Eastern Journal of Agricultural and Biological Sciences (EJABS)
ISSN: 2753-3247
Website: https://qabasjournals.com/index.php/ejabs

Diatom Diversity of Two Lake in Bali Island as Supporting Data for Forensic Analysis

Ni Made Suartini[1], I Ketut Junitha[2], Ni Luh Suriani*[3], Agus Manto[4]

[1] *Animal Taxonomy Laboratory, Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Udayana, Bukit Jimbaran Campus, Badung, Bali-Indonesia*
[2] *Genetic Laboratory, Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Udayana, Bukit Jimbaran Campus, Badung, Bali-Indonesia*
[3]*Biology Study Program, Faculty of Mathematics and Natural Sciences, Udayana University, Bali, Indonesia*
[4]*Akademi Komunitas Perkebunan Yogyakarta, Indonesia*

Corresponding Author: Ni Luh Suriani, E-mail: niluhsuriani@unud.ac.id; made_suartini@unud.ac.id

ARTICLE INFO

Received: September 15, 2022
Accepted: October 20, 2022
Volume: 2
Issue: 3

KEYWORDS

Diatom, forensic, lake, Bali

ABSTRACT

Diatom distribution range is very wide from marine to highlands waters and mostly live as benthos in rocks, sand, silt and other organisms such as plants or aquatic animals. As a microalgae organism, the size of diatoms are between 10-200 µm with characteristic cell walls composed of silica that distinguish them from other unicellular organisms. This study was done to identify the species of diatoms in lakes Buyan and Beratan as part of an endeavor to compile a database of diatom species from the waterways of Bali for forensic purposes. Each lake included 10 sampling stations where water samples were collected using the approach of purposive sampling. Diatom found in both lakes are 36 species. In Lake Buyan found 28 species and in Lake Beratan found 17 species. There are eight species of diatoms can be found in both of lakes. Melosira granulata species in Lake Buyan has the highest percentage (18.1%) while in Lake Beratan the highest percentage is Fragilaria tenera (30.5%). Denticula subtilis, D. tennuis, Fragilaria crotonensis, F. tenera, Fragilaria sp., Navicula pupula, N. pygmaea and Pinnularia viridis is eight species that can be found in both lakes. Among the eight species, Fragilaria sp. is the species with the highest percentage.

1. Introduction

Diatoms are unicellular organisms. Diatom distribution range is very wide from marine to highlands waters (McLaughlin, 2012). Diatom species mostly live as benthos in rocks, sand, silt and other organisms such as plants or aquatic animals. As plankton, diatoms inhabit the surface of lakes, rivers, and seas (Buf & Bayer, 2002). Benthic diatoms are mostly Pennales order while the pelagic ones mostly Centrales order (Hasrun et al., 2013) . As a microalgae organism, the size of diatoms are between 10-200 µm with characteristic cell walls composed of silica that distinguish them from other unicellular organisms (Soeprobowati & Hadisusanto, 2009).

Diatoms are producer organisms in aquatic ecosystems that need light to be able to carry out photosynthesis (Resosoedarmo et al., 1985) (Nybakken Eidman, H. Muhammad., 1992). The existence of diatoms will be disrupted by water turbidity that prevents light from penetrating water (Nybakken Eidman, H. Muhammad., 1992). Generally, diatoms will be in the limnetic zone (Resosoedarmo et al., 1985). The condition of the aquatic environment influenced by the surrounding conditions, for example, the source of water that flows into it. The conditions around the lake affect the chemical of water so that it will affect the presence of diatom species. Human activities, especially agriculture, occur mostly around the lake.

Diatom species that are exclusive to particular bodies of water can be utilized to determine the location and cause of death of drowning victims. When a person's body sinks or is drowned alive, the water will enter the lungs due to the process of breathing. When water is inhaled, the diatoms in the water will enter the victim's body through the respiratory system. Therefore, diatoms in the victim's body can be utilized as evidence to pinpoint the location of death (Peabody & Cameron, 2010).

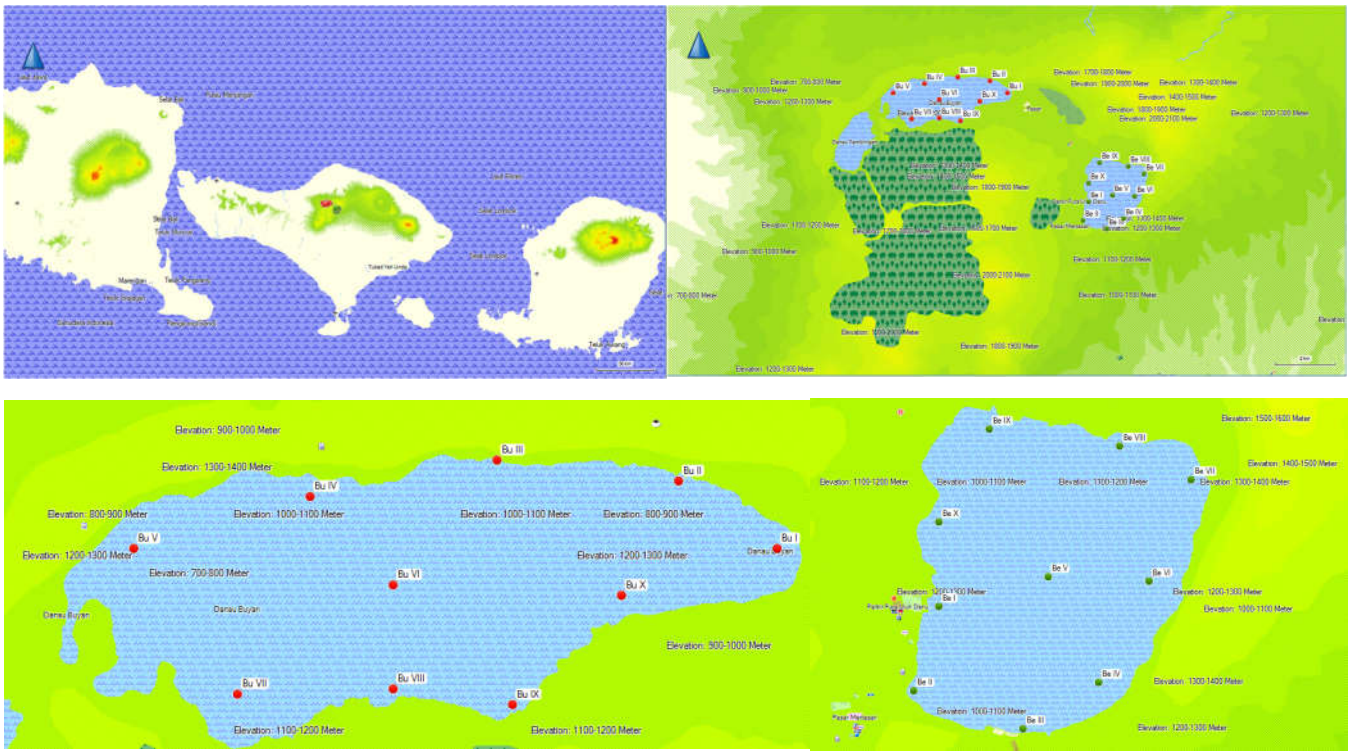
It is possible to determine the cause of death of a person whose body was discovered in water by studying diatoms in his body. The similarity of diatoms species found in the waters where the victim's body was found provides evidence that the death of the victim due to drowning. For example, if diatoms are found reach the bone marrow, It is possible to determine that the victim is still alive when entering the water. because the diatom enters the lungs together with the inhalation water then follows the blood stream to the bone marrow (Verma, 2013).

Diatoms species data in a water will greatly help the forensic analysis. The purpose of this research is to identify the diatoms species in lakes Buyan and Beratan to provide a database of diatom species in the waters of the Bali Island.

2. Methodology

2.1. Water Sampling

Water sampling to determine the diatom species in lake Buyan and Beratan. Lake Buyan is located in the Sukasada sub_district of Buleleng regency at an altitude of 1.210 m above sea level with an area of 3.9 km^2 and depth of 87 m. Lake Beratan is located in Tabanan Regency, precisely in Baturiti District at an altitude of 1.231 m above sea level with a surface area of 3.85 km2, a maximum depth of 20.0 m and an average depth of 12.8 m (Badan Pengendalian Dampak Lingkungan Wilayah II, 1998). Water sampling conducted at 10 sampling stations on each lake (**Fig**. 1). Purposive sampling is used to collect water samples. Using a bucket of up to 50 liters, collect surface water from the lake's edge around 2-3 meters away. Water is also taken in the middle of the lake at a depth of 2-2.5 m using a paralon pipe at the top end given a tap. The water was filtered using a plankton net equipped with a bottle. Sample bottle volume was 25 ml. Filtered water added 10 drops fixative Lugol and further observations were done in the laboratory. At each sample site, water temperature, air temperature, turbidity, pH, and dissolved oxygen are recorded.



• Bu (Buyan Lake), • Be (Beratan Lake)

2.2. Identification of diatoms

Diatoms observation was done in Animal Taxonomy Laboratory of Biology Study Program, Faculty of Mathematics and Natural Sciences, Universitas Udayana. Observation method refers to (Purnomo et al., 2015), (Suartini & Junitha, 2016). Identification of diatoms using morphological characteristics and determination of species refered to (Taylor et al., 2007), (Bellinger & Sigee, 2010) and (Al-Yamani & Saburova, 2011). To determine the amount of each diatom species at each sample site refered to (Purnomo et al., 2015) with formula:

$$\frac{\text{water volume in the bottle collection}}{\text{water volume were observed}} \times \text{number of diatom} \Big/ \text{water volume were taken}$$

3. Results and Discussion

Diatom found in both lakes are 36 species. In Lake Buyan found 28 species and in Lake Beratan found 17 species. There are eight species of diatoms can be found in both lakes. Diatom species found in both lake are presented in Table 1. Diatom species found at each sampling station in each lakes are presented in Table 2 and Table 3. Percentages of each species found in each lake are presented in Fig. 2.

Table 1. Diatom species found in Lake Buyan and Beratan

No	Species	Buyan	Beratan
1	*Achnanthes* sp.	-	+
2	*Amphora ovalis*	+	-
3	*Cocconeis placentula*	-	+
4	*Cymbella cistula*	+	+
5	*Cymbella ventricosa*	+	-
6	*Cymbella aspera*	+	-
7	*Cymbella* sp.	+	-
8	*Denticula subtilis*	+	+
9	*Denticula tenuis*	+	+
10	*Diatoma* sp.1	-	+
11	*Diatoma* sp.2	-	+
12	*Fragilaria crotonensis*	+	+
13	*Fragilaria tenera*	+	+
14	*Fragilaria subtilis*	+	-
15	*Fragilaria* sp.	+	+
16	*Frustulia* sp.	+	-
17	*Gomphonema truncatum*	+	-
18	*Gomphonema venusta*	+	-
19	*Gomphonema affine*	+	-
20	*Gomphonema* sp.	+	-
21	*Gyrosigma acuminatum*	+	-
22	*Melosira varians*	-	+
23	*Melosira granulate*	+	-
24	*Navicula pupula*	+	+
25	*Navicula pygmaea*	+	+
26	*Navicula gastrula*	+	-
27	*Navicula cuspidata*	+	-
28	*Navicula* sp.	-	+
29	*Nitzschia closterium*	-	+
30	*Nitzschia* sp.	+	-
31	*Pinnularia viridis*	+	+
32	*Pinnularia subbrevistriata*	+	-
33	*Rhopalodia gibba*	+	-
34	*Surirella* sp.	-	+
35	*Synedra acus*	+	-
36	*Synedra ulna*	+	-
	Total	**28**	**17**

+ = found, - = not found, ▭ound in both lake

Associated with the interests of forensics, which is an indicator of death due to drowning, the knowledge or information of diatoms in a water is needed and will be very beneficial for the benefit of the forensics. Diatom species information found in a waters can be used as supporting data in the forensic field, namely to determine the cause of death of drowning victims. (Sasidharan & S, 2014) The presence of the same species of diatoms as that of the alleged drowning medium in the internal organs of drowning victims is corroborative or even decisive evidence to support the death diagnosis.

Several genera found in this study are often found on examination of organs samples of drowning victims. Some of them mentioned in (Wilianto, 2012), the genus *Cocconeis* especially *C. placentula* often found in liver samples, Gomphonema

generally found in the intestine, Nitszchia in the duodenum sample, Navicula in the lungs samples, Diatoma and fragments of *Synedra ulna* in bone marrow. (Malik et al., 2013) stated that the Cymbella found in the sternum, collarbone, femur and lungs.

Table 2. Number of each diatom species (sel/L) found at each sampling station in the lake Buyan

No	Species	Sampling station										Total
		BuI	**BuII**	**BuIII**	**BuIV**	**BuV**	**BuVI**	**BuVII**	**BuVIII**	**BuIX**	**BuX**	
1	*Amphora ovalis*	4	9	8	3	1	0	3	1	4	4	37
2	*Cymbella cistula*	11	14	0	1	1	6	1	1	9	11	55
3	*C. ventricosa*	9	1	1	1	5	19	9	3	8	8	64
4	*C. aspera*	8	8	1	1	6	14	0	1	16	9	64
5	*Cymbella* sp.	9	1	1	0	1	0	0	0	0	0	12
6	*D. subtilis*	1	5	1	0	0	1	1	1	3	3	16
7	*D. tenuis*	0	10	5	0	0	3	0	0	1	6	25
8	*F. crotonensis*	23	14	14	25	25	13	29	23	33	14	213
9	*F. tenera*	33	24	10	6	0	5	6	5	10	2	101
10	*F. subtilis*	14	23	1	0	1	8	3	3	4	6	63
11	*Fragilaria* sp.	16	54	25	16	10	19	14	1	9	5	169
12	*Frustulia* sp.	1	4	0	0	0	2	3	3	0	4	17
13	*Gomphonema venusta*	3	4	0	1	0	2	0	0	8	2	20
14	*G. truncatum*	5	14	0	0	3	5	0	1	11	2	41
15	*G. affine*	0	1	1	0	1	0	0	1	3	0	7
16	*Gomphonema* sp.	6	14	1	0	1	1	0	0	0	0	23
17	*Gyrosigma acuminatum*	0	0	1	0	0	0	0	0	0	0	1
18	*Melosira granulata*	31	78	10	31	9	8	16	50	40	35	308
19	*Navicula pupula*	1	4	3	1	0	0	0	0	0	0	9
20	*N. pygmaea*	0	1	0	0	0	0	0	0	0	0	1
21	*N. gastrula*	0	0	0	0	0	0	0	0	0	1	1
22	*N. cuspidate*	0	3	0	0	0	0	0	0	0	1	4
23	*Nitzschia* sp.	5	0	0	0	0	0	0	0	0	0	5
24	*Pinnularia viridis*	6	9	1	0	1	4	0	0	0	7	28
25	*P. subbrevistriata*	5	5	1	0	1	3	3	1	6	10	30
26	*Rhopalodia gibba*	3	4	1	0	0	1	3	0	5	1	18
27	*Synedra acus*	36	20	6	15	18	0	11	10	38	15	169
28	*S. ulna*	34	61	4	6	8	5	16	16	31	23	204
	Total	264	385	96	107	92	119	118	121	239	169	1705

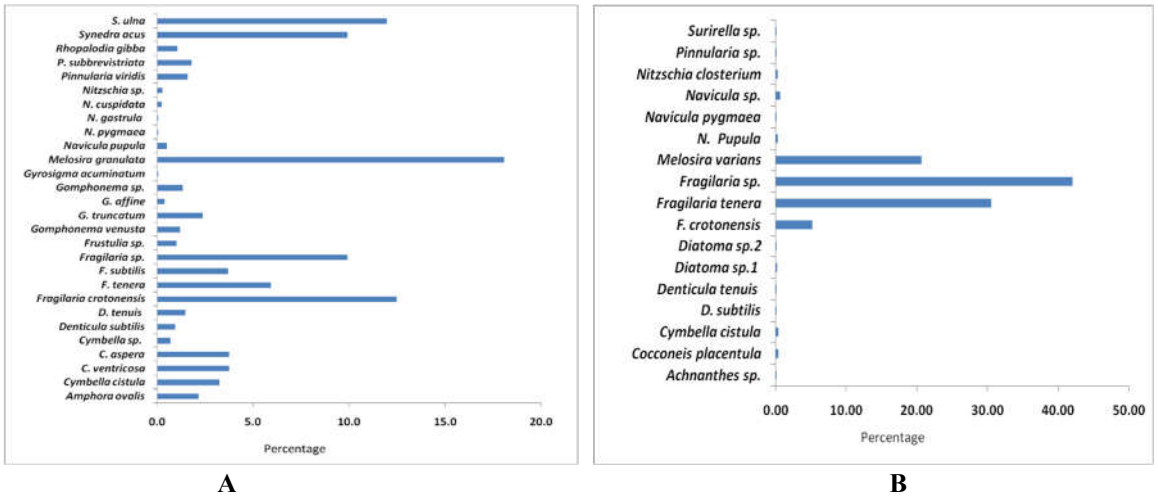
Note: BuI (S8°14'35,0" E115°08'34.0"), BuII (S8°14'22,0" E115°08'15.0"), BuIII (S8°14'18,0" E115°07'40.0"), BuIV (S8°14'25,0" E115°07'04.0"), BuV (S8°14'35,0" E115°06'30.0"), BuVI (S8°14'42,0" E115°07'20.0"), BuVII (S8°15'03,0" E115°06'50.0"), BuVIII (S8°15'02,0" E115°07'20.0"), BuIX (S8°15'05,0" E115°07'43.0"), BuX (S8°14'44,0" E115°08'04.0").

Table 3. Number of each diatom species (sel/L) found at each sampling station in the lake Beratan

No	Species	Sampling station										Total
		BeI	**BeII**	**BeIII**	**BeIV**	**BeV**	**BeVI**	**BeVII**	**BeVIII**	**BeIX**	**BeX**	
1	*Achnanthes* sp.	1	0	0	0	0	0	0	0	0	0	1
2	*Cocconeis placentula*	1	1	3	4	1	1	1	0	0	0	12
3	*Cymbella cistula*	1	0	0	1	0	3	0	1	3	0	13
4	*Denticula subtilis*	1	0	0	0	0	0	0	0	0	0	1
5	*D. tenuis*	3	0	1	0	0	0	0	0	0	0	4

6	*Diatoma* sp.1	0	1	3	0	0	0	1	0	0	1	5
7	*Diatoma* sp.2	0	0	3	0	0	0	0	0	0	1	4
8	*Fragilaria crotonensis*	51	11	90	19	3	3	9	10	1	3	200
9	*F. tenera*	34	119	111	78	109	141	74	131	248	126	1171
10	*Fragilaria* sp.	49	128	141	106	120	215	90	259	304	226	1638
11	*Melosira varians*	28	46	56	91	61	71	15	111	163	161	803
12	*Navicula pupula*	3	1	3	0	0	0	1	0	0	1	9
13	*N. pygmaea*	0	0	0	0	0	0	0	0	1	0	1
14	*Navicula* sp.	3	4	5	0	0	1	6	1	3	0	23
15	*Nitzschia closterium*	1	1	4	0	1	3	0	0	0	0	10
16	*Pinnularia viridis*	0	1	0	0	0	0	0	0	0	0	1
17	*Surirella* sp.	1	0	0	0	0	0	0	0	0	0	1
	Total	**177**	**313**	**420**	**299**	**295**	**438**	**197**	**513**	**723**	**519**	**3897**

Note: BeI (S8°16'32,0" E115°10'02.0"), BeII (S8°16'52,0" E115°09'56.0"), BeIII (S8°17'01,0" E115°10'22.0"), BeIV (S8°16'50,0" E115°10'40.0"), BeV (S8°16'25,0" E115°10'28.0"), BeVI (S8°16'26,0" E115°10'52.0"), BeVII (S8°16'02,0" E115°11'02.0"), BeVIII (S8°15'54,0" E115°10'45.0"), Be IX (S8°15'50,0" E115°10'14.0"), BeX (S8°16'12,0" E115°10'02.0").



A **B**

Fig. 2. Percentage of each species in lake Buyan and Beratan
A= lake buyan, B= lake Beratan

The number of diatom species discovered at each lake Buyan and Beratan sample site varied. The largest proportion (18.1%) of *Melosira granulata* was discovered in lake Buyan. and *Fragilaria* sp. is the species identified in the highest proportion (40.03%) in lake Beratan.Number of diatoms species different in each sampling station likely influenced by different environmental factors in each station. Referring to Table 1, there are 8 species of diatoms that can be found in Buyan and Beratan lakes. The percentage of the diatom species to the total diatom found in each lake is presented in Fig. 2.

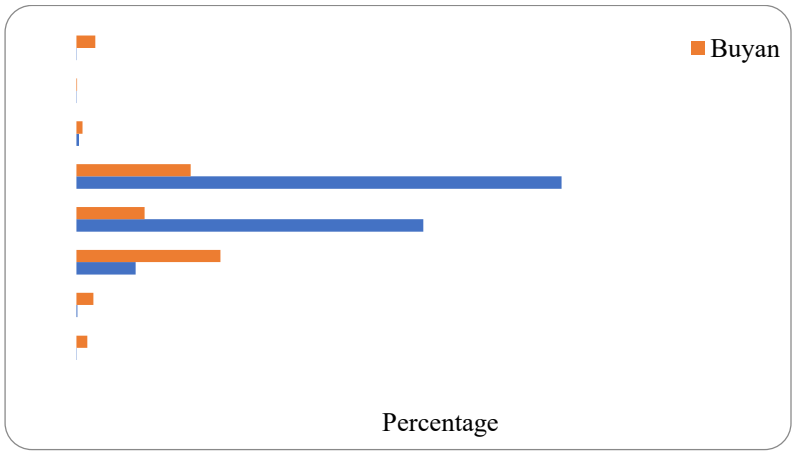


Fig 3. Percentage of eight diatom species found in both lake

Based on Figure 3, *Fragilaria* sp. is one of the species found in both lakes and has the highest percentage. The species can also be found at each sampling station in both lake. Eight species found in lake Buyan and Beratan are also found in other lakes on Bali Island. *Fragillaria tenera* was found in lake Tamblingan (Suartini et al., 2015) and *Fragillaria* sp. found in lake Batur (Suartini & Junitha, 2016). In Lake Batur, *Fragillaria* sp. also has the highest percentage compared to other species found in the lake. (Taylor et al., 2007) states that this species is a species that is often found or cosmopolitan in rivers and lakes.

The conditions of each sampling station in each lake are varied. The environmental factors data from lakes Buyan is presented in the Table 4 and in lake Beratan is in Table 5.

Table 4. Environmental factor in Lake Buyan

Environmental factor	Samling station										Mean
	BuI	BuII	BuIII	BuIV	BuV	BuVI	BuVII	BuVIII	BuIX	BuX	
Water temperature (°)	21	21	21	21	21	21	22	21	21	22	21.2
Water pH	7.5	8	8	8	8	7.5	8	7.5	7.5	7.5	7.75
Water Disolved oxygen (mg/l)	9.4	8.6	8.4	8.6	8.3	8.8	8.7	8.5	7.9	7.9	8.51
Water Turbidity (cm)	100	160	170	150	200	160	165	150	150	150	155.5
Air temperature (°)	27.3	25.8	24.1	24.8	25.2	26.9	30.2	26.5	26.4	25.1	26.23
Humidity (%)	63	60	68	53	62	57	44	60	61	65	59.3

Table 5. Environmental factor in Lake Beratan

Environmental factor	Sampling station										Mean
	BeI	BeII	BeIII	BeIV	BeV	BeVI	BeVII	BeVIII	BeIX	BeX	
Water temperature (°)	20	20	21	22	21	22	22	21	21	22	21.2
Water pH	6	5.5	6	5.5	6	5.5	6	7	6.5	6.5	6.05
Water Disolved oxygen (mg/l)	8.1	7.2	8.3	7.8	8.6	8.2	8.2	8.2	8.2	8.1	8.09
Water turbidity (cm)	200	180	195	210	180	190	200	170	190	190	190.5
Air temperature (°)	24.2	25	25.7	25	24.8	24	22.7	21	22	26.3	24.07
Humidity (%)	64	57	57	61	69	63	69	73	74	62	64.9

The environmental factors assessed in lakes Buyan and Beratan are still conducive to the survival of diatoms. The range of measured temperature at lake Buyan is 21 °C -22 °C (Table 4) and 20 °C -22 °C in lake Beratan (Table 5). (Hefni Effendi, 2013) stated that the range of temperatures where diatoms can grow well is 20 °C -30°C. So it can be said that the temperature range in

both lakes still supports diatom live. Diatom also needs an oxygen for respiration. Water dissolved oxygen in lake Buyan is 7.9-9.4 mg/L and in lake Beratan is 7.2-8.6 mg/L (Soeprobowati & Hadisusanto, 2009) the needed dissolved oxygen concentration for diatoms is 7-12 mg/L, while some species may survive in concentrations as low as 6.5 mg/L.

4. Conclusion

Diatom found in both lakes are 36 species. In Lake Buyan found 28 species and in Lake Beratan found 17 species. *Melosira granulata* species in Lake Buyan has the highest percentage (18.1%) while in Lake Beratan the highest percentage is *Fragilaria tenera* (30.5%). *Denticula subtilis, D. tennuis, Fragilaria crotonensis, F. tenera, Fragilaria* sp*., Navicula pupula, N. pygmaea* and *Pinnularia viridis* is eight species that can be found in both lakes. Among the eight species, *Fragilaria* sp. is the species with the highest percentage.

References

Al-Yamani, F. Y., & Saburova, M. A. (2011). *Illustrated guid on the benthic diatoms of Kuwait's marine environment*. http://www.kisr.edu.kw/en/publications/books

Badan Pengendalian Dampak Lingkungan Wilayah II. (1998). *Norma dan Program Danau Lestari Provinsi Dati I Bali.*

Bellinger, E. G., & Sigee, D. C. (2010). *Freshwater Algae: Identification and Use as Bioindicators* (Vol. 7, Issue 1). Wiley-Blackwell. https://www.researchgate.net/publication/269107473_What_is_governance/link/548173090cf22525dcb61443/download%0Ahttp://www.econ.upf.edu/~reynal/Civil wars_12December2010.pdf%0Ahttps://think-asia.org/handle/11540/8282%0Ahttps://www.jstor.org/stable/41857625

Buf, H. du, & Bayer, M. (2002). *Automatic Diatom Identification, Series in Machine Perception and Artificial Intelligence, vol. 51*. http://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:ADIAC:+Automatic+Diatom+Identification+And+Classification#1%5Cnhttp://scholar.google.com/scholar?hl=en&btnG=Search&q=intitle:Project:+ADIAC:+Automatic+diatom+identification+and+classification%230

Hasrun, L., Ma'ruf, K., & Salwiyah. (2013). Studi Biodiversitas Diatom Bentik pada Areal Mangrove di Perairan Kecamatan Kolono Kabupaten Konawe Selatan. *Jurnal Mina Laut Indonesia*, *2*(6), 35–47.

Hefni Effendi. (2013). *Telaah kualitas air bagi pengelolaan sumber daya dan lingkungan perairan*. Kanisius.

Malik, M. J., Jakhar, P., & Kadian, A. (2013). Role Of Diatoms In Forensic Investigation : Case Studies From Haryana. *International Journal of Forensic Science & Pathology (IJFP)*, *1*, 11–12.

McLaughlin, R. B. (2012). An introduction to the Microscopical Study of Diatoms. *T & T Clark Approaches to Biblical Studies*, 445.

Nybakken Eidman, H. Muhammad., J. W. (1992). *Biologi laut : suatu pendekatan ekologis*. PT Gramedia Pustaka Utama.

Peabody, A. J., & Cameron, N. G. (2010). *The Diatom: Application for The Enveronmental Sciences. Second Edition.* Cambirdge University Press.

Purnomo, A. A., Junitha, K., & Suartini, N. M. (2015). Variasi Spesies Diatom Pada Tipe Perairan Berbeda Untuk Kepentingan Forensik Sebagai Petunjuk Kematian Akibat Tenggelam Variation of Diatom Species in Different Types of Water for Forensic Study As Death Indication Caused By Drowning. *Jurnal Simbiosis*, *3*(1), 247–257.

Resosoedarmo, S., Kartawinata, K., & Soegiarto, A. (1985). *Pengantar ekologi*. Remaja Rosdakarya.

Sasidharan, A., & S, R. (2014). Forensic Diatomology. Review. *Forensic Diatomology: A Review.*, *3*(10), 47–52.

Soeprobowati, T., & Hadisusanto, S. (2009). Diatom dan Paleolimnologi: Studi Komparasi Perjalanan Sejarah Danau Lac Saint-Augustine Quebeq-City, Canada dan Danau Rawa Pening Indonesia Diatom and Paleolimnology: Comparation Study of Historical Lakes Lac Saint- Augustine Quebeq-City, Canada and Rawa. *Universitas Atmajaya Yogyakarta*, *14*(1), 60–68.

Suartini, N. M., & Junitha, I. K. (2016). Diatom Species in Lake Batur, Bali Province, Indonesia as Supporting Data For Forensic Analysis of Drowned Victim. *International Journal of Pure and Applied Bioscience (IJPAB)*, *4*(4), 8–14.

Suartini, N. M., Junitha, I. K., Suryadipura, P., & Watiniasih, N. L. (2015). *Variasi Jenis Diatom di Danau Tamblingan untuk Kepentingan Forensik Sebagai Indikator Kematian Akibat Tenggelam.* Prosiding. Seminar Sains dan Teknologi. Universitas Udayana.

Taylor, J. ., Harding, W. R., & Archibald, C. G. M. (2007). *An Illustrated Guide to Some Common Diatom Species from South Africa*.

Verma, K. (2013). Role of Diatoms in the World of Forensic Science. *Journal of Forensic Research*, *04*(02). https://doi.org/10.4172/2157-7145.1000181

Wilianto, W. (2012). Pemeriksaan Diatom pada Korban Diduga Tenggelam. *European University Institute*, *14*(2), 2–5.