REPORT SNO 7253-2018

Conservation of biodiversity and improved management of protected areas in Myanmar

Aquatic macrophytes and phytoplankton in Indawgyi Lake

Photo: NIVA

Norwegian Institute for Water Research

REPORT

Main Office	NIVA Region South	NIVA Region East	NIVA Region West	NIVA Denmark
Gaustadalléen 21 NO-0349 Oslo, Norway Phone (47) 22 18 51 00 Telefax (47) 22 18 52 00 Internet: www.niva.no	Jon Lilletuns vei 3 NO-4879 Grimstad, Norway Phone (47) 22 18 51 00 Telefax (47) 37 04 45 13	Sandvikaveien 59 NO-2312 Ottestad, Norway Phone (47) 22 18 51 00 Telefax (47) 62 57 66 53	Thormøhlensgate 53 D NO-5006 Bergen Norway Phone (47) 22 18 51 00 Telefax (47) 55 31 22 14	Njalsgade 76, 4th floor DK 2300 Copenhagen S, Denmark Phone (45) 39 17 97 33

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Summary

The aim of the study has been to give important and improved knowledge about aquatic macrophytes and phytoplankton biodiversity in the Indawgyi Lake. The survey took place in September 2017 and included physical measurements, water chemistry, phytoplankton, and aquatic macrophytes. Indawgyi Lake is the largest natural lake in Myanmar. The lake is a moderate alkaline and clear lake, with periodically very low oxygen levels. However, nutrient levels were low, most likely because of dilution due to integrated samples. The most important phytoplankton group was the cyanobacteria, dominated by *Microcystis ichthyoblabe* and *M. viridis*, which are known producers of hepatotoxic microcystins. One of the other present cyanobacterial species, *Chrysosporum ovalisporum, is a potential* producer of the hepatotoxic cyanotoxin cylindrospermopsin and is an invading species. Although the lake gave optically the impression of a eutrophic lake, the phytoplankton biomasses were relatively low. In total, 22 species of aquatic macrophytes were recorded, with the free-floating species *Eichornia crassipes* and n*Salvinia cucellata* as the most frequent species. They made large stands in most areas. Also, the submerged species *Ceratophyllum demersum* and *Vallisneria spiralis* were recorded in most areas. *Eichornia crassipes* was the only invasive species found in the lake. The most spectacular species in the lake is the very large floating-leaved species *Euryale ferox*. Based on preliminary indices, the ecological status of phytoplankton and aquatic macrophytes are classified as poor. However, to get a better understanding of the conditions in Indawgyi Lake and track the sources of pollution, a more extended survey is needed. To get a more complete overview of the aquatic biodiversity in Indawgyi Lake, we suggest visiting the lake again, preferably early in the dry season.

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Marit Mjelde	*Markus Lindholm*
Project Manager	Research Manager

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Conservation of biodiversity and improved management of protected areas in Myanmar

Aquatic macrophyte and phytoplankton in Indawgyi Lake

Preface

This study was performed by Norwegian Institute for Water Research (NIVA) on commission from Norwegian Environment Agency (NEA).

The field survey in Indawgyi lake was part of a joint field trip together with Ramsar Experts and representatives from Indawgyi Wildlife Sanctuary, Forest Research Institute (FRI), Ministry of Natural Resources and Environmental Conservation (MONREC), Norwegian Environment Agency (NEA), and Norwegian Institute for Water Research (NIVA).

The aquatic macrophyte field survey was performed by Marit Mjelde (NIVA) and Thida Swe (FRI). Thida Swe (FRI) collected the phytoplankton and water samples. In addition, Khin Maung Lwin, Saw Htoo Min, Thant Zin Oo and Tin Naing Win, from Indawgyi Wildlife Sanctuary, participated in the field survey.

The phytoplankton samples are analysed and reported by Andreas Ballot (NIVA), while aquatic macrophytes are described and reported by Marit Mjelde. The water samples are analysed at the chemical laboratory at NIVA. Similar analyses will be performed at FRI laboratory in Nay Pyi Thaw. The photos are taken by Thida Swe and Marit Mjelde. John Rune Selvik, NIVA, has provided the locality map. The report is written by Marit Mjelde, Andreas Ballot and Thida Swe. Markus Lindholm has done the quality assurance.

Jan-Petter Hubert Hansen has been our contact in Norwegian Environment Agency (NEA) and initiated the field study in Indawgyi Lake. We are very grateful to this initiative and to the Indawgyi Park Warden U Maung Win, who organized the whole field trip.

Thanks to all for a nice and very interesting collaboration!

Oslo, 6th March 2018

Marit Mjelde

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Summary

The survey in Indawgyi Lake is part of the project "Conservation of biodiversity and improved management of protected areas in Myanmar", a joint project between Ministry of Natural Resources and Environmental Conservation (MONREC) and Norwegian Environment Agency (NEA).

The aim of the field survey is to give important and improved knowledge about aquatic biodiversity in Indawgyi Lake, with focus on aquatic macrophytes and phytoplankton. In addition, the survey will contribute to the lake management through a preliminary assessment of ecological status of the lake. The survey will also provide important synergy to the project "Integrated Water Resources Management - Institutional Building and Training", a co-operation between MONREC and the Norwegian Institute for Water Research (NIVA). The survey took place in September 2017 and included physical measurements, and the analyses of water chemistry, phytoplankton, and aquatic macrophytes.

Indawgyi Lake is the largest natural lake in Myanmar. It is a moderate alkaline and clear lake, with periodically very low oxygen levels, which may cause fish deaths. Nutrient levels measured were low. However, low oxygen concentrations are an indication of high bacterial decomposition of organic biomass. To get a better understanding of the conditions in the lake and track the sources of pollution, a more extended survey is needed.

In total, 69 phytoplankton taxa were determined in the lake. The most important group was the cyanobacteria, dominated by *Microcystis ichthyoblabe* and *M. viridis*, which are known producers of hepatotoxic microcystins. One of the other present cyanobacterial species, *Chrysosporum ovalisporum,* is apotential producer of the hepatotoxic cyanotoxin cylindrospermopsin and is an invasive species. The lake gave optically the impression of a eutrophic lake, and the PTI-index indicated poor-bad conditions. However, measured phytoplankton biomasses were low.

A total of 22 species of aquatic macrophytes were recorded in Indawgyi Lake, dominated by the free-floating species. Most of these species can survive in water with bad light conditions, and are characterized as tolerant species according to eutrophication. The most frequent species were the free-floating species *Eichornia crassipes* and *Salvinia cucellata.* They were present at all localities and made large stands in most areas. Also, the submerged species *Ceratophyllum demersum* and *Vallisneria spiralis* and the floating-leaved species *Nymphoides indica* were recorded in most areas. Most of the recorded species are native and common in Asia; the water hyacinth *Eichornia crassipes* was the only invasive species. The most spectacular species in Indawgyi Lake is the very large floating-leaved species *Euryale ferox*, which may be rare in Myanmar. Very few aquatic macrophyte surveys in lakes in Myanmar are performed. Whether the species diversity in Indawgyi Lake is within what is normal for this lake type in Myanmar, we do not know. However, the species number in Indawgyi Lake is similar to what is found in Inlay Lake (Shan State). Based on the preliminary species sensitivity for Myanmar species and the suggested trophic index, the status of aquatic macrophytes in Indawgyi Lake is classified as poor.

Due to our experience, the biodiversity and species abundance in lakes in Myanmar seem to vary a great deal throughout the year. To get a more complete overview of the aquatic biodiversity in Indawgyi Lake, we suggest visiting the lake again, preferably early in the dry season.

Sammendrag

Undersøkelsene i Indawgyi Lake er en del av prosjektet “Conservation of biodiversity and improved management of protected areas in Myanmar”, som er et fellesprosjekt mellom Ministry of Natural Resources and Environmental Conservation (MONREC) i Myanmar og Miljødirektoratet. Resultatene herfra vil også har betydning for prosjektet “Integrated Water Resources Management - Institutional Building and Training”, som er et samarbeid mellom MONREC and NIVA.

Formålet med undersøkelsen var å gi viktig og forbedret kunnskap om biodiversiteten i Indawgyi Lake, med fokus på vannplanter og planteplankton. I tillegg ble det samlet inn vannprøver og foretatt fysiske målinger.

Innsjøen var preget av næringsfattige vannmasser, men hadde svært lave oksygennivåer. Planteplanktonet var dominert av cyanobakterier, først og fremst av de toksinproduserende *Microcystis ichthyoblabe* og *M. viridis*. Biomassen var imidlertid lav, til tross for at det ble registrert en markert algeoppblomstring i vannsøylen i september. Totalt 22 arter i vannvegetasjonen ble registrert. De frittflytende artene dominerte og dannet til dels store bestander. Artssammensetning av både planteplankton og vannplanter indikerte dårlig økologisk tilstand i innsjøen.

Det er behov for en mer omfattende undersøkelse for å kunne foreta en fullstendig vurdering av tilstanden i Indawgyi Lake og finne årsakene til de dårlige forholdene.

Tittel: Conservation of biodiversity and improved management of protected areas in Myanmar. Aquatic macrophytes and phytoplankton in Indawgyi Lake.
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1 Introduction

1.1 Background

Indawgyi Lake is the largest natural lake in Myanmar, situated in Kachin State in the northern part of the country. The Indawgyi Lake area was established as a Wildlife Sanctuary in 1985, as ASEAN Heritage Park in 2003, and designated as Indawgyi Lake Wildlife Sanctuary in 2004. Indawgyi Lake is also a Ramsar site, and is being considered as UNESCO Biosphere Reserve. However, the lake is threatened by pollution from various sources. Knowledge about pollution levels and trends, and their effects on the biology of Indawgyi Lake, is essential for the management of the lake.

The survey in Indawgyi Lake is part of the project "Conservation of biodiversity and improved management of protected areas in Myanmar", a joint project between Ministry of Natural Resources and Environmental Conservation (MONREC) and Norwegian Environment Agency (NEA). One of the aims of this project is to contribute to the development of a Management Plan for Indawgyi Lake Wildlife Sanctuary.

1.2 The aim of the survey

The main goal of our survey is to give important and improved knowledge about aquatic biodiversity in Indawgyi Lake, with focus on aquatic macrophytes and phytoplankton. Knowledge about the distribution and status of aquatic macrophytes and phytoplankton are important when discussing management of the lake. In addition, the survey will contribute to the lake management through a preliminary assessment of the ecological status of the lake.

The field survey in Indawgyi Lake will also provide important synergy to the project "Integrated Water Resources Management - Institutional Building and Training", a co-operation between MONREC and Norwegian Institute for Water Research (NIVA). One of the outputs from this project is to suggest preliminary ecological status criteria for lakes in Myanmar.

A similar survey has been performed in Moeyingyi Reservoir (Mjelde et al. 2016). This wetland area was the first Ramsar site in Myanmar.

2 Indawgyi Lake

2.1 General information

Indawgyi Lake is situated in Mo-Thyin Township, Myitkyina District, in Kachin State in the northern part of Myanmar (Figure 1). It is located 170 meters above sea level. The lake is the largest natural lake in the country with a surface area of 140 km^2, however, with some variation between the rainy and the dry season. Compared to most lakes in Myanmar, Indawgyi Lake is a deep lake, with a maximum depth of 22 m.

The water level in the lake varies during dry and rainy season, and during the wet period the lake expands by 5-10 m laterally and the low lying surrounding areas are flooded (Meyers, unpubl.).

Table 1. Characteristic data about Indawgyi Lake

Water body	State	type	coordinates	Altitude m.a.s.l.	lake area km^2	max. depth m
Indawgyi Lake	Kachin	natural lake	25°08’34” N, 96°20’02” E	170	140	22

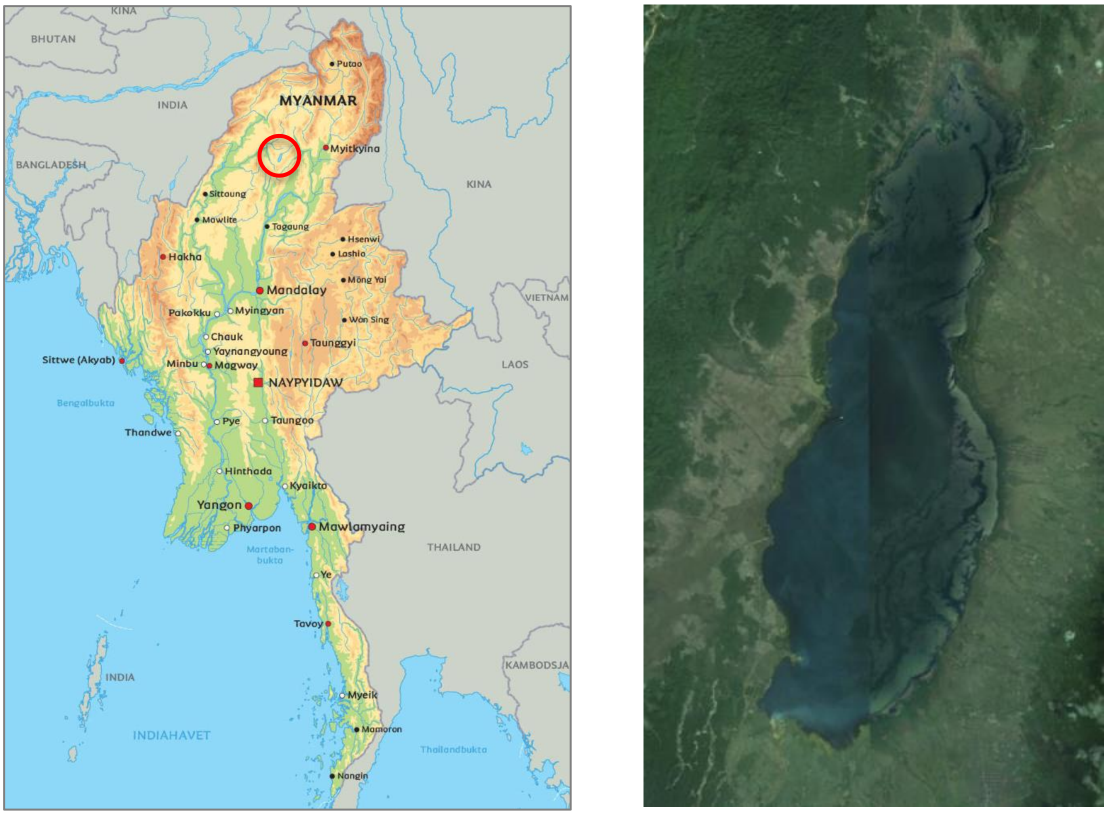


Figure 1. Indawgyi Lake, situated in Kachin state in the northern part of Myanmar (the overview-map from www.albatros-travel.no and the lake map from google earth).

The three major rivers flowing into the lake are the Nam Yin Hka, Nam San Da, and Na Mun Chuang, located in the southwestern, northwestern and southeastern part of the lake, respectively. Other significant inflows include the Hkaung Tung Hka Chaung, Mok So Chaung and Nam Yin Hka Chaung (Meyers, unpubl.). The outlet Indaw Chuang is in the northeast.

The major villages close to the lake are Lon Ton and Nyaung Bin on the western side, and Nan Mun, Hepu and Lon Sant on the eastern side (Bhangari et al 2015). Most of the gold mining areas are situated south of the lake.

Runoff from the surrounding agricultural lands, logging in the catchment area and gold extraction, mining and panning upstream, lead to increased turbidity in the rivers and sedimentation in the lake (Bhangari et al 2015). Measured turbidity values in some of the rivers in September 2017, varying between 45 and 184 FNU (Veiteberg Braathen, pers.com.), confirm the high sedimentation load. Washing clothes, bathing, erosion, use of mercury and acid in gold mining and agricultural runoff are the main source of pollution in the lake (Bhangari et al 2015).

2.2 Geology and soil

The bedrock in the Indawgyi Lake area is dominated by hard rock types gneiss and granite (http://www.mappery.com/map-of/Myanmar-Burma-Rock-Types-Map), which usually cause low alkalinity lake water. However, the bedrock in the area is covered with several meters of alluvial soil (Bhangari et al 2015), which may be the reason for the moderate calcium content in the lake water.

2.3 Climate conditions

The Indawgyi area has a humic subtropical climate, with hot and humid summers, and mild winters (Köppen-Geiger classification, www.wikpedia) (Figure 2).

No climate data are currently available from the Indawgyi Lake area, and the nearest climate station seem to be the Myitkyina station east of Indawgyi Lake (http://www.climatemps.com/). The dry season ranges from November to April, with the driest period in December-January. In the wet period in June-August average precipitation varies between 410 and 530 mm per month (Figure 2). The average precipitation per year is around 2200 mm. The average temperature ranges from 17-18 °C in December-January to around 27 °C in March-September (Figure 2).

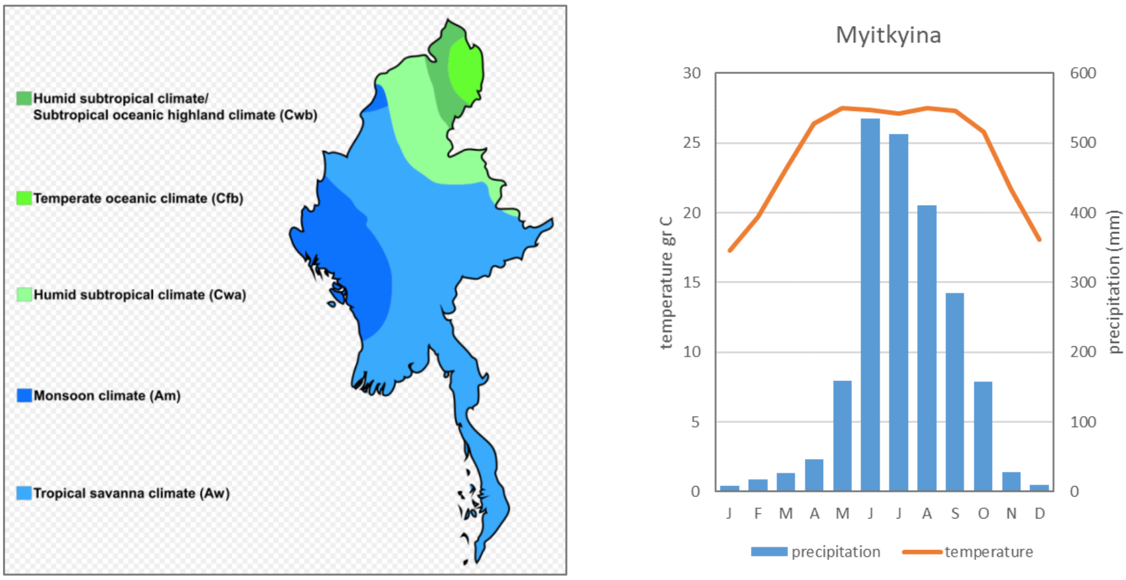


Figure 2. Climate zones in Myanmar (left) and average monthly precipitation and temperature at the nearest climate station, Myitkyina (from: http://www.climatemps.com/) (right).

3 Material and methods

3.1 Field survey and localities

The registrations and sampling in Indawgyi Lake was a joint field survey with representatives from NIVA, FRI and Indawgyi Wildlife Sanctuary (Figure 3).

Figure 3. The field survey was performed by Marit Mjelde and Thida Swe (picture to the right), with help from Khin Maung Lwin, Saw Htoo Min, Thant Zin Oo and Tin Naing Win from Indawgyi Wildlife Sanctuary.

Photos: T. Swe and M. Mjelde

On the 19-21. September 2017, we visited 20 different localities in Indawgyi Lake (Figure 4, Table 2). Phytoplankton samples, physical measurements and water samples for chemistry were taken at three localities in the middle of the lake (IDW1-3), while aquatic macrophyte species were recorded at the other 17 localities (ID1-17) (Table 2).

In November and December 2017, and January 2018, Thida Swe made some additional physical measurements in the lake and collected water samples and phytoplankton samples. Some of the results from these surveys are included. In addition, we have included data from two localities from a preliminary visit in May 2015 (Mjelde & Wathne 2015).

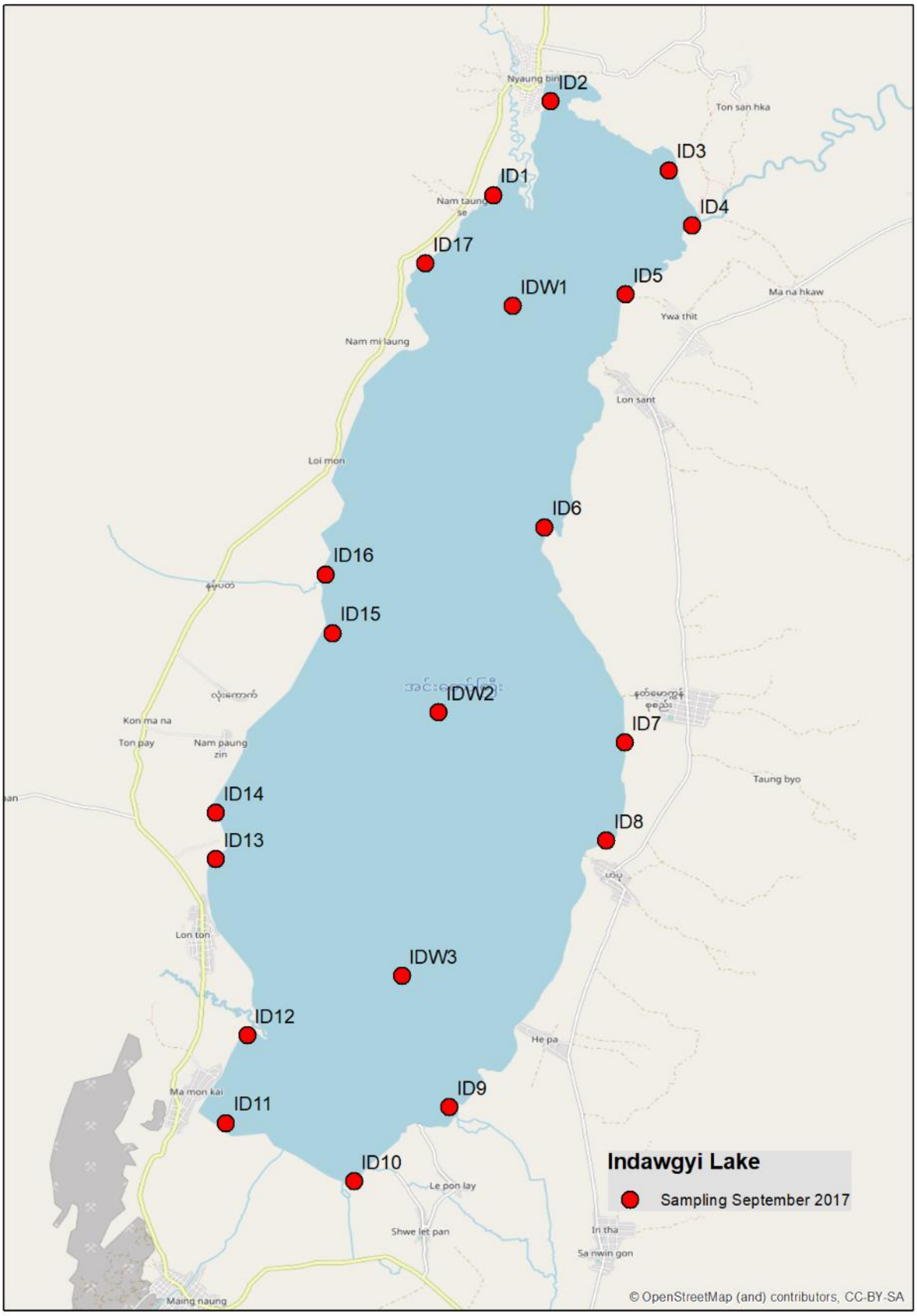


Figure 4. Visited localities in Indawgyi Lake 19-21. September 2017.

Table 2. Localities visited 13.5.2015 and 19-21. 9.2017. The addition measurements (Nov. 2017- Jan. 2018) were done at IDW1-3. Quality elements: AM=aquatic macrophytes, PP=phytoplankton, PM=physical measurements, WS= water sample.

Loc. name	Date	Latitude	Longitude	Quality element
A	13.05.2015	25,206741	96,364826	AM, WS
B	13.05.2015	25,232019	96,382538	AM, WS
ID1	20.09.2017	25,23768866	96,34416897	AM
ID2	20.09.2017	25,25602542	96,35542888	AM
ID3	20.09.2017	25,24255067	96,37850468	AM
ID4	20.09.2017	25,23170206	96,38311104	AM
ID5	20.09.2017	25,2182968	96,3700724	AM
ID6	21.09.2017	25,17276311	96,3542322	AM
ID7	21.09.2017	25,13072686	96,36984492	AM
ID8	21.09.2017	25,11158494	96,3663298	AM
ID9	21.09.2017	25,05950868	96,33565648	AM
ID10	19.09.2017	25,045	96,317	AM
ID11	19.09.2017	25,05639095	96,29197251	AM
ID12	19.09.2017	25,07354594	96,29617461	AM
ID13	19.09.2017	25,10799154	96,29011223	AM
ID14	20.09.2017	25,11704978	96,29002439	AM
ID15	20.09.2017	25,15212041	96,31283834	AM
ID16	20.09.2017	25,1635623	96,31150804	AM
ID17	20.09.2017	25,22432791	96,3309404	AM
IDW1	20.09.2017	25,2160046	96,34804023	PM, WS, PP
IDW2	21.09.2017	25,13662353	96,33354491	PM, WS, PP
IDW3	21.09.2017	25,08513811	96,32638617	PM, WS, PP

3.2 Field and analysis methods

3.2.1 Physical measurements and water samples

The physical measurements and water samples were taken at 3 localities in the middle of the lake; IDW1-3 (Figure 4, Table 2). The water samples were taken as integrated water samples 0-10 m depth, fixed in the field with 4M H_2SO_4 and transported to NIVA for analyses of turbidity, calcium, colour, NH_4, NO_3, PO_4, total nitrogen and total phosphorus. Similar samples are or will be analysed at the FRI laboratory in Nay Pyi Daw (not included in this report). Data from earlier analyses in 2015 are included.

3.2.2 Phytoplankton

The phytoplankton comprises microscopic prokaryotic cyanobacteria and eukaryotic algae. They are freely floating organisms, which move mainly with water currents. The highest biodiversity of phytoplankton organisms is often observed under low nutrient concentrations. Increasing nutrient concentrations often lead to a decrease in phytoplankton biodiversity and an increase in biomass of some adapted phytoplankton taxa. At eutrophic conditions very often blooms of one or a few phyto-plankton taxa can be observed.

Sampling and analysing method
Qualitative samples using a plankton net (pore size 20 µm) and quantitative water samples using a Limnos water sampler for phytoplankton composition and biomass were taken at three selected sites (Table 2) as integrated water samples, 0-10 m depth, in September 2017 and at 1 m depth in December 2017. The samples were fixed with formaldehyde (qualitative samples) or acidic Lugol's

solution (quantitative samples), stored in the dark and later analysed at NIVA. For the analysis of the qualitative samples compound microscopy was used and for the analysis of the quantitative samples, plankton sedimentation and counting chambers according to Utermoehl (1958) and inverted microscopy was used. Samples for chlorophyll-a were not taken, since all samples, at this stage, had to be transported and analysed at the laboratory at the Norwegian Institute for Water Research.

Identification keys
The knowledge about phytoplankton in Asia and especially in Myanmar is scarce (e.g. Skuja 1949). However, many phytoplankton organisms are found both in tropical and temperate regions. This allows a determination of many species with standard literature from Europe and North America (e.g. Croasdale et al. 1983, Huber-Pestalozzi 1969, 1983, Prescott et al. 1977, 1981, 1982, Komárek and Anagnostidis 1998, 2005, Komárek 2013). Several taxa however, could only be determined to genus or family level so far. In a later stage the use of genetic methods could help to identify some of these species. All taxa are determined by Andreas Ballot.

Ecological status and trophic indices
According to the EU Water Framework Directive (WFD), several parameters are used to characterize the ecological status of lakes with phytoplankton: chlorophyll-a, total biovolume of phytoplankton, Phytoplankton Trophic Index (PTI) and biomass of cyanobacteria.

The four indices which are developed for phytoplankton combine all the changes and are well correlated to total phosphorous in lakes (Lyche-Solheim et al 2013). Chlorophyll-a is the most important pigment involved in the photosynthesis of phytoplankton and can be used as a proxy for phytoplankton biomass.

The Phytoplankton Trophic Index (PTI) describes the increase of tolerant species (often nuisance algae or cyanobacteria) and the reduction of sensitive taxa along the phosphorus gradient. The index is based on a modification of Ptacnik et al. (2009), see also Direktoratsgruppa (2015). It sums up the indicator value for each taxon in a sample in relation to the proportion of each taxon in the sample. The indicator value for each taxon can vary from 1 to 5. The index value for lakes can vary between 1,5 and 4,0.

$$\mathrm{PTI} = \frac{\sum_{j=1}^{n} a_j s_j}{\sum_{j=1}^{n} a_j}$$

aj = proportion of taxon j in a sample
sj= indicator value for taxon j in a sample

The maximum volume for cyanobacteria (Cyanomax) describes the biomass of cyanobacteria. Cyanobacteria are associated with eutrophication in lakes. They can produce high biomasses and are potential toxin producers. Their presence can limit the use of lakes as drinking water source for recreation and other purposes. This index reflects an unwanted disturbance of the phytoplankton community and is linked to risk levels of the WHO (1999). The thresholds are 4 000, 20 000 and 100 000 cells/ml (WHO 1999). These values are converted to biovolume thresholds of 0.2, 1 and 5 mm^3/l (or mg/l) and multiplied with a cell volume (based on spherical cells like those from *Microcystis* with a cell diameter of 4.5 µm (Hillebrand et al. 1999).

In this report, we use the combination of the indices PTI, Cyanomax and phytoplankton biovolum, see suggestions in Mjelde et al. (2017). Because of the methodological challenges, chlorophyll was not included in the sampling procedure in Indawgyi Lake. Boundaries for Myanmar are not yet developed. Therefore, we have used the boundaries for the phytoplankton indices in Norwegian lake types (Direktoratsgruppa 2015) as a first approach, see Table 3. Ecological status assessment for phytoplankton in other lakes in Myanmar (e.g. Inlay Lake) based on these indices and boundaries seem to fit very well with the general impression of the lake status'. However, it is important to keep in mind that the ecological status presented here is based on very few data, and will only give a first indication of the status. The boundaries need to be evaluated and further developed based on additional data from Myanmar lakes, feedback from experts from Myanmar, and compared to other available assessment systems.

Table 3. Norwegian class boundaries for phytoplankton-indices for medium alkaline lakes, as Indawgyi Lake. H=high, G=good, M=moderate, P=poor, B=bad.

Lake type	Class	Chlorophyll µg/l	Biovolume mg/l	PTI	Cyanomax mg/l
Lowland, moderate alkalinity, clear	H	<6	<0.64	<2.26	<0.16
	G	6-9	0.64-1.04	2.26-2.43	1.00
	M	9-18	1.04-2.35	2.43-2.60	1.00-2.00
	P	18-36	2.35-5.33	2.60-2.86	2.00-5.00
	B	>36	>5.33	2.86-4.0	>5.00

3.2.3 Aquatic macrophytes

Definition

A simple definition of macrophytes is aquatic plants growing in or close to the water. They can be divided into semi-aquatic plants (i.e. emergent plants, helophytes) and aquatic macrophytes (hydrophytes), i.e. submerged plants or plants with floating leaves. The definition of species included among helophytes versus species included among hydrophytes may vary.

In this study we only include aquatic macrophytes (hydrophytes). These are the species most depending on water quality. They are used in the indices, developed and used in the Water Framework Directive, Northern Intercalibration Group (Hellsten et al. 2014).

The aquatic macrophytes can be divided into growth form groups (see Figure 5); isoetids (2), elodeids (3), nymphaeids (4), lemnids (5). Some macrophyte species can occur in both helophyte and true aquatic forms. These are also included here. In addition, the charophytes (macroalgae) are included.

Helophytes (emergent aquatic plants) (1) are not included in the definition, neither are the aquatic bryophytes or filamentous algae.

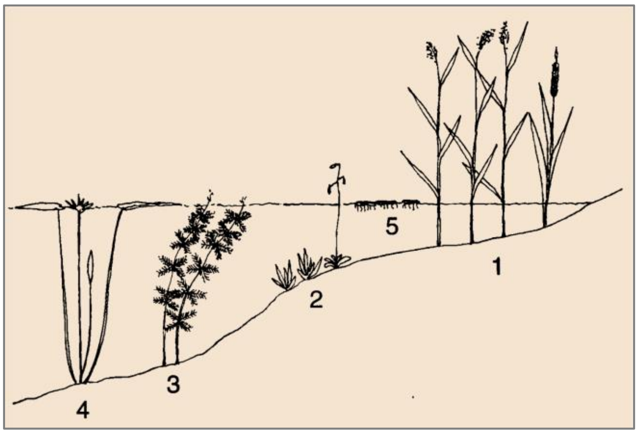


Figure 5. Growth forms of aquatic macrophytes.

Sampling method

Aquatic macrophytes in Indawgyi Lake were sampled on the 19-21. September 2017. In Myanmar, as well as in other tropical areas, the appearance and abundance of species differ throughout the year. Therefore, to get a more complete overview of the species, it may be necessary to do an additional survey in Indawgyi Lake, in another period of the year (see Ballot et al., 2017).

At different localities in the lake the plants were recorded using an aqua scope and collected by dredging from the boat. The abundance of the species is scored by a semi-quantitative scale, where 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant.

Flora and identification keys
All species are determined by Marit Mjelde, based on morphological keys in floras for the region, primarily Cook (1996), in addition to updated or more specialized taxonomic work, e.g. La-Ongsri et al. (2009), Margua Raya et al. (2010), Sivarajan & Joseph (1993), and Triest (1988). When updated taxonomic literature was not available, different internet-sites like Flora of China (http//www.efloras.org) and Encyclopedia of life (http//eol.org) were used.

Ecological status
Coverage and species richness of macrophytes decrease with increasing enrichment of lakes (Phillips, et al., 1978, Rørslett, 1991). The enrichment causes a change from the submerged isoetids or charophytes, via elodeids, to floating leaved or free-floating species, and in the end disappearance of aquatic macrophyte species. The decrease in submerged macrophyte cover and species diversity are mainly due to shading by phytoplankton or epiphytic algae, or competition for nutrients (see Mjelde and Faafeng, 1997, with references).

At present, no approved indices for ecological status based on aquatic macrophytes in Myanmar lakes are available. As a preliminary assessment, the ecological status of aquatic macrophytes in Indawgyi Lake is based on a trophic index and an index based on coverage of lemnids and submerged species, see Mjelde et al. (2017).

Trophic index
The index is based on the relationship between species sensitive to eutrophication and species that are tolerant to this impact (Mjelde et al., in prep., also see Penning et al 2008).

$$TI_C = \frac{N_S - N_T}{N} \times 100$$

N_S is the number of sensitive species, while N_T is the number of tolerant species. N is the total number of all aquatic macrophyte species.

The index-value can vary between +100, if all present species are sensitive, and -100, if they all are tolerant. The index calculates one value for each lake, however, for larger lakes index-values for different parts of the lake should be considered.

Species sensitivities has to be established exclusively for Myanmar or for South-Eastern Asia. As a start, we suggest a preliminary list of Myanmar sensitive and tolerant species, based on expert judgement and literature survey from Asian countries (updated list from Mjelde et al. 2017, see Appendix A). The list is an important basis for calculating the trophic index and to give a correct ecological status assessment. This preliminary list has to be corrected and updated as soon as more data is available from Myanmar.

Boundaries for Myanmar are not yet developed. Therefore, we have used the same boundaries as established for Norwegian lake types (Direktoratsgruppa 2015), see Table 3. They seem to fit very well with the general impression of the lake status'. However, the boundaries must be evaluated when more data from Myanmar lakes are available.

Table 4. Norwegian class boundaries for the TIc-index for moderate alkalinity, clear lakes. H=high, G=good, M=moderate, P=poor, B=bad (from Direktoratsgruppa 2015).

Lake type		**calcium mg Ca/l**	**colour mg Pt/l**	**reference value**	**H/G**	**G/M**	**M/P**	**P/B**
201	Moderate alkalinity, clear	4-20	<30	74	66	30	5	-35

Relative abundance index (RA index)
As recommended by Mjelde et al. (2017), we have tested a metric based on the relative abundance of the growth form group lemnids (tolerant to eutrophication). It is an overall agreement of the sensitivity of this group (Penning et al 2008a), which make such metric robust at this stage. High abundance of lemnids gives low ecological status while low abundance gives high status, see Table 5.

The other suggested metrics in this index were abundance of the growth form group charophytes and of the sensitive submerged species *Potamogeton lucens* (see Mjelde et al 2017). Charophytes are not recorded in Indawgyi Lake, and the elodeide *Potamogeton lucens* is not common in the lake. Hence, these metrics are not suitable for Indawgyi Lake. Instead we suggest to include coverage of submerged species, i.e. the elodeid growth form group.

Table 5. Relative abundance metrics for lemnids and for submerged species, with suggested boundaries. The average of both metrics and all localities gives a number 1-5, where 5= high status, 4= good status, 3= moderate status, 2=poor status and 1= bad status.

Metrics/Ecological Class	High (5)	Good (4)	Moderate (3)	Poor (2)	Bad (1)
Coverage of lemnids [2]	0	1-2	3	4	5
Coverage of submerged species[2]	3	4-5	2	1	0

2: using average of highest semi-quantitative scores at each locality

4 Results and discussion

4.1 Physical measurements and water chemistry

Indawgyi Lake is a large and deep lake with inflow from several rivers. The water is clear (low colour and low turbidity), with calcium values around 9 mg Ca/l (Table 6). The lake can be characterized as a medium alkaline, clear water lake.

Table 6. Physical-chemical properties in Indawgyi Lake in September 2017-January 2018.

Localities	Date	depth (m)	Oxygen mg/l	Temp. ºC	pH *	Conductivity µS/cm	depth (m)	Calcium mg Ca/l	Colour mg Pt/l	Turbidity FNU
IDW-1	20.09.2017	surface	8.47	31.0	9.03	123.3	0-8	9.44	6	1.1
IDW-2	21.09.2017	surface	8.95	31.8	9.27	121.9	0-10	8.6	5	1.4
IDW-3	21.09.2017	surface	8.75	30.5	9.24	122.5	0-9	9.02	5	0.97
IDW-1	30.11.2017	surface	3.95	25.4						
IDW-2	30.11.2017	surface	5.99	25.5						
IDW-3	30.11.2017	surface	5.72	27.8						
IDW-1	25.12.2017	surface	2.56	23.1						
IDW-2	25.12.2017	surface	2.12	22.7						
IDW-3	25.12.2017	surface	5.14	22.3						
IDW-1	24.01.2018	surface	6.15	21.4						
IDW-2	24.01.2018	surface	6.89	21.0						
IDW-3	24.01.2018	surface	6.28	21.2						

In September 2017, the water temperature was higher than 30° C in the upper 7-8 m depths and showed just a minor decrease down to 15 m depth (Figure 6), which is typical for tropical lakes. The reason for the small temperature variations may be the heavy storm and rainfall just before and during the sampling period which have lead to homogenous temperature in most of the water column.

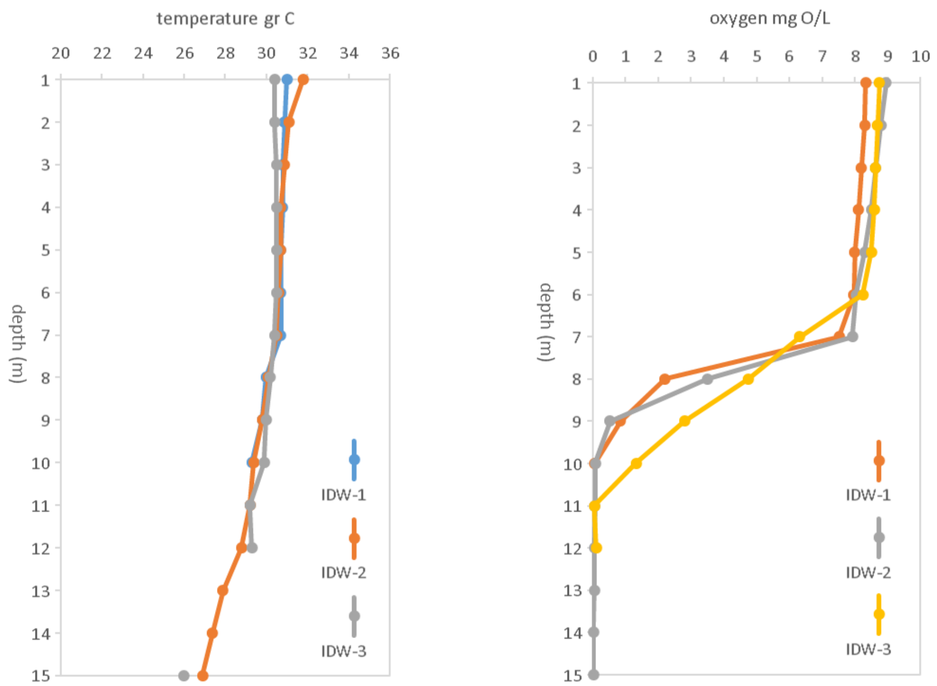


Figure 6. Temperature and oxygen conditions in Indawgyi Lake 20-21. September 2017.

In spite of the homogenous temperature conditions, the oxygen conditions in the water column in September 2017 showed a dramatical decrease at 7-8 m depth in all three localties, and nearly anoxic conditions at 12-15 m depth (Figure 6). Bad oxygen conditions will effect flora and fauna in the lake, and can in periods cause fish kills. Therefore, it is essential to get better knowledge about the levels and variations of oxygen in the lake, and the oxygen conditions should be monitored frequently, for instance each month in a two years period.

Monthly measurements of the oxygen concentrations in surface layer at all sampling stations showed a clear oxygen decrease towards November and December 2017 (Figure 7). In December only 2.1 mg/l oxygen were measured at the surface at station IDW2, indicating a massive oxygen depletion in the whole lake caused most likely by a large degradation of organic biomass. In the same period the water temperature decreased at the surface from 31°C to 21.8°C in January 2018 (Figure 8).

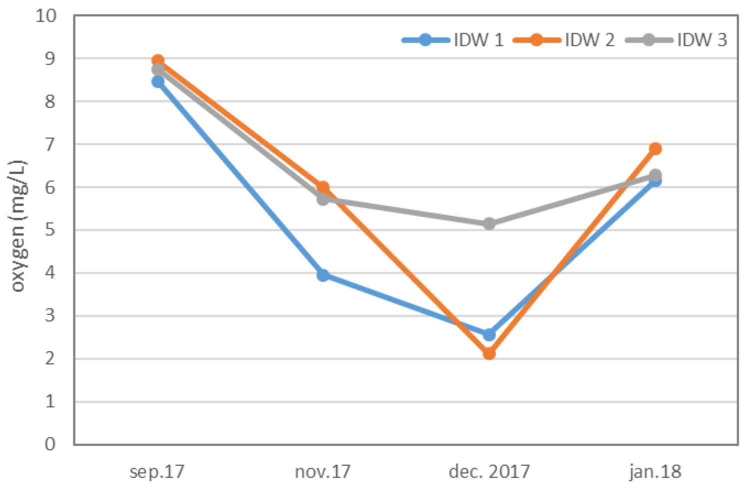


Figure 7. Oxygen concentrations (surface) in Indawgyi Lake in the period September 2017- January 2018.

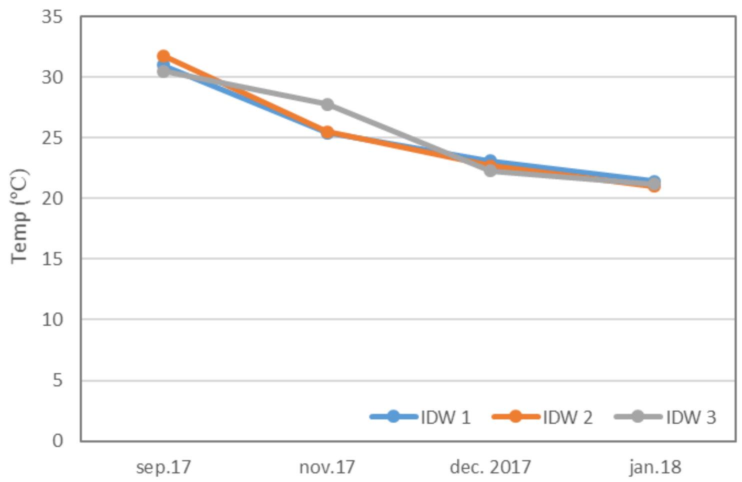


Figure 8. Temperature (surface) in Indawgyi Lake in the period September 2017- January 2018.

Average values of total phosphorus and total nitrogen in September 2017 were 7.3 µg P/l and 532 µg N/l, respectively. The levels of phosphorous were low and as expected in a more or less pristine area (Table 7, Figure 9), however very low compared to phytoplankton trophic index (see Chap. 4.2). The reason for the low values may be due to some heavy rain storms and flushing during sampling and/or dilution due to the merged samples 0-10 m. Phosphorus values in the dry season May 2015 were higher than in 2017. The nitrogen values measured in 2017 were slightly higher in 2015 (Table 7, Figure 6).

Table 7. Water quality at two localities in May 2015 and three localities in September 2017. Analysed by NIVA in Oslo.

Localities	Date	depth (m)	Total Phosphorus µg P/l	Phosphate (PO4) µg P/l	Total nitrogen µg N/l	Nitrate+nitrite (NO3+NO2) µg N/l	Ammonium (NH4) µg N/l
IDW-A	13.5.2015	surface	13	2	305	2	38
IDW-B	13.5.2015	surface	11	2	260	1	29
IDW-1	20.09.2017	0-8	8	1	635	<2	21
IDW-2	21.09.2017	0-10	8	<1	650	<2	25
IDW-3	21.09.2017	0-9	6	<1	310	<2	15
Average 2017			7.3	<1	532	<2	20.3

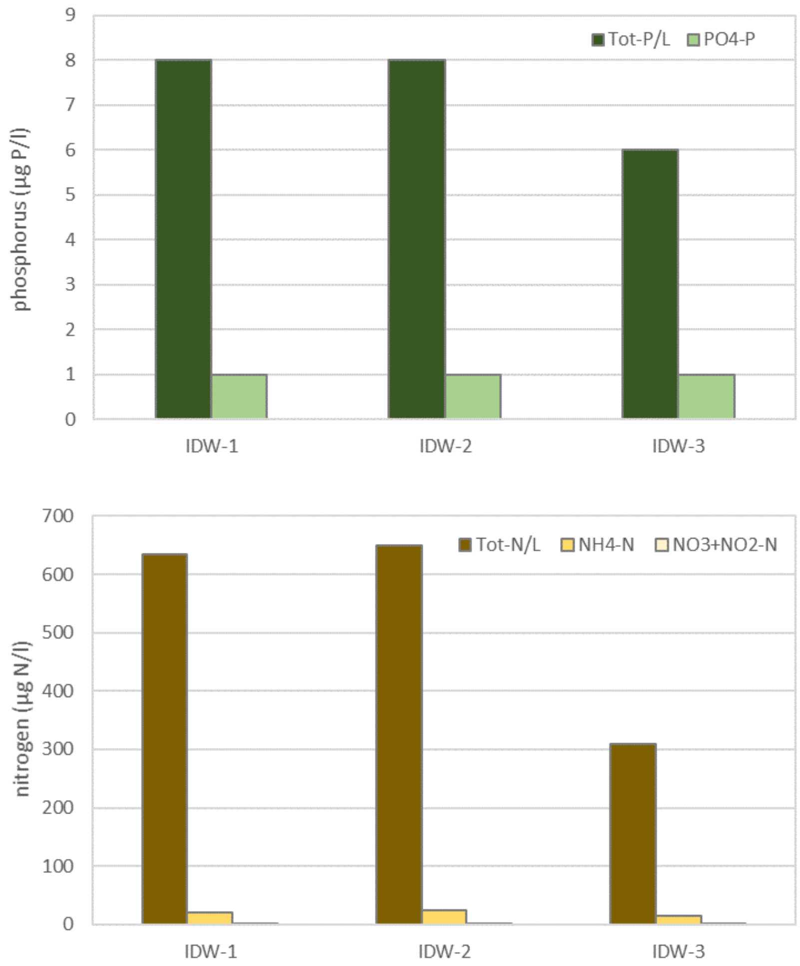


Figure 9. Levels of phosphorus and nitrogen at the three localities IDW-1, IDW-2 and IDW-3 in Indawgyi Lake in September 2017. Analysed by NIVA in Oslo.

The low oxygen concentrations are an indication of high bacterial decomposition of organic biomass. However, to get a better understanding of the conditions in the lake and track the sources of pollution, a more extended survey is needed.

4.2 Phytoplankton

4.2.1 Species diversity

The three sampling points IDW1, IDW2 and IDW3 (Figure 4) were investigated for phytoplankton composition and its abundance in September and November 2017. Altogether 69 phytoplankton taxa were identified at the three sampling locations. The phytoplankton taxa and their abundance based on a semi-quantitative scale are depicted in Appendix B. As a number of taxa could be determined to genus level only, the number of taxa present in Indawgyi Lake is supposed to be higher.

Figure 10 shows the phytoplankton composition and biomass in Indawgyi Lake for the three sampling sites IDW1, IDW2 and IDW3 and two sampling dates. The phytoplankton biomass found in the selected samples ranged from 0.2 to 1.9 mg^{-1}. Although the lake gave optically the impression of an eutrophicated lake (see Figure 11), the biomasses measured were relatively low and mostly in a range typical for non-productive lakes.

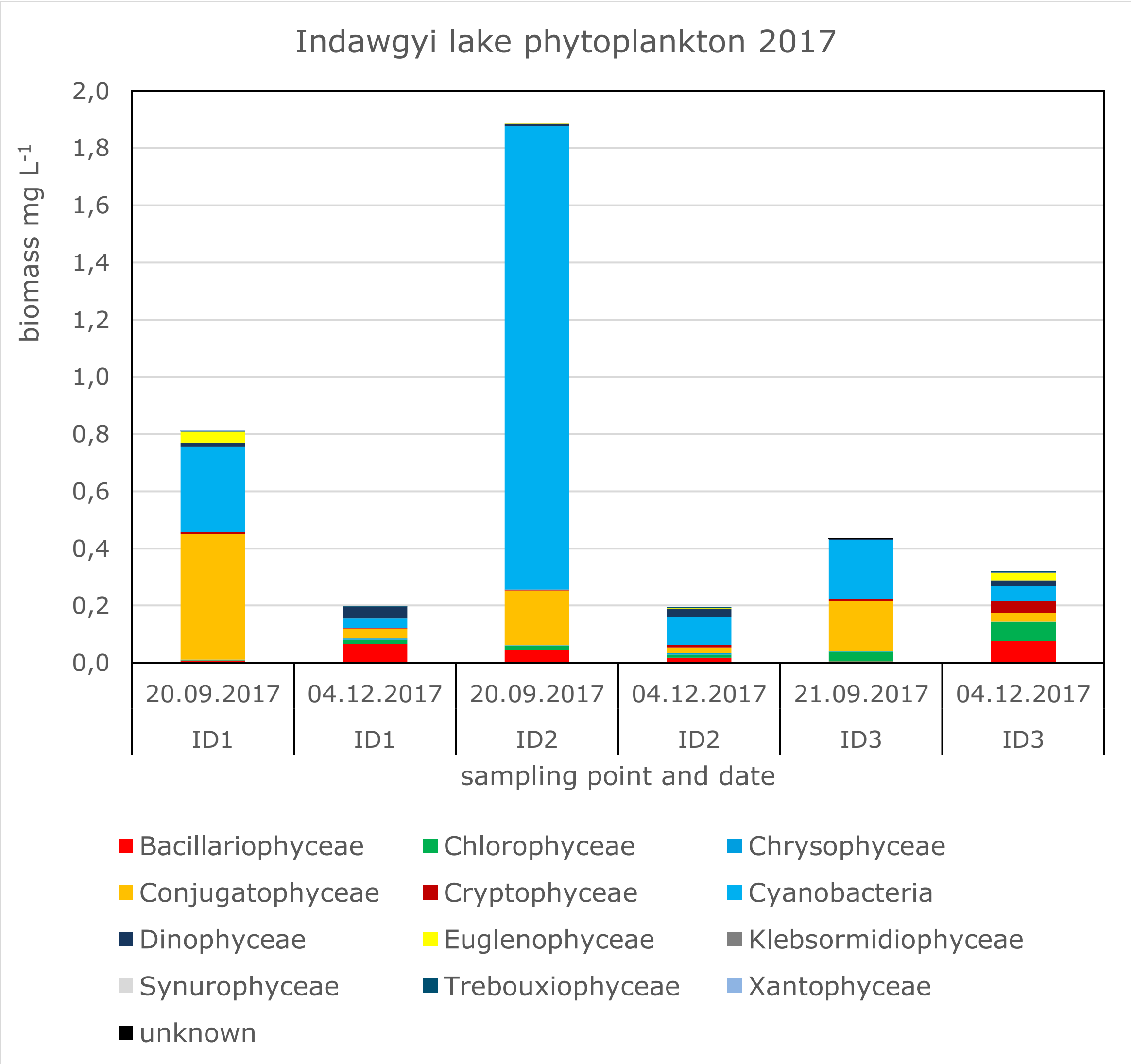


Figure 10. Phytoplankton composition and biomass at three sampling points and two sampling dates in Indawgyi Lake in 2017.

Figure 11. Algae bloom (flakes of cyanobacteria) in the water column at IDW2 in Indawgyi Lake September 2017. Photo: T. Swe.

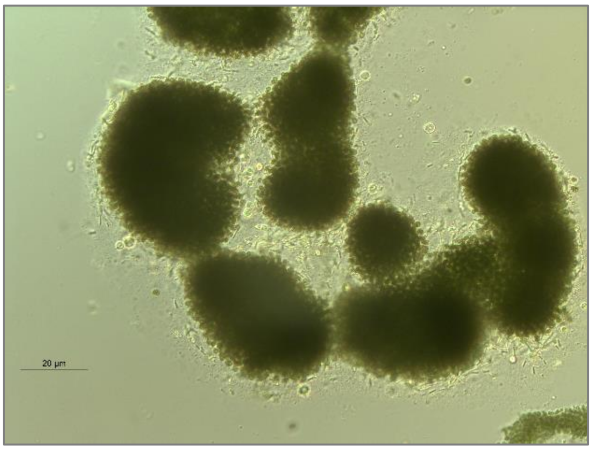
The low biomasses can be explained as follows. In September 2017, the samples were taken as integrated samples from 0 to 10 m. The oxygen measurements showed, however, that below 7 m depth the oxygen concentrations decreased considerably, indicating that there was only a limited amount of phytoplankton to expect in these deeper areas. The integration of the water column between 0 and 10 m has certainly led to a dilution of the samples resulting in a lower average biomass measured.

In December 2017, Indawgyi Lake was characterized by very low oxygen concentrations; between 2 and 5 mg/l at the surface. The water samples for phytoplankton were taken in 1 m depth. Also at this time the low oxygen concentrations indicated a low phytoplankton biomass in that area. These conditions have to be considered when future adjusted sampling. Consequences are a changed sampling procedure for Indawgyi Lake in the future, e.g. avoid phytoplankton sampling in anoxic areas.

4.2.2 Dominating species

A dominating group in all samples is the cyanobacteria. The most present cyanobacterial morpho-species were *Microcystis ichthyoblabe* and *Microcystis viridis* (Figure 12). Both *M. ichtyoblabe* and *M. viridis* are known producers of hepatotoxic microcystins. It has to be noted that according to recent findings all *Microcystis* spp. genetically are placed into the same species complex (Harke et al. 2016). Other cyanobacteria present were *Sphaerospermopsis aphanizomenoides*, *Chrysosporum ovalisporum* and *Planktothrix* cf. *mougeotii*. *Chrysosporum ovalisporum* is a known producer of the hepatotoxic cyanotoxin cylindrospermopsin and as an invasive species, probably spread also to other water bodies in Myanmar. Other dominating groups were the diatoms (Bacillariophyceae), including the species *Aulacoseira granulata*, and Conjugatophyceae, a class of green algae including members of the genera *Staurastrum* and *Cosmarium*.

Despite the low phytoplankton biomasses, the dominance of the cyanobacteria shows that Indawgyi Lake is in bad condition.



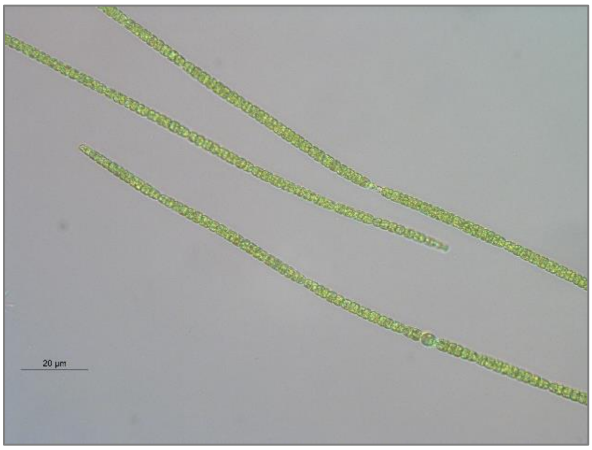


Figure 12. Colonies of *Microcystis viridis* (left) and filaments of *Sphaerospermopsis aphanizomenoides* (right).

4.2.3 Ecological status

Based on the phytoplankton biomass and composition, and the trophic index PTI (without chlorophyll), and with Norwegian boundaries (see Table 3), we have exemplified the ecological status of Indawgyi Lake in September and December 2017 (Figure 13).

The status at all three central sampling stations IDW1, IDW2 and IDW3 in Indawgyi Lake could be classified as moderate to bad status, both in September and in December 2017. The exception is IDW1 which was evaluated as in good condition in December 2017, according to the low phytoplankton biomass measured. In contrast, the Phytoplankton Trophic Index (PTI) indicates poor to bad status at all sampling localities. These contradictory results are most likely due to the field sampling method (see explanation on page 23). Consequences are a changed sampling procedure for Indawgyi Lake in the future, e.g. avoid phytoplankton sampling in anoxic areas.

Many phytoplankton taxa are more or less globally distributed. Indices and boundaries used in Norway therefore seem to be suitable also for assessments in Myanmar, at least in this phase. However, the indices and boundaries have to be evaluated and further developed when more data from Myanmar are available.

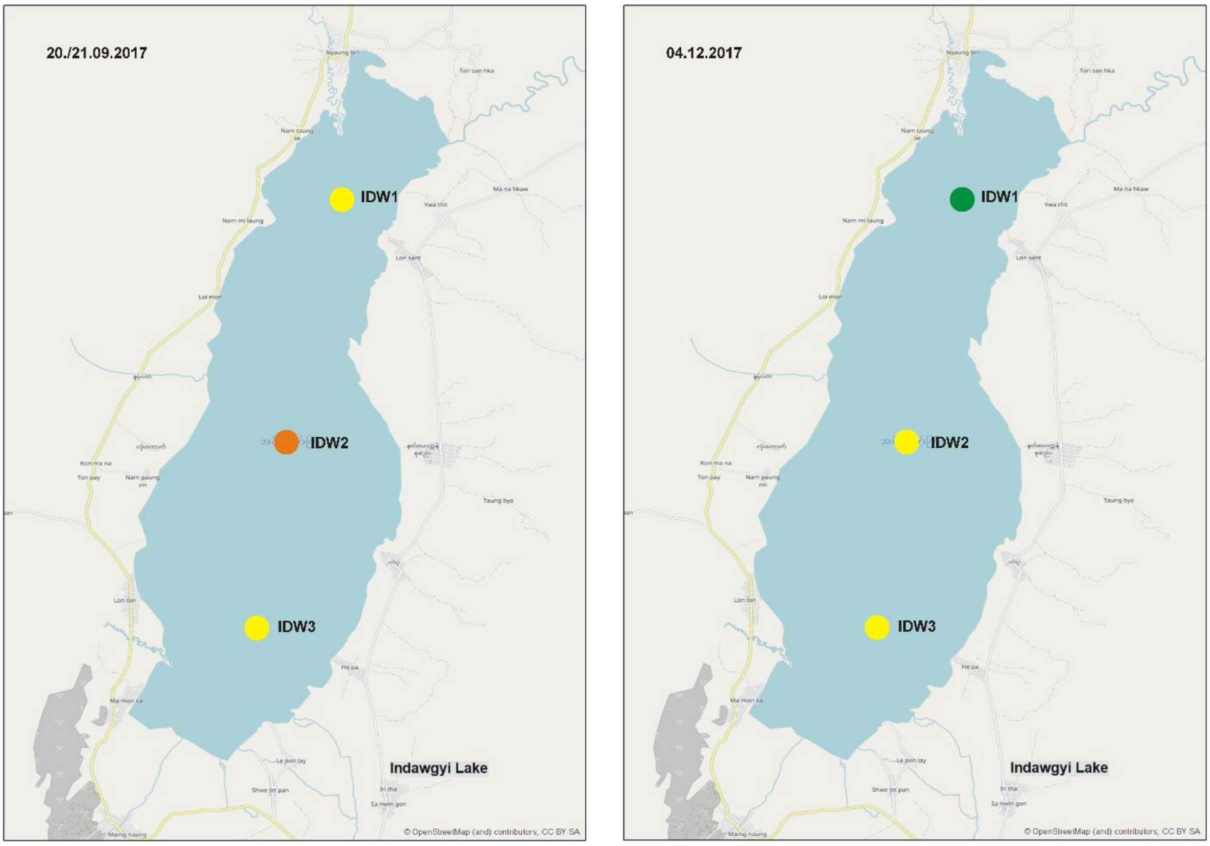


Figure 13. Ecological status of Indawgyi Lake using phytoplankton biomass, PTI index and cyanobacteria biomass. The classification is based on phytoplankton data from Indawgyi Lake 2017 and exemplified based on Norwegian boundaries in Table 3. Green =good status, yellow= moderate status and orange = bad status.

4.3 Aquatic macrophytes

4.3.1 Species diversity

A total of 22 aquatic macrophyte species were recorded in Indawgyi Lake in September 2017 (see Table 8). The species number in each locality varied between 6 and 13. In addition, *Ottelia alismoides,* was recorded at a few localities in November, i.e. a total of 23 aquatic species are recorded in the lake.

Species belonging to the growth form groups nymphaeids and lemnids, i.e. species with floating leaves or free-floating species, in addition to two submerged elongated species (elodeids), dominated in the lake. The free-floating species and most of the floating-leaved species can survive in water with bad light conditions, and are, hence, characterized as tolerant species according to eutrophication.

A total of 9 submerged species were recorded. The most frequent of this group, *Ceratophyllum demersum*, is often free-floating in the water column, which allow it to float close to the surface and avoid bad light conditions in deeper water.

Table 8. Aquatic macrophytes in Indawgyi Lake. Registered 19-21. September and November 2017. Abundance scores: 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant.

	Localities																
Latin names	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
ELODEIDER																	
Ceratophyllum demersum	2	5	2		1-2	2	3	2	5	2	4	5	2	3	3	2	5
Hydrilla verticillata	4	3	1		1						3					1	3
Najas indica	3	4	2		1-2	1			2	2	3	2-3					
Najas minor											2						
Potamogeton cf wrightii	1	4							+	5					3	4	1
Potamogeton cf nodosus						2-3		3								3	
Utricularia cf aurea	2-3	1	1	2							1						
Utricularis gibba	1			1												1	
Vallisneria spiralis	2	2	2-3		1	1	2	+	+	3	2	2	2	3	4	4	4
NYMPHAEIDER																	
Euryale ferox	3	5		2							3	2-3					
Nymphaea pubescens						2							4	1			2
Nymphoides indica	5	2-3	2		2	4	4	2	2	3	4	3	3	2		3	2
Nymphoides hydrophylla						2	1										
Ottelia alismoides																	
Trapa natans	4	3	1				2		2		2	2		1	1	1	2
LEMNIDER																	
Azolla pinnata		2		2-3		2		1	4	2	2	2				1	
Eichornia crassipes	3	4	3	3	3	3	4	4	5	5	5	5	3	4	4	4	3
Hydrocharis dubia							1			2							
Lemna minor				1	1											1	
Pistia stratiotes					1		1	2	2	2	2			1			
Salvinia cucullata	4	3	4	4	4	2-3	3	3	4	4	5	5	2	3	4	4	4
Spirodela polyrhizza			1				2	1	2-3	1		1				1	
total number of species	**12**	**12**	**10**	**7**	**9**	**10**	**10**	**9**	**11**	**11**	**13**	**10**	**6**	**8**	**6**	**13**	**9**

Very few aquatic macrophyte surveys in lakes in Myanmar are performed. Whether the species diversity in Indawgyi Lake is within what is normal for this lake type in Myanmar, we do not know. However, the species number in Indawgyi Lake is similar to the number found in Inlay Lake (Shan State).

Due to our experience, the aquatic biodiversity and species abundance in Myanmar lakes seem to vary a great deal throughout the year. To get a more complete overview of the aquatic biodiversity in Indawgyi Lake, we suggest visiting the lake again, preferably early in the dry season.

4.3.2 Dominating species

The aquatic macrophytes in Indawgyi Lake are dominated by free-floating species (Table 8). Of these, *Eichhornia crassipes* and *Salvinia cucullata* (Figure 14) were the most frequent ones. They were present at all localities and made large stands in most areas.

Figure 14. The most frequent species in Indawgyi Lake; the free-floating species *Eichhornia crassipes* (upper) and *Salvinia cucullata* (lower). The Figure shows both overview and close-up pictures of the two species. Photos: M. Mjelde and T. Swe, September 2017.

Also, the submerged species *Ceratophyllum demersum* and *Vallisneria spiralis* (Figure 15), and the floating-leaved species *Nymphoides indica* (Figure 16) were recorded in most areas. Other frequent species were *Trapa natans* (Figure 16), *Najas indica* (Figure 17) and *Azolla pinnata* (Figure 17). All other species had frequencies less than 42 %.

Figure 15. The most frequent submerged species in Indawgyi; *Vallisneria spiralis* (upper), at low water level in May 2015, and *Ceratophyllum demersum* (lower), in September 2017. Photos: M. Mjelde.

Figure 16. *Nymphoides indica* (left) and *Trapa natans* (right) were also among the common species in Indawgyi Lake, September 2017. Photos: M. Mjelde.

Figure 17. The submerged *Najas indica* (left) and the small free-floating species *Azolla pinnata* (reddish colour, right) were recorded in more than 50 % of the localities in Indawgyi Lake, September 2017. Photos: M. Mjelde and T. Swe.

4.3.3 Invasive species

Most of the recorded species are native and common in Asia. We recorded only one invasive species among the aquatic macrophytes; the water hyacinth *Eichhornia crassipes* (see figure 14), native in the Amazon basin in South-America. The species was the most frequent species in Indawgyi Lake and made large stands in most areas.

4.3.4 Other interesting species

Euryale ferox

The amazing floating-leaved species *Euryale ferox* (Figure 18) made large stands in the northern and southern part of Indawgyi Lake. The species is one of the largest species among the Nymphaeaceae. The floating leaves can be up to 100 cm in diameter and are densely spinous on both sides.

The species is restricted to the tropical and subtropical regions of South-east and East Asia (Shankar et al. 2010), and according to Kress et al. (2003), Kachin state is the only reported region for this species in Myanmar. The species is not included in Ito & Barfod (2014) and we have not recorded it in other lakes in Myanmar (Mjelde et al; in prep).

Figure 18. *Euryale ferox* in Indawgyi Lake. Photos: M. Mjelde, May 2015.

The species is considered as not threatened (least concern) in the red-list of Indo-Burma, which include most of Myanmar (Allen et al 2012, see also Zhuang 2011). However, aquatic macrophytes are not yet included in the red-list assessment for the Eastern Himalaya region (which include the northern part of Myanmar, also Indawgyi area) (Allen et al 2010).

Euryale ferox seem to prefer permanent stagnant water (Shankar et al. 2010). The standing waters in Myanmar are dominated by reservoirs, and natural lakes are rare. In Kachin state, Indawgyi Lake may be the only, or one of few, natural habitats for this species in Myanmar. The few natural localities may also be threatened by eutrophication and sedimentation (Khan et al. 2000, 2004). However, *Euryale ferox* has edible and medicinal uses, and the plant is a common cultivation plant (makhana cultivation).

Hydrocharis dubia

This species was recorded only in a few localities in Indawgyi Lake (Figure 19). It did not flower when we visited the lake, and only buds in November. Because of the small leaves and without flowers it may be difficult to discover among the other free-floating and floating-leaved species.

Figure 19. *Hydrocharis dubia* in Indawgyi Lake. Photos: M. Mjelde, September 2017.

This species is distributed in southeast and east Asia, Indonesia and northern Australia, but according to Kress et al. (2003), Shan state is the only reported region in Myanmar. Ito & Barfod (2014) has included localities in Thailand and noted that it might be distributed also in Myanmar. Indawgyi Lake is the only lake where we have recorded this species, we did not record it in Inlay lake (Shan state) in 2015-2017 (Ballot et al. 2017).

4.3.5 Ecological status

Based on a preliminary species sensitivity for Myanmar species (see Appendix A), and using the suggested trophic index (TIc) and Norwegian boundaries, the status of aquatic macrophytes in Indawgyi Lake is classified as poor (Table 9). Also the suggested relative abundance metrics for lemnids and submerged species (elodeids) indicates poor status for aquatic macrophytes in Indawgyi Lake (see Table 9).

Table 9. Ecological status of aquatic macrophytes in Indawgyi Lake in 2017.
Indawgyi Lake is type 201: moderate alkalinity, clear. Orange: poor status.

Index	Index value	Status
Trophic index (TIc)	-27.3	poor
Relative abundance index (RA)	2.5	poor

The aquatic macrophytes in Indawgyi Lake are dominated by tolerant species, which give a negative TIc-value, and poor status. The high coverage of the free-floating species, the lemnids, compared to the submerged species coverage is the reason for the low RA-index value.

These preliminary indices and boundaries have to be evaluated and updated as soon as more data are available from Myanmar.

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Appendix A. Macrophytes - species sensitivity

Preliminary eutrophication sensitivity for Myanmar species (NB! Not all of these are recorded in Indawgyi Lake). T = tolerant species, S = sensitive species and I = indifferent species. See text chapter 3.2.3 and Mjelde et al. (2017) for more explanation.

Lifeform groups/ Latin names	Preliminary sensitivity
ELODEIDS	
Ceratophyllum demersum	T
Hydrilla verticillata	S
Limnophila sessiflora	T
Myriophyllum spicatum	T
Myriophyllum tuberculatum	T
Myriophyllum verticillatum	T
Najas indica	I
Najas minor	I
Nechamandra alternifolia	T
Potamogeton crispus	I
Potamogeton lucens	S
Potamogeton lucens-hybrid	S
Potamogeton nodosus	I
Potamogeton nodosus-hybrid	I
Potamogeton cf. wrigthii	I
Stuckenia pectinata	T
Stuckenia pectinata-hybrid	T
Utricularia aurea	S
Utricularia australis	S
Utricularia gibba	S
Utricularia punctata	S
Vallisneria spiralis	I
NYMPHAEIDS	
Euryale ferox	S
Nelumbo nucifera	I
Nymphaea cyanea	I
Nymphaea nouchali	I
Nymphaea pubescens	I
Nymphaea rubra	I
Nymphoides indica	T
Nymphoides hydrophylla	T
Nymphoides cordata	T
Ottelia alismoides	I
Ottelia cordata	I
Trapa natans	T

Life form groups/ Latin names	Preliminary sensitivity
LEMNIDS	
Azolla pinnata	T
Eichornia crassipes	T
Hydrocharis dubia	T
Lemna minor	T
Lemna trisulca	I
Pistia stratiotes	T
Spirodela polyrhizza	I
Salvinia cucullata	T
Salvinia natans	T
CHAROPHYTES	
Chara sp. zeylandica	S
Chara sp.	S

Appendix B. Phytoplankton composition in Indawgyi Lake in September and December 2017.Legend: + = sporadic, ++ = frequent, +++ = dominant.

Taxon	IDW1 20.09. 2017	IDW1 04.12. 2017	IDW2 20.09. 2017	IDW2 04.12. 2017	IDW3 21.09. 2017	IDW3 04.12. 2017
Domain Eubacteria						
Division Cyanobacteria (Cyanoprokaryota)						
Aphanocapsa delicatissima West & G.S.West	+++	+++		+++	+++	+++
Aphanothece smithii Komárková-Legnerová & G.Cronberg	+		+		+	+
Chrysosporum ovalisporum (Forti) E.Zapomelová, O.Skácelová, P.Pumann, R.Kopp & E.Janecek	+++		+++		+++	
Komvophoron K.Anagnostidis & J.Komárek, 1988						+
Leptolyngbya Anagnostidis & Komárek	+					
Merismopedia tenuissima Lemmermann	++	+++			++	
Merismopedia warmingiana (Lagerheim) Forti				+++		+++
Microcystis ichthyoblabe (G.Kunze) Kützing	+++	+++	+++	+++	+++	+++
Microcystis viridis (A.Braun) Lemmermann	+++	+++	+++	+++	+++	
Planktothrix cf. *Mougeotii* Suda et al.	+++		+++		+++	
Pseudanabaena sp. Lauterborn		+			+	
Pseudanabaena limnetica (Lemmermann) Komárek	+					
Pseudanabaena mucicola (Naumann & Huber-Pestalozzi) Schwabe	+++			++		++
Sphaerospermopsis aphanizomenoides (Forti) Zapomelová, Jezberová, Hrouzek, Hisem, Reháková & Komárková	++				++	
Synechococcus C.Nägeli		+		+++		+++

Appendix B. (cont.).

Taxon	IDW1 20.09. 2017	IDW1 04.12. 2017	IDW2 20.09. 2017	IDW2 04.12. 2017	IDW3 21.09. 2017	IDW3 04.12. 2017
Domain Eukarya						
Class Bacillariophyceae						
Aulacoseira granulata (Ehrenberg) Simonsen	+++	+	++	++	+++	++
Aulacoseira granulata var. *angustissima (Otto Müller) Simonsen*	+					
Cyclotella (Kützing) Brébisson		++	+	++		++
Cymbella sp. C.Agardh		++				+++
Epithemia sp.Kützing	+					
Eunotia sp. Ehrenberg					+	
Fragilaria ulna (Nitzsch) Lange-Bertalot	+	++				
Gomphonema sp. Ehrenberg		+				
Navicula sp. Bory		+				
Nitzschia palea (Kützing) W.Smith		+				
Nitzschia Hassall					+	
Pinnularia sp. Ehrenberg		+				
Class Conjugatophyceae						
Closterium aciculare T.West		++	+	+		
Closterium spp. Nitzsch ex Ralfs	+	+++	+	+	+	
Cosmarium contractum O.Kirchner	+	+	+++			
Spondylosium pulchrum (Bailey) W.Archer	+					
Staurastrum cf. *longiradiatum* West & G.S.West	++	+	++	+		
Staurastrum spp. Meyen ex Ralfs	+++	+++	+++	++	+++	+++
Class Chlorophyceae						
Ankistrodesmus spiralis (W.B.Turner) Lemmermann	+	+		+	+	+
Chlamydomonas sp. Ehrenberg		+				

Appendix B. (cont.).

Taxon	IDW1 20.09. 2017	IDW1 04.12. 2017	IDW2 20.09. 2017	IDW2 04.12. 2017	IDW3 21.09. 2017	IDW3 04.12. 2017
Coelastrum reticulatum (P.A.Dangeard) Senn		+	++	+	++	+
Coenochloris planoconvexa Hindák					+	
Coenochloris planctonica (West & G.S.West) Hindák			+			
Eudorina elegans Ehrenberg		+				
Kirchneriella contorta (Schmidle) Bohlin		+		+	++	+
Monoraphidium circinale (Nygaard) Nygaard	+	+++	+	+	+	+++
Monoraphidium dybowskii (Woloszynska) Hindák & Komárkova Legnerová						+++
Monoraphidium griffithii (Berkeley) Komárková-Legnerová			+		+	++
Monoraphidium minutum (Nägeli) Komárková-Legnerová	+	+			+	+
Monoraphidium tortile (West & G.S.West) Komárková-Legnerová	++		+		+	
Pseudoschroederia robusta (Korshikov) Hegewald & Schnepf		++	+	+	+++	+
Schroederia indica Philipose						+
unknown Chlorophyceae						+
Class Trebouxiophyceae						
*Botryococcus braun*ii Kützing	+	++		+		
Nephrocytium perseverans Printz				+		
Nephrocytium sp. Nägeli	+					
Oocystis sp. Nägeli ex A.Braun						+
Class Euglenophyceae						
Euglena spp. Ehrenberg	+		+			
Trachelomonas superba Svirenko	+		+			
Trachelomonas cf. *sydneyensis* Playfair				+		
Trachelomonas volvocina (Ehrenberg) Ehrenberg				+		+++

Appendix B. (cont.).

Taxon	IDW1 20.09. 2017	IDW1 04.12. 2017	IDW2 20.09. 2017	IDW2 04.12. 2017	IDW3 21.09. 2017	IDW3 04.12. 2017
Class Dinophyceae		++			+	
Ceratium hirundinella (O.F.Müller) Dujardin			+	++		++
Gymnodinium sp. F.Stein						
Gymnodinium simplex (Lohmann) Kofoid & Swezy				+		
Peridinium sp. Ehrenberg				+		
Class Chrysophyceae						
Bitrichia chodatii (Reverdin) Chodat						
Chromulina spp. L.Cienkowsky	+	++		+++	++	++
Ochromonas spp. Vysotskij spp.	+	+	+	+	+	
Stokesiella acuminata (A.Stokes) Lemmermann					++	
Class Synurophyceae						
Mallomonas splendens (G.S.West)		+				
Class Xanthophyceae Eustigmatophyceae						
Centritractus belonophorus (Schmidle) Lemmermann	+					
Class Cryptophyceae						
Cryptomonas spp. Ehrenb	++	+		++	++	+++
Class Klebsormidiophyceae						
Elakatothrix viridis (J.W.Snow) Printz	++		++	+	+	+

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Norwegian Institute for Water Research

Gaustadalléen 21 • NO-0349 Oslo, Norway
Telephone: +47 22 18 51 00 • Fax: 22 18 52 00
www.niva.no • post@niva.no