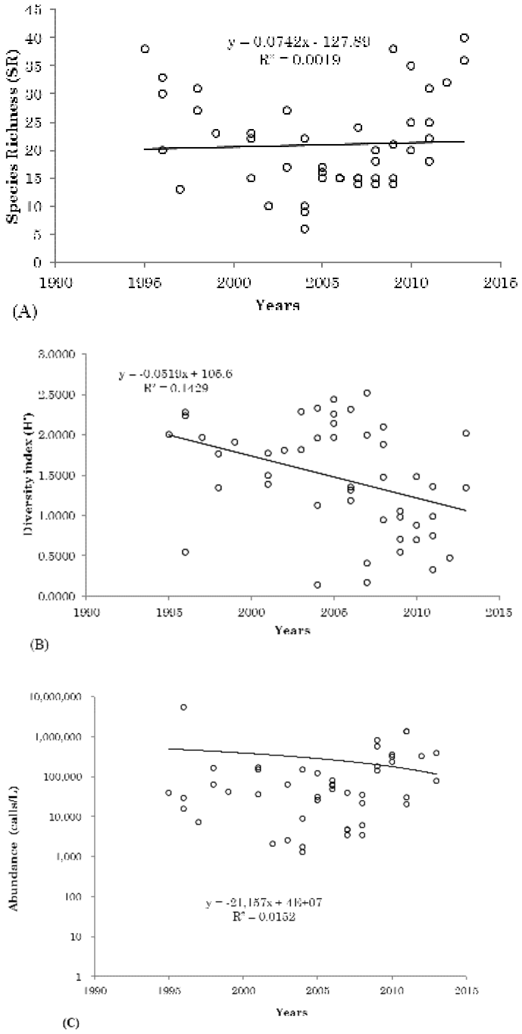

Figure 4. Trend in species richness (A), diversity index (B), and abundance of Phytoplankton in Cirata Reservoir during 19 years of study.

Table 1. Regression and correlation analysis between temperature and parameters for Phytoplankton community structures in Cirata Reservoir for 19 years (1995-2013)

Food categories	Slope	R^2	P-value	r
Temperature and species richness	+3.213	0.1163	0.0177	0.342
Temperature and diversity index	-0.1941	0.0664	0.0768	-0.258
Temperature and abundance	-25.144	0.0007	0.8569	-0.027

Based on the percentage composition (Figure 5), phytoplankton which belong to Bacilariophyceae were dominant (48.45%) followed by Cyanophyceae (41.13%), Chlorophyceae (2.15%). The dominance of *Fragilaria* sp. (Bacilariophyceae) was started by the early period until the mid-period (See Figure 6). As for *Synedra* sp (Bacilariophyceae) always appears every year but its appearance was escalating significantly at the end of the study period. Unlike *Synedra* sp, *Volvox* sp. (Chlorophyceae) dominates at the beginning of the study period but tends to disappear in the middle and then its abundance is increasing again by the end of the period. In contrast to these two species, *Oscillatoria* sp. (Cyanophyceae) more dominant in the mid-period until end-period of study than at the beginning. Furthermore, altered with *Microcystis* sp. which is almost appeared every year, *Microcystis seruginosa* only appeared in the mid-period. However, the study also shows the dominant appearance of *Staniera* sp which categorized as Cyanophyceae in 2013.

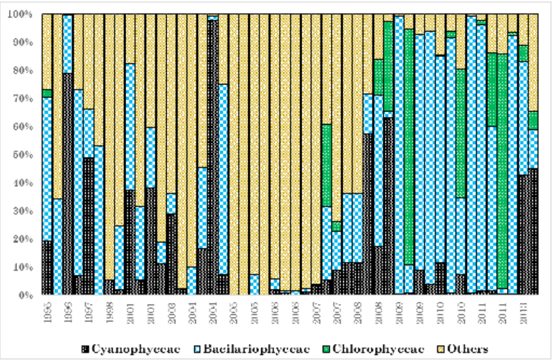

Figure 5. Class composition of phytoplankton in Cirata Reservoir for 19 years (1995-2013)

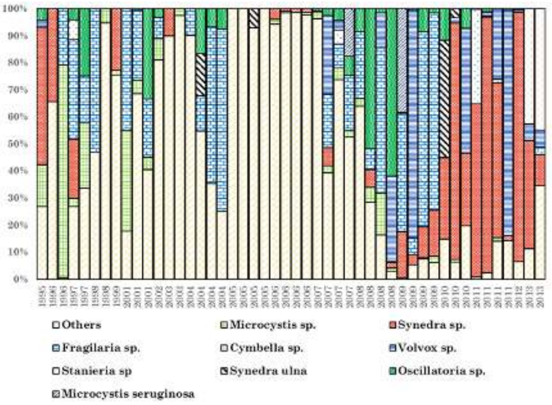

Figure 6. Species composition of phytoplankton in Cirata Reservoir for 19 years (1995-2013)

Warmer air temperature may result in warmer surface water through heat transfer conduction. A rising water temperature in Cirata

Reservoir in last 19 years could be an influence of warmer air temperature. Compared with subtropical lake which has annual increment of 0.089°C (Vincent, 2009), Cirata experiences lower water temperature shift. The scale of water temperature escalation of Cirata Reservoir is in the range of warming rate of air temperature in Indonesia which falls between 0.2 to 0.3°C per decade (Boer & Faqih 2004; Candradijaya et al., 2014). In the lake, shifting temperature can cause the surface layers become warmer but cooler at certain depths which leads to stronger water stratification, and hence vertical mixing of water. The shifting temperature and mixing water have an immediate influence to the live of phytoplankton (Winder & Sommer, 2012; Ndebele-Murisa et al., 2010; Tirok & Gaedke, 2007). The interactions between climate warming and phytoplankton are complex. Many factors contribute to the dynamic in abundance, distribution, and the structure of community, such as predation and resource availability. As an artificial lake, Cirata is facing severe problem of eutrophication. The effects of eutrophication are also potentially mediated by climate. High level of nutrients, pollution load and sediment contains organic matters in Cirata (Zahidah et al., 2011; IoE, 2015) have a possibility to promote certain species of phytoplankton to grow.

The river flows could also carry phytoplankton species into the lake. When the temperature and nutrients supports the growth of phytoplankton species, the species easily adapt to the environmental conditions in Cirata. One of the new emerging species in Cirata during the the study period was *Stanieria* sp, member of Cyanophyceae. In general, this class is a poor quality food for zooplankton (Wilson et al., 2009), and can be toxic to zooplankton (Hansson et al., 2007); Cyanophyceae members may be free from predation of zooplankton. No study indicate the better performance of Cyanophyceae under rising temperature (Moss et al., 2003), however, this study has shown the opposite result.

The appearance of Cyanophyceae, specifically *Stanieria* sp. was dominant in mid-period until end-period when the temperatures were slightly higher than the average. Therefore, it is predicted that these species could thrive under the increase of temperature. According to Hays et al. (2005), new species appearing in a body of water will be followed by the persistence to dominate or even become a key species in water body.

Vertical mixing of water is reported to affect the distribution of phytoplankton, and change the composition and abundance (Ndebele-Murisa et al., 2010), and finally the diversity in freshwater ecosystem. In Cirata, despite an increase in the number of species, the distribution of each individual was uneven. One group or species is more adaptable than the others causing a decrease in diversty, mainly if such group or species becomes pedominant. Schabhüttl et al. (2013) stated that an increase of 4°C can have a negative impact on phytoplankton diversity. However, the warming water seemed not to affect phytoplankton diversity in Cirata.

Our study revealed that the abundance of phytoplankton has no correlation with warmer temperature in Cirata. However, the tendency of decrease in phytoplankton abundance could be caused by increasing stratification that limits nutrient supply (Boyce et al., 2010). Increased zooplankton grazing might limit phytoplankton abundance as well, but information discussing this correlation is few. The other reason, the declined phytoplankton production was caused by the temperature limitation of its growth rate (Cloern & Dufford, 2005).

Bacilariophyceae, Cyanophyceae, and Chlorophyceae were the classes that dominated the Cirata water. This is presumably because the classes play an important role in the food chain, and have the ability to distribute widely in the waters. For example, diatom is the most important food supply for primary consumers (Schabhüttl et al., 2013) such as zooplankton, invertebrate larvae and nekton. During the study period, it appeared that diatom (e.g. *Synedra* sp) was the dominant group throughout the years. Diatoms seem to have the capacity to either fix their selves to the substrate or float in the water column (Morales, 2001). Therefore, they have a high ability to tolerate changes in environmental conditions of waters. The studies have indicated that diatoms are indicators for climatic changes (Recasens et al., 2015; Barron et al. 2013). Domination of Diatomae used to be main characteristic features of tropical freshwater (Dunck et al., 2012), such as Cirata.

CONCLUSION

This study emphasized that warming temperature contribute to changes in phytoplankton community structure in tropical lake. The increased species richness was obvious as the impacts of climate warming. Warming climate may promote certain species to develop in new environment. The research found Bacilariophyceae and Cyanophyceae to be dominant in the lake ecosystem assuming their good capacity to adapt the temperature, compared to remaining groups. The increased temperature seems to facilitate the freshwater ecosystem development.

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REFERENCES

APHA. (1989). *Standard Methods for the Examination of Water and Wastewater*. 17th edition. Washington D. C.: American Public Health Association.

Aryawati, R., Bengen, D. G., Prartono, T., & Zulkifli, H. (2016). Harmful Algal in Banyuasin Coastal Waters, South Sumatera. *Biosaintifika: Journal of Biology & Biology Education*, 8(2), 231-239.

Baron, J. S., & Poff, N. L. (2004). Sustaining healthy freshwater ecosystems. *Water Resources Update*, 127, 52-58.

Barron, J. A., Bukry, D., Field, D. B., & Finney, B. (2013). Response of diatoms and silicoflagelates to climate change and warming in the California Current during the past 250 years and the recent rice of toxic diatom Pseudo-nitzschia australis. *Quaternary International,* 310, 140–154.

Boer, R., & Faqih, A. (2004). Current and future rainfall variability in Indonesia: in an integrated assessment of climate change impacts, adaptation and vulnerability in watershed areas and communities in Southeast Asia. Report form AIACC Project. http://sedac.ciesi.org/aiacc/progress?FinalRept_AIACC_AS21.pdf

Boyce, D. G., Lewis, M. R., & Worm, B. (2010). Global phytoplankton decline over the past century. *Nature*, 466(7306), 591-596.

Brown, A., & Matlock, M. D. (2011). *A review of water scarcity indices and methodologies*. University of Arkansas: Sustainability consortium.

Candradijaya, A., Kurmana, C., Syaukat, Y., Syaufina, L., & Faqih, A. (2014). Climate change impact on rice yield and adaptation response of local farmers in Sumedang District, West Java, Indonesia. *International Journal of Ecosystem,* 4(5), 212-223.

Cavelle, J. (2013). A political ecology of the Citarum river basin: exploring integrated water resources. *Berkeley Undergraduate Journal*, 86-107.

Cellamare, M., Morin, S., & Coste, M. (2011). Ecological assessment of French Atlantic lakes based on phytoplankton, phytobenthos and macrophytes. *Environmental Monitoring and Assessment*, 184(8), 4685-4708.

Cloern, J. E., Foster, S. Q., & Kleckner, A. E. (2014). Phytoplankton primary production in the world's estuarine-coastal ecosystems. *Biogeosciences*, 11(9), 2477-2501.

Dunck, B., Nogueira, I. D. S., & Machado, M. S. D. (2012). Planktonic diatoms in lotic and lentic environments in the Lago dos Tigres hydrologic system (Britânia, Goiás, Brazil): Coscinodiscophyceae and Fragilariophyceae. *Brazilian Journal of Botany*, 35(2),181-193.

Ficke, A. D., Myrick, C. A., & Hansen, L. J. (2007). Potential impacts of global climate change on freshwater fisheries. *Reviews in Fish Biology and Fisheries*, 17(4), 581-613.

Hansson, L. A., Hylander, S., & Sommaruga, R. (2007). Escape from UV threats in zooplankton: a cocktail of behavior and protective pigmentation. *Ecology*, 88(8), 1932-1939.

Hays, G. C., Richardson, A. J., & Robinson, C. (2005). Climate change and marine plankton. *Trends in Ecology and Evolution*, 20(6), 337-344.

Institute of Ecology (IOE). (2015). *Cirata Annual Report*. Institute document for Monitoring Cirata Reservoir

IPCC. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K & Reisinger, A.* (eds.)]. Switzerland: IPCC, Geneva.

Karabulut, A., Egoh, B. N., Lanzanova, D., Grizzetti, B., Bidoglio, G., Pagliero, L., Bouraoui, F., Aloe, A., Reynaud, A., Maes, J., Bandecesteele, I. & Mubareka, S. (2016). Mapping water provisioning services to support the ecosystem-water-food-energy nexus in the Danube river basin. *Ecosystem services*, 17, 278-292.

Morales, E. A. (2001). Morphological studies in selected fragilarioid diatoms (Bacillariophyceae) from Connecticut waters, USA. *Proceedings of the Academy of Natural Sciences of Philadelphia*, 151, 39-54.

Moss, B., McKee, D., Atkinson, D., Collings, S. E., Eaton, J. W. & Gill, A. B. (2003). How important is climate? Effects of warming, nutrient addition and fish on phytoplankton assemblages in temperate lakes. *Applied Ecology*, 40(5), 782-792.

Ndebele-Murisa, M., Musil, C. F. & Raitt, L. (2010). A review of phytoplankton dynamics in tropical African lakes. *South African Journal of Science,* 106(1-2), 13-18.

Recasens, C., Ariztegui, D., Maidana, N. I., Zolitschka, B. & Pasado Science Team. (2015). Diatoms as indicators of hydrological and climate changes in Laguna Potrok Aike (Patagonia) since the late Pleistocene. *Paleogeography, Paleoclimatology, Paleoecology*, 417, 309-319.

Schabhüttl, S., Hingsamer, P., Weigelhofer, G., Hein, T., Weigert, A. & Striebel, M. (2013). Temperature and species richness effects in phytoplankton communities. *Journal of Oecologia*, 171(2), 527-536.

Soares, E. M., Figueredo, S. S., Gucker, B. & Boechat, I. G. (2013). Effects of growth condition on succession patterns in tropocal phytoplankton assemblages subjected to experimental eutrophication. *Plankton Research*, 35(5), 1141-1153.

Sunardi, Gunawan, B., Manatunge, J. & Pratiwi, F. D. (2012). Livelihood status of resettlers affected by the Saguling Dam project, 25 years after inundation. *Water Resources Development*, 20(1), 22-31.

Thorp, J. H. (1996). *Aquatic Ecology Series: Freshwater Benthic Ecosystem*. United States of America: Elsevier.

Tirok, K., & Gaedke, U. (2007). The effect of irradiance, vertical mixing and temperature on spring phytoplankton dynamics under climate change: long-term observations and model analysis. *Oecologia,* 150(4), 625-642.

Vincent, W. F. (2009). Effects of climate change on lakes. *Pollution and Remediation*, 55-60

Wilson, A. E., Sarnelle, O., & Tillmanns, A. R. (2006). Effects of cyanobacterial toxicity and morphology on the population growth of freshwater zooplankton: Meta-analyses of laboratory experiments. *Limnology and Oceanography*, 51(4), 1915–1924.

Winder, M., & Sommer, U. (2012). Phytoplankton response to a changing climate. *Hydrobiologia,* 698(1), 5-16.

World Commission on Dams. (2000). Dams and Development. A New Framework for Decision-Making. UK: Earthscan. http://www.unep.org/dams/WCD/report/WCD_DAMS%20report.pdf

Zahidah, Herawati, H., & Sumeru, S. (2011). Restoking ikan mola (*Hypopthalmichthys molitrix*) sebagai upaya peningkatan sumberdaya ikan dan pengendalian blooming fitoplankton di Waduk Cirata.