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Integrated Water Resources Management in Myanmar

Assessing ecological status in Inlay Lake

Preliminary report

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REPORT

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Abstract

The report is one of the deliverables of the project *Integrated water resources management – Institutional building and training*. The main purpose of the report has been to achieve improved knowledge about aquatic biodiversity and water chemistry in Inlay Lake, and to give an example for assessing the ecological status. In addition, to develop preliminary recommendations for a monitoring programme for Inlay Lake. Physical measurements, water and phytoplankton samples and aquatic macrophytes were collected at several sites in different parts of the lake in 2014-2015. Inlay Lake can be characterized as a mid-altitude, very large and very shallow, calcareous, clear lake, and the nutrient concentration show mesotrophic-semi-eutrophic conditions. Preliminary ecological status for phytoplankton and aquatic macrophytes are suggested based on different indices. Preliminary recommendations for a monitoring programme for Inlay Lake are included.

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2. Nasjonalt vanndirektiv i Myanmar	2. National Water Framework Directive in Myanmar
3. Karakterisering	3. Characterisation
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Preface

Inlay Lake, a freshwater lake located in the Nyaungshwe Township of Taunggyi District of Shan State, is of particular importance to the Myanmar people due to its cultural significance, beauty, and aquatic biodiversity present. The close relationship between people and the lake has been described as a symbiosis, and the lake is accepted as a "Man and the Biosphere Area (MAB)". The lake suffers from environmental effects of increased population and rapid growth in both agriculture and tourism. Assessing the ecological status of the lake requires knowledge of ecological water quality criteria, and in this project the EU Water Framework Directive is used as a baseline for depicting adapted ecological water quality criteria.

The IWRM project is a collaboration between the Norwegian Institute for Water Research (NIVA) and the Department of Forest, Ministry of Natural Resources and Environmental Conservation (MONREC). The project leader at MONREC is U Bo Ni, director of Watershed Management Division, Forest Department, and researcher Ingrid Nesheim is the project leader at NIVA. The steering group has representatives from Forest Department (FD), Irrigation and Water Utilization Management Department (IWUMD), the Directorate for Water Resources and Improvement of River Systems (DWIR) and NIVA. The project leaders have a close dialogue with the National Water Resources Committee in Myanmar. The project is part of the Norwegian – Myanmar Bilateral Environment Programme, 2015-2018, and is funded by the Norwegian Ministry of Foreign Affairs. The development goal of the IWRM project is to make a significant and positive contribution to the implementation and functioning of Integrated Water Resources Management in Myanmar, for inland waters at the national level. The objective is to establish methods and standards for Integrated Water Resources Management and to support initiation of the implementation process.

The current report is a deliverable under the output: 'Pilot Case study 6: Monitoring programme for Inlay Lake'. The report presents the approach and the method for ecological status classification according to the EU WFD and provides a preliminary status classification for Inlay Lake based on field work in 2014 and 2015. All field surveys and analyses have been conducted by Andreas Ballot, Marit Mjelde and Thida Swe. The chemical analyses have been conducted at NIVA's chemical laboratory in Oslo, Norway, however future chemical analysis will take place at the new water laboratory at the Forest Research Institute, Yezin, Myanmar. This report was prepared by Andreas Ballot and Marit Mjelde (NIVA), and Thida Swe (Forest Research Institute, Myanmar).

Oslo, 31 May 2017

Andreas Ballot

စကားချီး

ယဉ်ကျေးမှုအမွေအနှစ်များကြွယ်ဝမှု၊ သာယာလှပမှုနှင့် ဇီဝမျိုးစုံမျိုးကွဲများပေါများမှုတို့ကြောင့် ရှမ်းပြည်နယ်၊ ညောင်ရွှေမြို့နယ်အတွင်းရှိ အင်းလေးကန်သည် နိုင်ငံသားတို့အတွက် အရေးပါသည့်ဒေသတခုဖြစ်ပါသည်။ အင်းလေးကန်ဒေသသည် လူနှင့်ပတ်ဝန်းကျင် ယှဉ်တွဲနေထိုင်သည့် ပြယုဂ်တစ်ခုဖြစ်သောကြောင့် ယူနက်စကိုမှ လူသားနှင့်ဇီဝအဝန်းဒေသ (MAB) ဟု သတ်မှတ်ခြင်းခံရသည်။ သို့သော်လည်း လူဦးရေတိုးပွားလာမှု၊ စိုက်ပျိုးရေးနှင့် ခရီးသွားလာရေးလုပ်ငန်းဖွံ့ဖြိုးတိုးတက်လာမှုတို့ကြောင့် ကန်၏ပတ်ဝန်းကျင်အနေအထားများ ယိုယွင်းလာလျက်ရှိပါသည်။ အင်းလေးကန်၏ဂေဟအဆင့်အတန်း (Ecological Status) ကို သတ်မှတ်ရန်အတွက် ရေ၏ဂေဟစနစ်ဆိုင်ရာ အရည်အသွေးအား သတ်မှတ်သည့်စံများရှိရန် လိုအပ်ပါသည်။ ဤအစီရင်ခံစာတွင် အင်းလေးကန်၏ ဂေဟစနစ်ဆိုင်ရာရေအရည်အသွေးနှင့်ဆိုင်သည့် စံများသတ်မှတ်ဖော်ပြရာ၌ ဥရောပသမဂ္ဂ၏ ရေသယံဇာတမူဘောင် (EU Water Framework Directive) ကိုအခြေခံ၍ ဆောင်ရွက်ထားပါသည်။

ရေသယံဇာတ ဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်းသည် နော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာနနှင့် မြန်မာနိုင်ငံ၊ သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင် ထိန်းသိမ်းရေးဝန်ကြီးဌာနတို့၏ ပူးပေါင်းဆောင်ရွက်မှုလုပ်ငန်းတစ်ရပ်ဖြစ်သည်။ အဆိုပါစီမံကိန်းသည် နော်ဝေ-မြန်မာနှစ်နိုင်ငံပတ်ဝန်းကျင်ကဏ္ဍပူးပေါင်းဆောင်ရွက်မှုအစီအစဉ် (၂၀၁၅-၂၀၁၈) တွင်ပါဝင်သည့် စီမံကိန်း ၃ ခုအနက်မှ တစ်ခုဖြစ်ပြီးနော်ဝေနိုင်ငံ၊ နိုင်ငံခြားရေးဝန်ကြီးဌာနမှ ရန်ပုံငွေထောက်ပံ့ပေး သည်။ မြန်မာနိုင်ငံ၊ သယံဇာတနှင့်သဘာဝပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဝန်ကြီးဌာန၊ သစ်တောဦးစီး ဌာနဘက်မှ ရေဝေရေလဲဒေသအုပ်ချုပ်ရေးဌာနမှ ညွှန်ကြားရေးမှူး၊ ဦးဘိုနီ က စီမံကိန်း တာဝန်ခံ အဖြစ်ဆောင်ရွက်ပြီးနော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာနဘက်မှ သုတေသနပညာရှင် Dr. Ingrid Nesheim က စီမံကိန်းလုပ်ငန်းခေါင်းဆောင်အဖြစ်ဆောင်ရွက်သည်။ လုပ်ငန်းများအောင်မြင်စေရန် စီမံကိန်းလုပ်ငန်းကော်မတီတစ်ရပ် ဖွဲ့စည်းဆောင်ရွက်လျက်ရှိပြီး သစ်တောဦးစီးဌာန၊ ရေအရင်း အမြစ်နှင့်မြစ်ချောင်းများဖွံ့ဖြိုးတိုးတက်ရေးဦးစီးဌာနတို့မှ တာဝန်ရှိပုဂ္ဂိုလ်များအပြင် နော်ဝေနိုင်ငံ ရေသုတေသနဌာနမှ ပညာရှင်များကအဖွဲ့ဝင်များအဖြစ်ပါဝင်ကြသည်။ စီမံကိန်းတာဝန်ခံများအနေ နှင့် မြန်မာနိုင်ငံအမျိုးသားရေသယံဇာတကော်မတီနှင့်လည်း နီးကပ်စွာပူးပေါင်းဆောင်ရွက်လျက်ရှိသည်။ ရေသယံဇာတဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်း၏ ရည်ရွယ်ချက်ပန်းတိုင်မှာ နိုင်ငံ၏ရေသယံဇာတမူဘောင်ဆိုင်ရာ ညွှန်ကြားချက်များနှင့်အညီ ရေသယံဇာတများအားစီမံအုပ်ချုပ်လုပ်ကိုင်နိုင်ရန်ဖြစ်ပြီး ရေတိုရည်ရွယ်ချက်မှာမြန်မာနိုင်ငံအတွင်းဘက်စုံရေသယံဇာတစီမံခန့်ခွဲမှုဆိုင်ရာလုပ်ထုံးလုပ်နည်းနှင့်စံများရေးဆွဲသတ်မှတ်ရန်နှင့် လက်တွေ့ အကောင်အထည်ဖော်မှုလုပ်ငန်းများ စတင်နိုင်ရေးအတွက် အထောက်အကူပြုနိုင်ရန်ဖြစ်သည်။

ဤအစီရင်ခံစာရေးသားတင်ပြခြင်းသည် စီမံကိန်းမှဆောင်ရွက်လျက်ရှိသည့် လုပ်ငန်းခေါင်းစဉ်အမှတ် (၆) ဖြစ်သော “အင်းလေးကန်၏ ရေအရည်အသွေးအား စောင့်ကြည့်ဆန်းစစ်ခြင်း” ၏ အောက်တွင် ပါဝင်သည့် ဆောင်ရွက်ရမည့်လုပ်ငန်းတရပ်ဖြစ်ပါသည်။ ဤအစီရင်ခံစာတွင် ရေ၏ ဂေဟစနစ် ဆိုင်ရာအရည်အသွေး အဆင့်အတန်းအား ဥရောပသမဂ္ဂရေသယံဇာတမူဘောင်ကိုအခြေခံ၍ သတ်မှတ်သည့်နည်းစနစ်များကို ဖော်ပြထားပြီး အင်းလေးကန်၏ရေအရည်အသွေးအား ၂၀၁၄ ခုနှစ်မှ ၂၀၁၅ ခုနှစ်အထိ တိုင်းတာစိစစ် ဖော်ပြထားပါသည်။ ကွင်းဆင်း၍ရေနမူနာယူခြင်းနှင့် ဓာတ်ခွဲစမ်းသပ်ခြင်းတို့အား Andreas Ballot၊ Marit Mjelde နှင့် ဒေါ်သီတာဆွေတို့ကဆောင်ရွက်ခဲ့ပါသည်။ ရေ၏ဓာတုဗေဒသရုပ်ခွဲစမ်းသပ်မှုများအား နော်ဝေနိုင်ငံ အော်စလိုမြို့ရှိ ရေသုတေသနဌာနဓာတ်ခွဲခန်းတွင် ဆောင်ရွက်ခဲ့ပါသည်။ အနာဂတ်တွင်မူ အဆိုပါလုပ်ငန်းစဉ်ကို နေပြည်တော် သစ်တောသုတေသနဌာန (ရေဆင်း) ရှိ ဓာတ်ခွဲခန်းတွင် ဆောင်ရွက်နိုင်တော့မည်ဖြစ်ပါသည်။ ဤအစီရင်ခံစာအား နော်ဝေနိုင်ငံ ရေသုတေသနဌာနမှ Andreas Ballot နှင့် Marit Mjelde တို့မှလည်းကောင်း မြန်မာနိုင်ငံ သစ်တောသုတေသနဌာနမှ ဒေါ်သီတာဆွေက လည်းကောင်း ပူးပေါင်းရေးသားပြုစုထားခြင်း ဖြစ်ပါသည်။

Contents

Summary

This report is one of the deliverables of the project *Integrated water resources management – Institutional building and training*, a collaboration between the Ministry of Natural Resources and Environmental Conservation (MONREC, previously MOECAF) and the Norwegian Institute for Water Research (NIVA) under the Norwegian - Myanmar Bilateral Environment Programme 2015-2018.

Inlay Lake is the second largest natural lake in Myanmar and very important for the people of Myanmar. The lake is however negatively affected by increasing human population and rapid growth in both agriculture and tourism, with aquatic biology under pressure and action needed. Before decisions about which actions to take can be made, sufficient data need to be collected as a basis for status assessments.

The main purpose of this report is to improve knowledge about aquatic biodiversity and water chemistry in Inlay Lake, and to give a preliminary assessment of the ecological status. In addition, the report's purpose is to develop preliminary recommendations for a monitoring programme in the Lake.

At 14 different lake sites, physical measurements, water samples and phytoplankton samples were collected. In addition, aquatic macrophytes were surveyed at the same sites. The investigation took place in November 2014, and February and November 2015. Phytoplankton and physico-chemical parameters were sampled monthly from March 2015 until October 2015. Some water samples from inflowing rivers and from the outlet are included.

Inlay Lake can be characterised as a mid-altitude, very large and very shallow, calcareous, clear lake. The nutrient content in the lake show mesotrophic-semi-eutrophic conditions, and both phosphorous and nitrogen are generally higher in the inlet rivers.

In 2014-2015, altogether 140 phytoplankton taxa were identified at the three main sampling sites. As the number of taxa could be determined to genus level only, the number of taxa present in Inlay Lake is supposedly higher. It is furthermore expected that the analysis of additional samples from other sites in the lake will increase the number of taxa. The phytoplankton biomass ranged from 0,44 to 1,85 mg/l, which indicate good to moderate status of the lake's phytoplankton. Without aquatic macrophytes the phytoplankton biomass would most likely be much higher. Removal of aquatic macrophytes from Inlay Lake would probably lead to an increased growth of phytoplankton, which would have negative effects on the water quality of the lake.

The shallowness and clear water conditions of Inlay Lake support a strong growth of aquatic macrophytes. A total number of 25 species of aquatic macrophytes were recorded in the lake in 2014-2015. Species frequency and abundance differed from season to season, and from year to year. However, in both years and seasons, the elodeids *Nechamandra alternifolia* and *Potamogeton lucens,* and the lemnid *Eichornia crassipes* dominated the aquatic macrophyte vegetation.

For assessing ecological status for macrophytes, we tested the three possible indices; i.e. the Norwegian trophic index (TIc), Relative abundance index (RA-index) and Submerged macrophyte coverage index (SMC index). The ecological status assessment of Inlay lake varies considerably, depending on the various indices. Macrophytes cover, particularly in shallow lakes like Inlay lake, are important for maintaining the clear water state. Since the nutrient input to the lake are high, decreased macrophyte cover will lead to an increased phytoplankton biomass and decreased water clarity. At this stage, we therefore suggest to emphasize the submerged cover index, maybe in combination with Relative abundance index. However, the suitability of different indices for Myanmar lakes have to be evaluated further, and boundaries exclusively for Myanmar have to be developed when more data from the country are available.

To assess ecological status of Inlay lake, we recommend a monitoring programme with the biological elements phytoplankton (including chlorophyll) and aquatic macrophytes. In addition, the following

physico-chemical parameters should be included: oxygen, pH, conductivity, calcium, colour, turbidity, total phosphorous (TP), PO_4, total nitrogen (TN), NO_3, NH_4, and total organic carbon (TOC). The original number of 14 sampling localities from 2014-2015 can be reduced to 6 localities for water chemistry and phytoplankton, while all localities should be maintained for aquatic macrophytes.

To detect the effects from use of pesticides in the floating gardens, we suggest sampling once a month in the period when farmers spray with pesticides. To detect metal pollution from small industries, sampling close to the outlet and downstream the industries are needed. Sewage from villages will mainly refer to nutrient and bacteria impact. Monitoring of bacteria levels need to occur regularly, but more frequent in the dry, summer season when particularly high levels of bacteria can be expected.

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အစီရင်ခံစာအကျဉ်းချုပ်

ဤအစီရင်ခံစာကို နော်ဝေ-မြန်မာနှစ်နိုင်ငံ ပတ်ဝန်းကျင်ဆိုင်ရာ ပူးပေါင်းဆောင်ရွက်မှု အစီအစဉ် (၂၀၁၅-၂၀၁၇) တွင်ပါဝင်သော စီမံကိန်းတစ်ခုဖြစ်သည့် ရေသယံဇာတဘက်စုံစီမံအုပ်ချုပ်လုပ်ကိုင်ခြင်းနှင့် စွမ်းဆောင်ရည်မြှင့်တင်ခြင်းစီမံကိန်းမှ ပြုစုတင်ပြခြင်းဖြစ်ပါသည်။ အဆိုပါ စီမံကိန်းကို မြန်မာနိုင်ငံသယံဇာတနှင့် သဘာဝပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဝန်ကြီးဌာနနှင့် နော်ဝေနိုင်ငံရေသုတေသနဌာနတို့မှ ပူးပေါင်းဆောင်ရွက်လျက်ရှိပါသည်။

အင်းလေးကန်သည် မြန်မာနိုင်ငံတွင် ဒုတိယအကြီးဆုံးသဘာဝရေကန်တစ်ခုဖြစ်ပြီး နိုင်ငံသားတို့အတွက် လူမှုစီးပွားရေးနှင့် ယဉ်ကျေးမှုဆိုင်ရာ အရေးပါသည့် ပြယုဂ်တစ်ခုဖြစ်ပါသည်။ သို့သော်လည်း အင်းလေးကန်ဝန်းကျင်တွင် လူဦးရေတိုးပွားလာမှု၊ စိုက်ပျိုးရေးနှင့် ကမ္ဘာလှည့်ခရီးသွားလုပ်ငန်း ဖွံ့ဖြိုးတိုးတက်လာမှုတို့ကြောင့် ရေအရည်အသွေးနှင့် ကန်၏အနေအထား ယိုယွင်းပျက်စီးလာခဲ့ပါသည်။ အထူးသဖြင့် ရေအတွင်းရှိ ဇီဝမျိုးစုံမျိုးကွဲများအပေါ်တွင် ဖိအားများကျရောက်လျက်ရှိပြီး ထိန်းသိမ်းပြုပြင်ရန်လိုအပ်လျက်ရှိသည်။ မည်သည့်ထိန်းသိမ်းပြုစုခြင်းလုပ်ငန်းများဆောင်ရွက်ရမည်ကို သိရှိနိုင်ရန်အတွက်ရေနှင့်ပတ်သက်သည့် သတင်းအချက်အလက်များကောက်ယူစုစည်း၍ ဆန်းစစ်ပြီးလျှင်ရေ၏အခြေအနေကို ဦးစွာသိရှိစေရေး ဆောင်ရွက်ရန်လိုအပ်ပါသည်။

ဤအစီရင်ခံစာ၏ အဓိကရည်ရွယ်ချက်မှာ အင်းလေးကန်အတွင်းရှိ ဇီဝမျိုးစုံမျိုးကွဲများနှင့် ရေအတွင်းပျော်ဝင်နေသော ဓာတုပစ္စည်းများကိုသိရှိစေရန်နှင့် ကန်အတွင်းဂေဟစနစ်အခြေအနေဆန်းစစ်ရရှိချက်များကို တင်ပြရန်ဖြစ်သည်။ ကန်၏နေရာ (၁၄) ခုတွင် ကန်၏ရုပ်ပိုင်းဆိုင်ရာအခြေအနေအားတိုင်းတာခြင်း၊ ရေနမူနာနှင့် Phytoplankton နမူနာများကို ရယူစုစည်းခြင်းများဆောင်ရွက်ခဲ့ပါသည်။ ထိုနေရာများတွင် Aquatic Macrophyte များကိုလည်း စာရင်းကောက်ယူခဲ့ပါသည်။ အဆိုပါလုပ်ငန်းများကို ၂၀၁၄ ခုနှစ် နိုဝင်ဘာလတွင်လည်းကောင်း၊ ၂၀၁၅ ခုနှစ် ဖေဖော်ဝါရီလနှင့် နိုဝင်ဘာလများတွင်လည်းကောင်း ဆောင်ရွက်ခဲ့ပါသည်။ Phytoplankton နမူနာနှင့် ဇီဝရူပအခြေအနေများကို ၂၀၁၅ ခုနှစ် မတ်လမှအောက်တိုဘာလအထိ လစဉ်ကောက်ယူတိုင်းတာခဲ့ပါသည်။ကန်အတွင်းစီးဝင်သောချောင်းများနှင့် စီးထွက်သော ချောင်းများအတွင်း၌လည်း ရေနမူနာများကိုကောက်ယူစုဆောင်း ခဲ့ပါသည်။

အင်းလေးကန်သည် ကုန်းမြင့်ဒေသတွင်ရှိပြီး ကြီးမားကျယ်ပြန့်၍ ရေတိမ်သည့်အပြင် ရေကြည်လင်၍ ထုံးကျောက်ဓာတ်ပျော်ဝင်လျက်ရှိသည့် ရေကန်ကြီးတခုဖြစ်ပါသည်။ ကန်အတွင်းရှိရေတွင် အာဟာရဓာတ်ပါဝင်မှုကို စိစစ်ခဲ့ရာတွင် mesophic-semi-eutrophic အခြေအနေတွင်ရှိကြောင်းတွေ့ရှိရပြီး အင်းလေးကန်အတွင်းစီးဝင်သော ချောင်များအတွင်းရှိ ရေတွင်နိုက်ထရိုဂျင်နှင့် ဖော့စ်ဖရပ်ဓာတ်များ ပါဝင်မှု မြင့်မားကြောင်းတွေ့ရသည်။ ဖော့စ်ဖရပ်နှင့် နိုက်ထရိုဂျင်ပါဝင်မှုကို ဆန်းစစ်ရရှိမှုအရတင်ပြရမည်ဆိုပါက အင်းလေးကန်အတွင်းရှိရေတွင် ဓာတုပစ္စည်းပါဝင်မှုအနေအ

ထားမှာ **ကောင်းနှင့်သင့်** အကြားတွင်ရှိသည်ဟုဆိုနိုင်သည်။ ရေတိမ်ခြင်းနှင့် ကြည်လင်ခြင်းတို့ကြောင့် ကန်အတွင်းရေပေါင်းပင် (Aquatic Macrophyte) များပေါက်ရောက်မှုအလွန်များပြားရခြင်းဖြစ်ပါသည်။ ရေပေါင်းပင်များတွင် အာဟာရဓာတ်များစုစည်းသိုလှောင်မှု များပြားလှသောကြောင့် ရေမှော်ပင်များရှင်သန်ပေါက်ရောက်မှု အပေါ်ကို ထိခိုက်စေသည်။

၂၀၁၄ နှင့် ၂၀၁၅ ခုနှစ်များအတွင်း နမူနာကွက် (၃) ကွက်တွင် ဆန်းစစ်ချက်အရ အင်းလေးကန်အတွင်း ရေမှော်ပင်မျိုးပေါင်း (၁၄၀) အထိ တွေ့ရှိမှတ်တမ်းတင်နိုင်ခဲ့သည်။ တွေ့ရှိသော ရေမှော်ပင်မျိုးများအား မျိုးစိတ်အဆင့် (genus) အထိသာ ခွဲခြားနိုင်ခဲ့သောကြောင့် အင်းလေးကန် အတွင်းရှိသော ရေမှော်ပင်မျိုးမှာ ထို့ထက်ပို၍ များပြားနိုင်သည်ဟု ယူဆရ ပါသည်။ ကန်၏အခြားနေရာများရှိ နမူနာကွက်များတွင် ထပ်မံစိစစ်ဖော်ထုတ်နိုင်ပါက ရေမှော်ပင်မျိုးအရေအတွက် ထပ်မံတိုးတက်လာနိုင်ပါသည်။ ရေမှော်ပင်ဇီဝဒြပ်ထုပါဝင်နှုန်းသည် တစ်လီ တာတွင် ၀.၄၄ မှ ၁.၈၅ မီလီဂရမ် (0.44 to 1.85 mg/l) အထိရှိပြီး ရေတွင် ရေမှော်ပင်ပေါက်ရောက်မှု အနေအထားမှာ **ကောင်းနှင့်သင့်** အခြေအနေတွင်ရှိကြောင်း သုံးသပ်ရရှိသည်။ အကယ်၍သာ ရေမျက်နှာပြင်ရှိ ရေပေါင်းပင် (Macrophyte) များမရှိပါက ရေမှော်ပင်ဇီဝဒြပ်ထု ပမာဏပိုမိုများပြား လာဖွယ်ရာရှိသည်။ ရေပေါင်းပင်များကို ဖယ်ထုတ်ရှင်းလင်းလိုက်ပါက ရေမှော်ပင်များ ပိုမိုများပြားလာဖွယ်ရာရှိပြီး အင်းလေးကန်၏ရေအရည်အသွေးကို အနှုတ်လက္ခဏာဆောင် သည့်အကျိုး သက်ရောက်မှုကိုဖြစ်စေနိုင်သည်။

၂၀၁၄ မှ ၂၀၁၅ အတွင်း ကန်၏ရေမျက်နှာပြင်တွင် ရေပေါင်းပင် (၂၅) မျိုးအထိ လေ့လာတွေ့ရှိရသည်။ အဆိုပါအပင်များ၏ တွေ့ရှိရသည့်အမျိုးအမည်နှင့် ပေါများမှုမှာ ရာသီအလိုက်တနှစ်နှင့်တနှစ် ကွဲပြားခြားနားမှုရှိသည်။ အင်းလေးကန်ရေပြင်တွင် *Nechamandra alternifolia*၊ *Potamogeton lucens* နှင့် *Eichornia crassipes* ပင်များအများဆုံးတွေ့ရှိရ သည်။ အဆိုပါအပင်များပေါက်ရောက်မှုအပေါ်တွင် အခြေခံ၍ ကန်၏ရေအရည်အသွေးကို ဆန်းစစ်ရန်အတွက် Norwegian Trophic Index (TLC)၊ Abundance Index နှင့် Submerged macrophyte coverage Index များကိုအသုံးပြုရန် အကြံပြုပါသည်။ အဆိုပါ Index များအပေါ်တွင် အခြေခံ၍ ရေအရည်အသွေး ကောင်းမကောင်း အတန်းအစားကို ခွဲခြားနိုင်မည်ဖြစ်သည်။

အင်းလေးကန်၏ ရေအရည်အသွေးကို စောင့်ကြပ်ဆန်းစစ်ရာတွင် phytoplankton (chlorophyll အပါအဝင်) နှင့် aquatic macrophyte များစသည့်ဇီဝဗေဒအခြေခံများကို အသုံးပြုဆောင်ရွက်ရန် အကြံပြုအပ်ပါသည်။ ထို့အပြင် ရူပဓာတုဆိုင်ရာသတ်မှတ်ချက်များဖြစ်သော အောက်ဆီဂျင်၊ ရေချဉ်ငံဓာတ်၊ ကယ်လဆီယမ်၊ ရေ၏အရောင်၊ ရေ၏ညစ်ညမ်းမှု (turbidity)၊ ဖော့စ်ဖရပ်ပါဝင်မှုစုစုပေါင်း (TP)၊ Po4၊ နိုက်ထရိုဂျင်ပါဝင်မှုစုစုပေါင်း (TN)၊ နိုက်တြိတ် (NO3)၊ မီသိန်း (NH4) နှင့် အော်ဂဲနစ်ကာဗွန်စုစုပေါင်း (TOC) တို့ကိုလည်း ဖြည့်စွက်တိုင်းတာရန်လိုအပ်သည်။

ကျွန်းမျောများတွင် ပိုးသတ်ဆေးအသုံးပြုခြင်းကြောင့် ရေတွင်အကျိုးသက်ရောက်မှုကိုသိရှိနိုင်ရန်အတွက် တောင်သူလယ်သမားများက ပိုးသတ်ဆေးဖြန်းသည့် အချိန်များတွင် တစ်လတစ်ခါ ရေနမူနာရယူဆန်းစစ်ရန် အကြံပြုပါသည်။ အိမ်တွင်းစက်မှုလုပ်ငန်းများကြောင့် ရေထုညစ်ညမ်းမှုကို သိရှိနိုင်ရန်အတွက် အညစ်အကြေးထုတ်လွှတ်သည့်လုပ်ငန်းမှ စတင်စီးထွက်ရာနေရာနှင့် စက်ရုံတည်နေရာ၏ အောက်ဘက်ပိုင်းနေရာများမှ ရေနမူနာတို့ကိုရယူဆန်းစစ်ရန်လိုအပ်သည်။ ကျေးရွာနေအိမ်များမှ ထုတ်လွှတ်သော မိလ္လာအညစ်အကြေးများကြောင့် ရေတွင်အာဟာရဓာတ်တိုးပွားစေပြီး ဘက်တီးရီးယားများကို ပေါက်ပွားစေသည်။ ရေတွင်ရှိ ဘက်တီးရီးယားများ၏အခြေအနေအား သိရှိ ရန်အတွက် ပုံမှန်ရေနမူနာကောက်ယူစစ်ဆေးရန်လိုအပ်သည်။ အထူးသဖြင့် ပူပြင်းခြောက်သွေ့သည့် ကာလတွင် ဘက်တီးရီးယားများ ပိုမိုပေါက်ပွားသောကြောင့် ထိုအချိန်များတွင် နမူနာပိုမိုကောက်ယူ ဆန်းစစ်သင့်သည်။

၂၀၁၇ ခုနှစ်တွင်ရေးသားသည်။

ရေးသားပြုစုသူများ ။ ။ Marit Mjelde ၊ Andreas Ballot နှင့် Thida Swe
ထုတ်ဝေသူ ။ ။ နော်ဝေနိုင်ငံ၊ ရေသုတေသနဌာန (Norwegian Institute for Water Research၊ ISBN 978-82-577-6897-3

1. Introduction

Inlay Lake is the second largest natural lake in Myanmar and is of particular importance to the Myanmar people due to its cultural significance and beauty. However, the lake is affected by increasing population and rapid growth in both agriculture and tourism. Considering this situation, Inlay Lake was selected as a case study area in the project *Integrated Water Resources management, Institutional Building and Training*, to provide monitoring results for assessing the ecological status of the lake and to contribute to a lake monitoring programme.

As a first approach to ecological status assessments in Myanmar lakes, Mjelde et al. (2017) recommended some biological elements and indices and physico-chemical parameters based on the EU WFD (European Water Framework Directive). The EU WFD uses an ecosystem-based approach for characterising and classifying water quality using ecological water quality criteria, an approach designed to protect, preserve and improve the aquatic environment. The directive requires monitoring of the biological, physico-chemical and the hydro-morphological water quality elements. According to this directive, all surface water bodies should be classified into one of five normative classes; i.e. high, good, moderate, bad or poor ecological status. Inspired by the EU Water Framework Directive, the The National Water Resources Committee in Myanmar adopted in 2014 the National Water Framework Directive (NWFD). The NWFD which is a policy framework, presents seven principles for achieving good ecological status for the water quality elements in Myanmar water bodies and river basins, principles which reflects the EU WFD. Among these principles, number three is particularly relevant regarding the topic of this report:

NWFD, Principle (3): The ecological and chemical status of surface waters should be assessed according to the following criteria:

- Biological quality (fish, benthic invertebrates, aquatic flora)
- Hydro-morphological quality such as status of river banks, river bank structures, river training works, river continuity or substrate of the river bed
- Physical-chemical quality such as temperature, oxygenation and nutrient conditions
- Chemical quality that refers to environmental quality standards for river basin specific pollutants. These standards specify maximum concentrations for specific water pollutants. If even one such concentration is exceeded, the water body will not be classed as having a 'good ecological status'.

The main purpose of this report is to provide improved knowledge about aquatic biodiversity and water chemistry in Inlay Lake, and provide a preliminary assessment of the ecological status. In addition, its purpose is to develop preliminary recommendations for a monitoring programme for Inlay Lake, based on the suggested biological and chemical elements in Mjelde et al. (2017) and the improved dataset achieved here.

The preliminary ecological assessment will require future discussions with Myanmar experts. A final classification of Inlay Lake, however, must be based on indices and boundaries developed exclusively for Myanmar, using a larger dataset from Myanmar water bodies. This preliminary monitoring program will be the baseline for further discussions with other experts, in Myanmar and elsewhere, for the development of a sampling and analysis protocol suitable for Inlay Lake and also for other lakes in Myanmar.

Chapter 2 gives a brief introduction to Inlay Lake and its catchment area, while Chapter 3 provides an overview of the field and analysis methods used in the period 2014-2015. Chapter 4 includes a succinct characterisation of the lake, water chemistry results and species diversity and abundance of phytoplankton and aquatic macrophytes, including assessment of ecological status based on Norwegian indices and boundaries. Chapter 5 provides a preliminary total assessment of physico-chemical status and ecological status for Inlay Lake, while a preliminary monitoring programme for the lake is suggested in chapter 6.

This report is one of the deliverables of the project *Integrated Water Resources management, Institutional Building and Training* (IWRM project), a collaboration between the Ministry of Natural Resources and Environmental Conservation (MONREC, previously MOECAF) and the Norwegian Institute for Water Research (NIVA) under the Norwegian - Myanmar Bilateral Environment Programme 2015-2018. The project aims to make a significant contribution to the implementation of well-functioning Integrated Water Resources Management (IWRM) for inland waters at the national level for Myanmar. Overall presentation of the EU WFD and other IWRM frameworks along with recommendations for IWRM in Myanmar are provided in in the report by Nesheim and Platjouw (2016): "Framework notes and recommendations for Integrated Water Resource management in Myanmar". Mjelde et al. (2017) presented an overview of water usage in Myanmar and preliminary suggestions for typology criteria and indices for assessing ecological status in lakes in Myanmar based on the EU WFD.

2. Inlay Lake

2.1 General information

Inlay Lake is situated in Nyaung Shwe township, Taunggyi District, Southern Shan State, in the eastern part of Myanmar (Figure 2.1), and is the second largest natural lake in Myanmar. It is located 884 meters above sea level in the Balu Chaung Valley between the Sinduang (east) and Letmaunggwe, Thandaung and Udaung mountain ranges (west). Today, the length of the lake is about 18 km and the width is 6 km. The lake surface is 116 km^2, however, varying between 150 km^2 in the rainy season and 100 km^2 in the dry season. It is a shallow lake, where maximum depth varies between approximately 4 m in the dry season and 5-6 m in the rainy season (IID 2012). The average depth is around 1.5 m in the dry season. In 2014-2015 a maximum depth of 3.7 m was measured (Table 2.1). The volume of Inlay Lake is 790 x 106 m^3. With a total water inflow of 1132 x 10^6 m^3 per year, the residence time can be estimated to 0.3 years (IID 2012).

Table 2.1. Characteristic data about Inlay Lake.

Water body	State	type	latitude	longitude	altitude m.a.sl.	lake area km^2	max. depth, m	mean depth, m
Inlay	Shan	natural lake	20,5725	96,911389	884	116	3,7	1,52

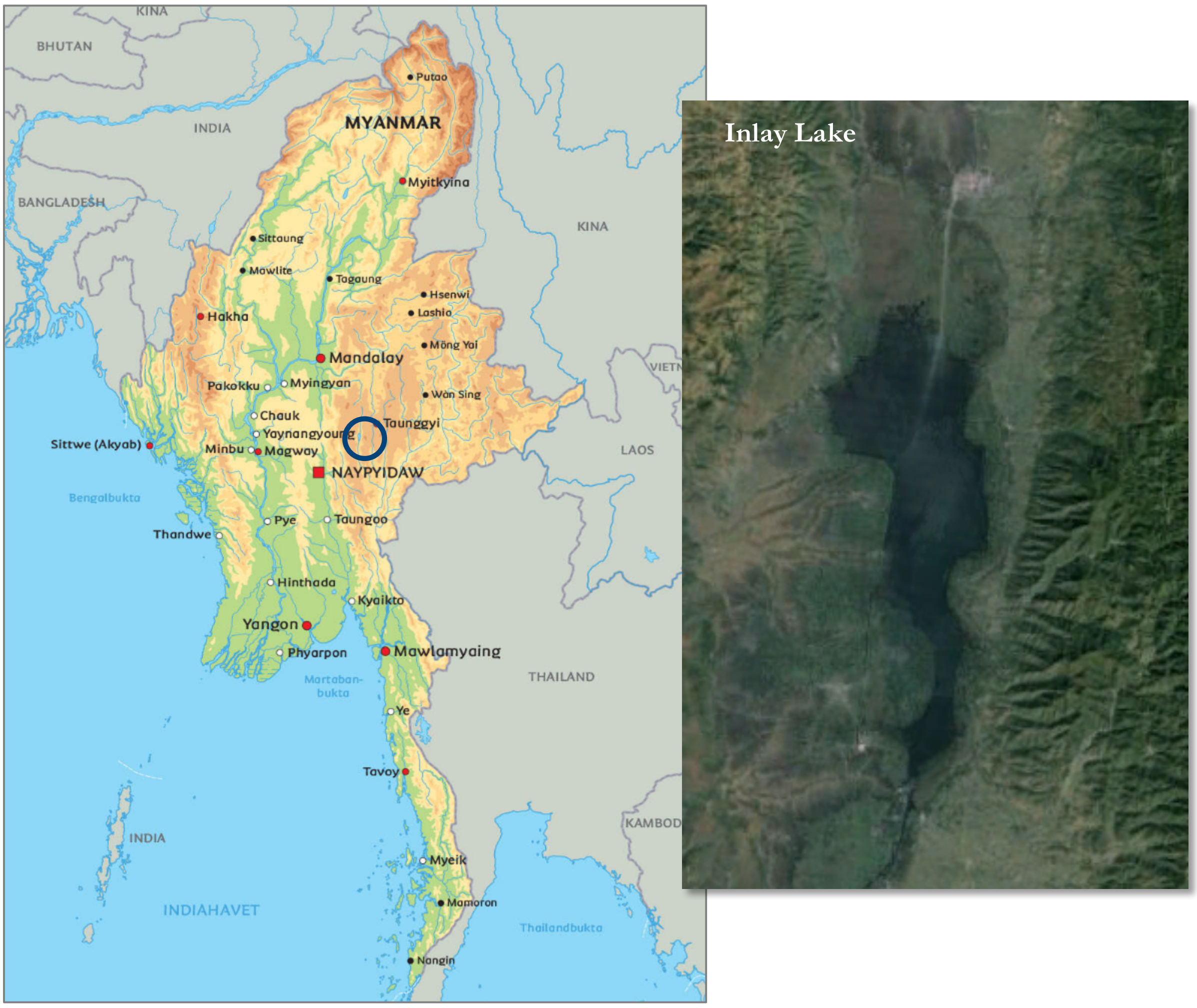


Figure 2.1. Inlay Lake in Myanmar. (Source: overview-map, www.albatros-travel.no; the satellite image is from Google Earth.)

The general formation of the lake is Shan Plateau limestone (Akaishi 2006), with limestone, dolomite and sandstone as the main bedrock components (http://www.mappery.com/Myanmar-Burma-Rock-Types-Map). As a result of the dominant limestone in the watershed, Inlay Lake is naturally alkaline, with high calcium concentration and pH values generally >8. In addition, the bedrock in the Inlay valley is covered by several meters of soil. The soil is mountainous brown and yellow brown, classified as Cambisol and Ferrasols according to FAO classification (MOECAF 2014).

2.2 Climate conditions

Most of Myanmar, including Shan state, has a tropical climate (Figure 2.2). The seasons at Inlay Lake are characterised by cold dry winter in November - February, hot dry summer season in March - May, and rainy season in June - October. The average annual temperature is about 23°C, while maximum temperature can reach more than 35°C during the summer season (Htwe 2015).

The average annual rainfall is about 950 mm, and the precipitation is mostly confined to the rainy season (May to October) (Akaishi 2006, referring to Ma 1996).

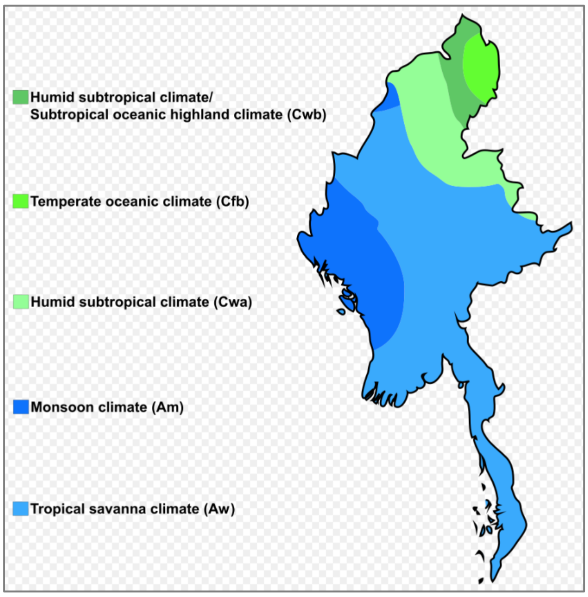


Figure 2.2. Main climate zones in Myanmar.
https://en.wikipedia.org/wiki/Geography_of_Myanmar

In summer the prevailing winds are south-westerly warm tropical winds, originating from the Bay of Bengal. In the cold season (December - February), the winds are north-easterly cold winds, originating from Central Asia (MOECAF 2014).

2.3 Main impacts

The deforestation in the Inlay Lake watershed is large. While open and closed forest cover 16% and 7%, respectively, degraded forest covers 30% of the watershed (MOECAF 2014). Deforestation is expected to be the main reason for the increasing silt load in Inlay Lake. The Forest Department of Myanmar has initiated an action plan, including natural forest protection, establishing forest plantation, etc. (MOECAF 2014).

The main business in Inlay Lake is agriculture on floating gardens. Tomato production from the lake farmers is over 300 tonnes/day in the tomato growing seasons, with annual production about 90,000 tonnes (for two growing seasons) (IID 2012). The floating islands have been cultivated for approximately 15 years, dependent on the floatability of the submerged mattress of vegetation and farmers' practices (Htwe 2015, referring to Than 2007). The farmers use chemical fertilisers, pesticides, and organic fertilisers for the tomato gardens.

Other businesses include fisheries, textile industries, weaving, and gold and silver-smithing (Akaishi 2006, referring to Ba 2003). FAO (2004) has estimated the annual production of fisheries in Nyaungshwe township to 550–650 tons. The lake is also important for transporting products around it and into distant townships.

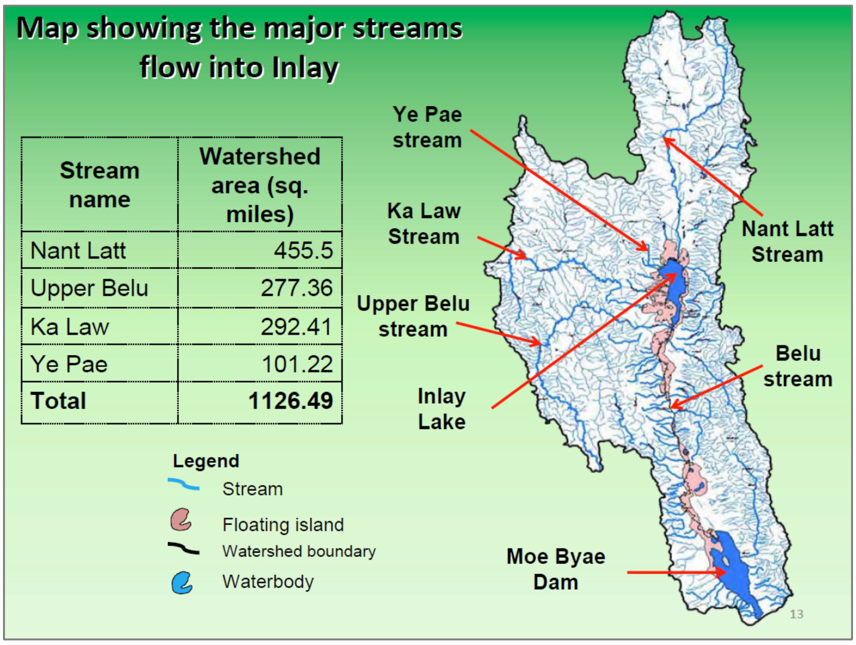
There are 35 village tracts within Nyaung Shwe Township. Of these, 17 lie within the lake and 5 lie partly in the lake and partly on land. The remainder 13 village tracts are situated in the lake surroundings

(MOECAF 2014). The most recent statistics indicate that the population concentration is 89 people/km² around the lake and 386 people/km² on the water (Htwe 2015). Many toilets in the area are ground pit latrines, which have bored holes in the back; some have a hole above the lake surface through which excretions are dropped directly into the lake. Even some factories and accommodation establishments that have septic tank systems do not adequately treat the sewage. UNDP suggested that 72% of households in Nyaungshwe township in 1999 used unsanitary open pits or had no latrines (FAO 2004). No wastewater treatment is done, and domestic drainage flows directly into the lake from around the area (Akaishi 2006).

Inlay Lake is one of three key tourism destinations in Myanmar, and attracts more than 300 000 visitors annually (IID 2012). Hotel accommodation in the area is increasing.

2.4 Inlet rivers

Inlay Lake has 4 main inlet rivers; Nan Latt, Upper Belu, Ka Law and Ye Pae, and the outlet river Belu Stream (Figure 2.3).



Map showing the major streams flow into Inlay

Stream name	Watershed area (sq. miles)
Nant Latt	455.5
Upper Belu	277.36
Ka Law	292.41
Ye Pae	101.22
Total	**1126.49**

Figure 2.3. Inlay Lake and main inlet rivers. (Figure from MOECAF 2014).

Large volumes of silt as well as water are transported to the lake through the rivers (Table 2.2). Based on the numbers in the table, the total silt inflow from all sub-catchments can be estimated to ca. 270,000 tons per year (around 200g silt per m³ water), whereas 62% deposited in deltas, 20% deposited in marshes and 1% deposited in the lake (Furuichi 2008).

Table 2.2 Inflow and silt load through the main inlet rivers. Data summarised by IID (2012). These values are slightly different from data from Shan State Irrigation Department (MOECAF 2014)

River	Watershed area km²	Water inflow 10^6 m³/yr	Silt flow t/yr	Run-off m³/yr/km²	Silt load t/yr/km²
Nam Let (Nant Latt) Chaung	1149	505,5	104 000	439 948	91
Negya (Ye Pae) Chaung	250	92,5	19 000	370 000	76
Kalaw (Ka Law) Chaung	742	275,6	56 000	371 430	75
Indein (Nam Bilu) (Upper Belu?) Chaung	813	479,6	98 293	589 914	121
Balu Chaung (outlet river)	3640	332*			

*: outflow

3. Material and methods

3.1 Localities in Inlay Lake

Inlay Lake is dominated by intensive growth of aquatic macrophytes and the program for physico-chemical and biological sampling has been adapted accordingly.

As a first comprehensive sampling program for physico-chemical and biological parameters, we selected three transects with 4-5 sampling points each, in different parts of the lake (Figure 3.1 and Table 3.1). All 14 sampling points were investigated in November 2014, and February and November 2015, for water chemistry, phytoplankton and aquatic macrophytes. In addition, 3 more points were sampled for aquatic macrophytes (D, E1 and E2, see Table 3.1). At a reduced number of six sampling points (see Figure 3.1), phytoplankton and physico-chemical parameters were sampled monthly from March 2015 until October 2015.

Additionally, water samples for physio-chemical parameters were sampled in the inflowing river Belui (Belu) in November 2014 and February and November 2015. In November 2015, water samples were taken from two additional inflowing rivers, Nei Gyar (Ye Pae) and Tham Daung (Nant Latt), and from the outlet river.

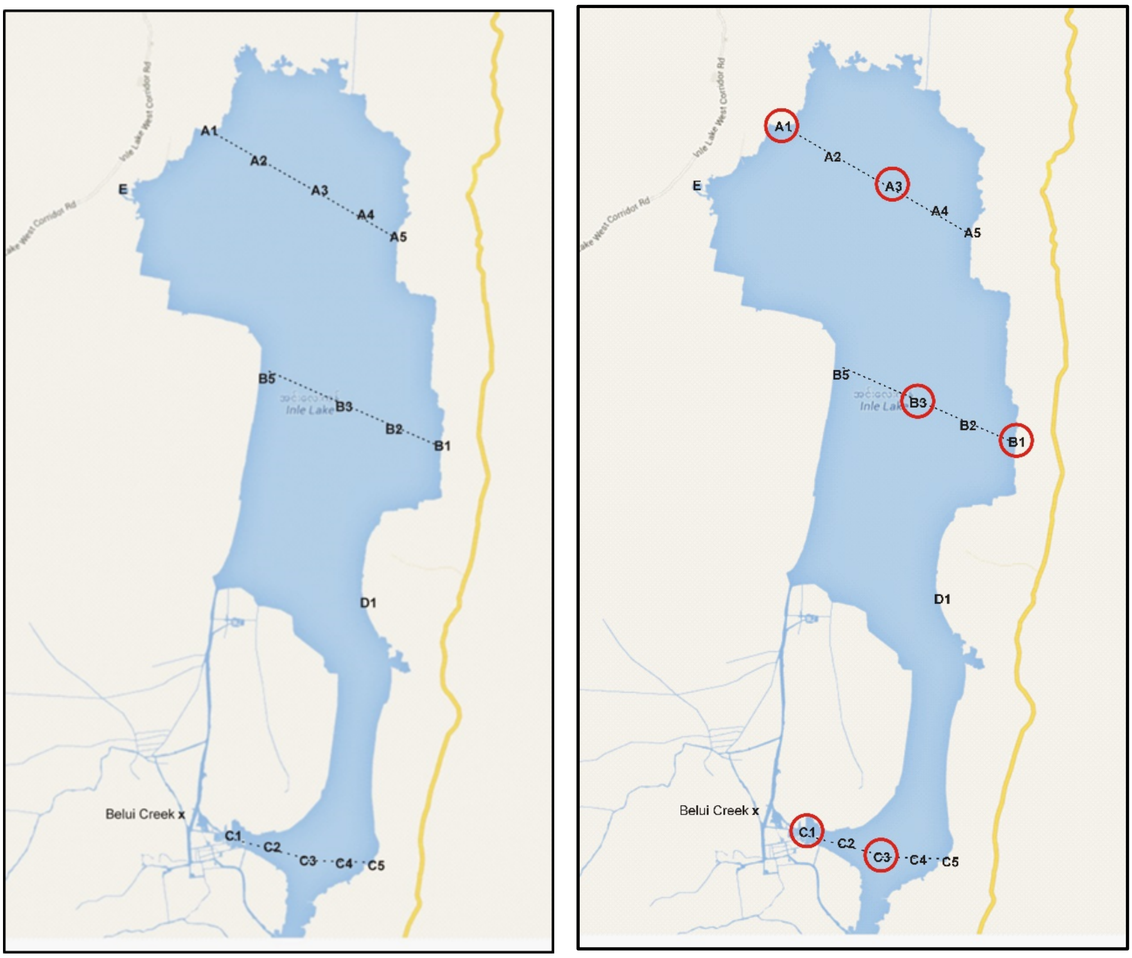


Figure 3.1. Sampling points for comprehensive sampling (left) and reduced set of sampling points for further sampling, red circles (right).

Table 3.1. Sampling points in Inlay Lake; November 2014, February and November 2015. W=water chemistry, PP=phytoplankton, AM=aquatic macrophytes.

Loc. no	Latitude	Longitude	Quality elements	Additional sampling
A1	20,603837	96,8956	W, PP, AM	monthly from Nov 2014 – Nov. 2015
A2	20,602125	96,901859	W, PP, AM	
A3	20,593999	96,91322	W, PP, AM	monthly from Nov 2014 – Nov. 2015
A4	20,589542	96,919611	W, PP, AM	
A5	20,58426	96,927998	W, PP, AM	
B1	20,550628	96,935768	W, PP, AM	monthly from Nov 2014 – Nov. 2015
B2	20,553565	96,926082	W, PP, AM	
B3	20,557946	96,918544	W, PP, AM	monthly from Nov 2014 – Nov. 2015
B5	20,562589	96,902898	W, PP, AM	
C1	20,48066	96,895886	W, PP, AM	monthly from Nov 2014 – Nov. 2015
C2	20,477061	96,901475	W, PP, AM	
C3	20,473896	96,910144	W, PP, AM	monthly from Nov 2014 – Nov. 2015
C4	20,470792	96,913435	W, PP, AM	
C5	20,47489	96,923759	W, PP, AM	
D1	20,519588	96,923003	W, PP, AM	
E1	20,591895	96,878807	AM	
E2	20,592841	96,876751	AM	

3.2 Field and analysis methods

All sample and analysis methods are in accordance with suggested methods in Mjelde et al. (2017), and based on the EU Water Framework Directive (WFD). The main focus in the EU WFD is the status of the biological elements, while the physico-chemical elements are supporting quality elements and assigned to detect the main pressures for rivers and lakes. The main focus of this report is eutrophication pressure, however, some input on priority substances are given.

3.2.1 Physical measurements and water chemistry

Physical measurements and water samples were taken at approximately 20 cm water depth at selected localities in the lake (Figure 3.1. and Table 3.1). The water samples were preserved in the field with 4M H_2SO_4 or not preserved and transported to NIVA. The analyses included calcium, colour, NH_4, NO_3, PO_4, total nitrogen (NT) and total phosphorus (TP). Calcium and colour are used in the characterization of the lake, while the nutrients are supporting quality elements to assess eutrophication pressure. Secchi depth, which is one of the main measurements, is not included due to the shallowness of the lake.
All chemical analyses are analysed according to standard metods (Direktoratsgruppa 2009), conducted at NIVA's chemical laboratory in Norway, while the physical measurements are done using a field kit.

In this phase, we present boundaries for the selected physico-chemical parameters in Norwegian lake types (Direktoratsgruppa 2015), see Table 3.2-3.5. The boundaries will be used with data from Inlay Lake and from the inlet and outlet rivers as a classification example, to assess a physico-chemical status. **The Norwegian boundaries however, is an example and should not be referred to, or considered as otherwise. The boundaries must be evaluated and suitable boundaries will be suggested based on feedback from Myanmar experts.** In a later phase, classification will be tested with boundaries from other regions in Europe and from assessment systems in Asia.

Table 3.2. Boundaries for total phosphorous (TP) in different lake types in **Norway** (from Direktoratsgruppa 2015).

Altitude	**Type**	**high**	**good**	**moderate**	**poor**	**bad**
Lowland	siliceous, clear, shallow	1-7	7-11	11-20	20-40	>40
Lowland	siliceous, clear, deep	1-4	4-9	9-16	16-38	>38
Lowland	siliceous, humus-rich	1-11	11-16	16-30	30-55	>55
Lowland	calcareous, clear	1-10	10-17	17-26	26-42	>42
Lowland	calcareous, humus-rich	1-13	13-20	20-39	39-65	>65
Forest	siliceous, clear	1-5	5-10	10-17	17-36	>36
Forest	siliceous, humus-rich	1-9	9-13	13-24	24-45	>45
Forest	calcareous clear	1-7	7-11	11-20	20-40	>83
Mountains	siliceous, clear	1-3	3-5	5-11	11-20	>40
Mountains	siliceous, humus-rich	1-5	5-10	10-17	17-36	>36

Table 3.3. Boundaries for total nitrogen (TN) in different lake and river types in **Norway** (from Direktoratsgruppa 2015).

Altitude	**Type**	**high**	**good**	**moderate**	**poor**	**bad**
Lowland	siliceous, clear, shallow	1-325	325-475	475-775	775-1350	>1350
Lowland	siliceous, clear, deep	1-200	200-400	400-650	650-1300	>1300
Lowland	siliceous, humus-rich	1-475	475-650	650-1075	1075-1755	>1755
Lowland	calcareous, clear	1-425	425-675	675-950	950-1425	>1425
Lowland	calcareous, humus-rich	1-550	550-775	775-1325	1325-2025	>2025
Forest	siliceous, clear	1-250	250-425	425-675	675-1250	>1250
Forest	siliceous humus-rich	1-400	400-550	550-900	900-1500	>1500
Forest	calcareous humus -rich	1-475	475-650	650-1075	1075-1755	>1755
Mountains	siliceous, clear	1-175	175-250	250-475	475-775	>775
Mountains	siliceous humus-rich	1-250	250-425	425-675	675-1250	>1250

Table 3.4. Boundaries for total phosphorous (TP) in different rivers types in **Norway** (from Direktoratsgruppa 2015).

Altitude	**Type**	**high**	**good**	**moderate**	**poor**	**bad**
Lowland	siliceous, clear, shallow	1-11	11-17	17-30	30-60	>60
Lowland	siliceous, humus-rich	1-17	17-24	24-45	45-83	>83
Lowland	calcareous, clear	1-15	15-25	25-38	38-65	>65
Lowland	calcareous, humus-rich	1-20	20-29	29-58	58-98	>98
Forest	siliceous, clear	1-8	8-15	15-25	25-55	>55
Forest	siliceous, humus-rich	1-14	14-20	20-36	36-68	>68
Forest	calcareous humus -rich	1-17	17-24	24-45	45-83	>83
Mountains	siliceous, clear	1-5	5-8	8-17	17-30	>30
Mountains	siliceous humus-rich	1-8	8-15	15-25	25-55	>55

Table 3.5. Boundaries for ammonium (NH_4+NH_3) and free ammonia (NH_3) in lakes and rivers in **Norway** (from Direktoratsgruppa 2015).

Watertype	**Parameter**	**high**	**good**	**moderate**	**poor**	**bad**
All types	free ammoniac (NH_3)	1-5	5-10	10-15	15-25	>25
All types	Total ammonium (NH_3+NH_4)	10-30	30-60	60-100	100-160	>160

* only valid for pH > 8 and temp. > 25 °C.

3.2.2 Phytoplankton

Field method

Qualitative and quantitative water samples for phytoplankton composition and biomass were taken at selected sites in Inlay Lake (Figure 3.1. and Table 3.1). All samples were fixed with Formaldehyde (for qualitative analysis) or acidic Lugol's solution (for quantitative analysis), stored in the dark and later analysed at NIVA using inverted and compound microscopy. 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.

Analysis methods

The species are identified to species or genus level, using selected identification keys (Büdel et al. 1978-2015, Croasdale 1983, Huber-Pestalozzi 1969, Komárek et al. 1983, Prescott et al 1977, 1981, 1982, Skuja 1949). Several taxa, however, can only be determined to genus or family level so far. Additionally, genetic methods are used for the identification of some uncertain taxa.

Testing trophic indices

Several parameters are used to characterise 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). 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. The maximum volume for cyanobacteria (Cyanomax) describes the presence of unwanted cyanobacteria.

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

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).

WHO defines different risk levels. 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 5mm^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 are testing the combination of the indices PTI, Cyanmax and phytoplankton biovolum see suggestions in Mjelde et al. (2017). Because of the methodological challenges, chlorophyll was not included in the sampling procedure in Inlay Lake in this first phase.

In this phase, we present boundaries for the phytoplankton indices in Norwegian lake types (Direktorats-gruppa 2015), see Table 3.6. The boundaries will be used with data from Inlay Lake as a classification example, to assess biological status. **The Norwegian boundaries however, is an example and should not be referred to, or considered as otherwise. The boundaries must be evaluated and suitable boundaries will be suggested based on feedback from Myanmar experts.** In a later phase, classification will be tested with boundaries from other regions, especially from assessment systems in Asia, if present.

Table 3.6. Class boundaries for phytoplankton-indices in **Norwegian lakes**. H=high, G=good, M=moderate, P=poor, B=bad.

Lake-Type	Class	chlorophyll µg/l	Biovolume mg/l	PTI	Cyanomax mg/l
Lowland, calcareous, clear, shallow	**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
Lowland, siliceous, clear, shallow or Forest, calcareous, clear, shallow	**H**	<4	<0,40	<2.17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-13	0,64-1,60	2,34-2,51	1,00-2,00
	P	13-27	1,60-3,79	2,51-2,69	2,00-5,00
	B	>27	>3,79	2,69-4,0	>5,00
Lowland, siliceous, clear, deep	**H**	<2	<0,18	<2,09	<0,16
	G	2-4	0,18-0,40	2,09-2,26	0,16-1,00
	M	4-7	0,40-0,77	2,26-2,43	1,00-2,00
	P	7-15	0,77-1,90	2,43-2,60	2,00-5,00
	B	>15	>1,90	2,60-4,0	>5,00
Lowland, siliceous, humus-rich, shallow or Forest, calcareous, humus-rich, shallow	**H**	<5,4	<0,60	<2,26	<0,16
	G	5,4-9	0,60-1,00	2,26-2,43	0,16-1,00
	M	9-16	1,00-2,00	2,43-2,60	1,00-2,00
	P	16-32	2,00-4,60	2,60-2,86	2,00-5,00
	B	>32	>4,60	2,86-4,0	>5,00
Lowland, siliceous, clear, shallow or deep Forest, siliceous, clear, shallow or deep	**H**	<2	<0,18	<2,00	<0-0,16
	G	2-4	0,18-0,40	2,00-2,17	0,16-1,00
	M	4-7	0,40-0,77	2,17-2,34	1,00-2,00
	P	7-15	0,77-1,90	2,34-2,51	2,00-5,00
	B	>15	>1,90	2,51-4,0	>5,00
Lowland or forest, siliceous, humus-rich, shallow	**H**	<4	<0,40	<2,17	<0,16
	G	4-6	0,40-0,64	2,17-2,34	0,16-1,00
	M	6-12	0,64-1,46	2,34-2,51	1,00-2,00
	P	12-25	1,46-3,46	2,51-2,69	2,00-5,00
	B	>25	>3,46	2,69-4,0	>5,00
Lowland, calcareous, humus-rich, shallow	**H**	<7	<0,77	<2,39	<0,16
	G	7-10,5	0,77-1,24	2,39-2,56	0,16-1,00
	M	10,5-20	1,24-2,66	2,56-2,73	1,00-2,00
	P	20-40	2,66-6,03	2,73-3,07	2,00-5,00
	B	>40	>6,03	3,07-4,0	>5,00

3.2.3 Aquatic macrophytes

Definition

A simple definition of aquatic macrophytes is 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. In this study we only include aquatic macrophytes (hydrophytes), i.e. species in the lifeform groups *isoetids, elodeids, nymphaeids, lemnids*, and *charophytes* (Mjelde, in prep.).

Field method

The surveys of aquatic macrophytes in Inlay Lake took place in November 2014, and February and November 2015. The survey included the 14 main localities in the lake (see Figure 3.1 and Table 3.1), and two additional localities (E and D1, Figure 3.1), to ensure eventually species differences in this close to shore habitat. At each locality the plants were recorded using an aqua scope and collected by dredging from the boat (casting rake).

The abundances of the species are scored by a semi-quantitative scale, where 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant. The lake is very shallow, and the aquatic macrophytes are covering the whole depth gradient.

Analysis method

All species are identified to species levels, using the floras and identification keys suggested below. Most of the identification was done in the field. However, a few specimens of each species are collected and dried. This herbarium collection is used for identification using microscope and for genetic analysis.

The most important species in the lake are presented as abundance (sum semi-quantitative scores of all localities where the species occur) and % frequency (number of localities with occurrence compared to total visited localities).

Flora and identification keys

For species identification, we have used the keys in standard floras for the region, i.e. Cook (1996), in addition to updated or more specialised taxonomic work, e.g. Wiegleb (1990), Wiegleb & Kaplan (1998), Ito et al. (2014), Triest (1988), La-Ongsri (2008), in addition to different internet-sites like Flora of China (http//www.efloras.org) and Encyclopedia of Life (http//eol.org). The *Chara*-species are identified based on Wood & Imahori (1965).

In the Asian region, some aquatic macrophyte genera are very variable without satisfactory taxonomic treatment. In addition, several genera have been cultivated for a long time, e.g. among the *Nymphaea* species, which may confuse the taxonomic identification. For these taxa, and other difficult genera, additional genetic analysis is needed as an identification supplement.

Testing different indices

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 to phytoplankton. 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).

In this report, we are testing three possible indices; the Norwegian trophic index (TIc-index), a relative abundance index (RA index) and a submerged macrophyte coverage index (SMC index), see suggestions in Mjelde et al. (2017). The TIc-index include the ratio between sensitive and tolerant species, the RA-index include ratio between sensitive and tolerant lifeform groups, while the SMC-index include a whole lake coverage.

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.).

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

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 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.

The different species of aquatic macrophytes have various distribution patterns, and most of the species found in temperate regions in Northern Europe are rare or non-existing in the tropical regions, and vice versa. Therefore, the Norwegian list of sensitive and tolerant species is not suitable for Myanmar lakes. Species sensitivity has to be established exclusively for Myanmar or for South-Eastern Asia. As a start, Mjelde et al. (2017) suggested a preliminary list of sensitive and tolerant species, based on expert judgement and literature survey (see Table 3.7). 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 the TIc-index only exist for Norwegian lake types (Direktoratsgruppa 2015), see Table 3.8. The boundaries will be used with data from Inlay Lake as a classification example, to assess biological status. **The Norwegian boundaries however, is an example and should not be referred to, or considered as otherwise. The boundaries must be evaluated and suitable exclusively for Myanmar lakes have to be developed as soon as more data are available.**

Table 3.7. Suggested eutrophication sensitivity for aquatic macrophytes identified through our investigations in Myanmar lakes. The background for the sensitivity is explaned in Mjelde et al (2017). S=sensitive, T=tolerant, I=indifferent.

Latin names	Preliminary sensitivity
ELODEIDS	
Ceratophyllum demersum	T
Hydrilla verticillata	S
Limnophila sessiflora	I
Myriophyllum spicatum	T
Myriophyllum verticillatum	T
Najas indica	I
Najas minor	I
Nechamandra alternifolia	T
Potamogeton crispus	I
Potamogeton lucens	S
Potamogeton nodosus	I
Potamogeton pusillus	I
Potamogeton nodosus-hybrid?	-
Potamogeton sp.	-
Stuckenia pectinata	T
Utricularia aurea	S
Utricularia australis	S
Utricularia punctata	S
Utricularia stellaris	S
Utricularia sp	S
Vallisneria spiralis	I

Latin names	Preliminary sensitivity
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 ovalifolia	I
Trapa natans v. bispinosa	T
Trapa natans v. natans	T
LEMNIDS	
Azolla pinnata	T
Eichornia crassipes	T
Lemna trisulca	I
Pistia stratiotes	T
Spirodela polyrhizza	I
Salvinia cucullate	T
Salvinia natans	T
CHAROPHYTES	
Chara sp. zeylandica	S

Table 3.8. Class boundaries for the aquatic macrophyte TIc-index in **Norwegian** lakes. H=high, G=good, M=moderate, P=poor, B=bad (from Direktoratsgruppa 2015).

Lake type		**Calsium mg Ca/l**	**Colour mg Pt/l**	**reference value**	**H/G**	**G/M**	**M/P**	**P/B**
001	Very low alkalinity, clear	<1	<30	95	92	55	40	15
002	Very low alkalinity, humic	<1	>30	78	71	55	40	15
101	Low alkalinity, clear	1-4	<30	79	75	55	40	15
102	Low alkalinity, humic	1-4	>30	78	71	55	40	15
201	Moderate alkalinity, clear	4-20	<30	74	66	30	5	-35
202	Moderate alkalinity, humic	4-20	>30	69	67	30	5	-35
301	High alkalinity, clear	>20	<30	75	63	30	5	-35
302	High alkalinity, humic	>20	>30	73	63	30	5	-35

Relative abundance index (RA index)

As recommended by Mjelde et al. (2017), we have tested metrics based on the relative abundance of the lifeform group charophytes (considered as sensitive to eutrophication) and the lemnids (tolerant to eutrophication). It is an overall agreement of the sensitivities of these lifeform groups, which make such an index more robust at this stage. Furthermore, we include the relative abundance of the sensitive elodeid *Potamogeton lucens* (Table 3.9). The average of the metrics in all localities in the lake gives a number 1-5, where 5 = high status, 4 = good status, 3 = moderate status, 2 = poor status and 1 = bad status. Decision of boundary borders are examples, and have to be tested further with available data from Myanmar lakes.

Submerged macrophyte coverage index (SMC index)

Macrophytes cover, particularly in shallow lakes, are important for maintaining the clear water state. In Inlay Lake, high coverage of submerged macrophytes seems to prevent massive growth of phytoplankton and especially nuisance cyanobacteria (chapter 4.3.1). We have therefore included a metric based on submerged macrophyte coverage (SMC), as suggested by Mjelde et al. (2017).

Table 3.9. Suggested abundance index, with possible metrics for assessing ecological status for aquatic macrophytes.

Indices and metrics	**High (5)**	**Good (4)**	**Moderate (3)**	**Poor (2)**	**Bad (1)**
RA: relative abundance index					
- *Potamogeton lucens* [1]	3	4-5	2	1	0
-charophytes [1]	4-5	3	2	1	0
-lemnids [1]	0	1-2	3	4	5
SMC: Submerged macrophyte coverage [2]	5	3-4	2	1	0

RA: relative abundance, 1: one or more species at each locality with given semi-quantitative score,
2: average semi-quantitative score

4. Results

4.1 Identification of water bodies and typology

Based on preliminary type factors suggested by Mjelde et al. (2017), and the morphological and water chemistry data (Table 2.1 and Table 4.2), Inlay Lake can be characterised as a **mid-altitude, very large and very shallow, calcareous, clear lake** (Table 4.1).

Table 4.1. Characteristic data for the lake.

Water body	State	Type	Altitude m.a.sl.	Lake Area km^2	Max. depth, m	Mean depth, m	Calcium mg Ca/l	TOC mg/l
Inlay	Shan	natural lake	884	116	3,7	1,52	48,8	4,8

4.2 Water chemistry

4.2.1 Seasonal variations

Inlay Lake is a shallow lake with inflow from 4 large rivers. The water is clear; with turbidity variations between 4.5 and 5.7 FNU (Table 4.2). However, some of the inflowing rivers have higher turbidity (Table 4.3). The lake is a calcareous lake, with average calcium value at 49 mg Ca/l. With average colour values at 17 mg Pt/l it can be characterised as a clear lake. The nutrient content in Inlay Lake show mesotrophic-semi-eutrophic conditions (Salas and Martino 1991), however, see discussion in next chapter. Both phosphorous and nitrogen are generally higher in the investigated inlet rivers (Table 4.3 and 4.4).

The inflowing rivers transport total suspended solids (TSS), which include inorganic and organic material into the lake. The ranges measured in this study varied between 149 g/m^3 in Belui river and 48 g/m^3 in Nay Gyar. The loads are a little bit lower than the transport of 200 g silt/m^3 water described by IID (2012).

Table 4.2. Physico-chemical data from Inlay Lake 2015 (min, max and mean values).

Period 2014-2015	Water temp. °C	pH	Conductivity µS/cm	Turbidity FNU	Silikate µg/l	TOC mg C/l
Min	20.30	7.33	286	0.64	1920	1.20
Max	28.00	9.43	491	-	13400	10.70
Mean	**24.67**	**8.23**	**369**	**-**	**6989**	**5.08**

Table 4.2. cont.

Period 2014-2015	Calcium mg Ca/l	Colour mg Pt/l	Tot-P/L µg P/l	PO4-P µg P/l	Tot-N/L µg N/l	NH4-N µg N/l	NO3-N+NO2-N µg N/l	Cl mg/l	SO4 mg/l
Min	46.7	16.7	3	1.0	290.0	26.0	3.0	6.4	2.9
Max	50.4	16.7	122	15.0	810.0	75.0	286.0	6.4	3.4
Mean	**48.6**	**16.7**	**17.1**	**3.6**	**478.3**	**40.2**	**33.8**	**6.4**	**3.2**

Table 4.3. Physico-chemical data from Belui (Belu) river 2014-2015 (min, max and mean values).

Period	Water temp., °C	pH	Conductivity µS/cm	Turbidity FNU	LOI mg/l	TSS mg/l	Silikate µg/l	TOC mg C/l
Min	21.70	8.19	352	39	129	149	7590	0.6
Max	25.20	8.36	483	39	129	149	11400	1.4
Mean	**23.6**	**8.28**	**407**	**39**	**129**	**149**	**9495**	**1.0**

TSS = total suspended solids, LOI = loss of ignition

Table 4.3. cont.

Period 2014-2015	Calcium mg Ca/l	Colour mg Pt/l	Tot-P/L µg P/l	PO4-P µg P/l	Tot-N/L µg N/l	NH4-N µg N/l	NO3-N+NO2-N µg N/l	Cl mg/l	SO4 mg/l
Min	51.5	3	18	13	635	19	485	2.0	2.8
Max	51.5	3	57	29	690	30	550	2.0	2.8
Mean	**51.5**	**3**	**38**	**21**	**663**	**25**	**518**	**2.0**	**2.8**

Table 4.4. Physical chemical data from the inlet rivers Tham Daung (Nant Latt) and Nei Gyar (Ye Pae), and the Inlay outlet river (23. November 2015).

River	Water temp., °C	pH	Conductivity µS/cm	Turbidity FNU	LOI mg/l	TSS mg/l	Silikate µg/l	TOC mg C/l
Tham Daung	24.0	8.19	483	-	54	61	9800	0.98
Nei Gyar	22.5	7.57	485	-	39	48	10600	4.7
Inlay outlet	24.1	7.61	367	-	-	-	11700	5

Table 4.4. cont.

River	Calcium mg Ca/l	Colour mg Pt/l	Tot-P/L µg P/l	PO4-P µg P/l	Tot-N/L µg N/l	NH4-N µg N/l	NO3-N+NO2-N µg N/l	Cl mg/l	SO4 mg/l
Tham Daung	-	-	27	14	620	14	500	-	-
Nei Gyar	-	-	42	20	560	60	130	-	-
Inlay outlet	-	-	23	8	475	40	20	-	-

4.2.2 Classification of physico-chemical parameters

The main focus in the EU WFR is the status of the biological elements. However, the physico-chemical elements are supporting quality elements and assigned to detect the main pressures for rivers and lakes.

One of the main impacts on Inlay lake is probably eutrophication. We therefore focus on nutrient concentration, and the parameters ammonium (NH_4), total nitrogen (TN) and total phosphorous (TP) are used to exemplify the classification for the supporting physico-chemical elements. The parameters secchi depth and oxygen are not relevant here because of the shallowness of the lake.

Total nitrogen

Inlay Lake had in most parts, low total nitrogen (TN) concentrations measured in 2014 and 2015 (Figure 4.1). The sampling points A3, B3 and C3 located in the lake centre had low or moderate concentrations. The other sampling points which are located close to the shore showed higher TN-concentrations. This reflects clearly the influence of fertilisers and wastewater from the floating garden and villages. It can be assumed that most of the nutrients are taken up by the aquatic macrophytes which densely cover most parts of the lake bottom. This suggests, that most of the nutrients are not available for the growth of phytoplankton.

All three inflowing rivers are sources of TN in Inlay Lake. The TN-concentrations are slightly higher than those measured in Inlay Lake. However, the concentrations measured are in a range which characterise the three investigated rivers as being in good status according to Norwegian boundaries.

Ammonium

The parameter ammonium shows a similar picture (Figure 4.2). Only sampling point A4 had high ammonium concentrations, that could be classified as moderate according to Norwegian boundaries (Figure 4.2). Three of the rivers had low ammonium concentrations while the Nei Gyar River (Ye Pae) in the North of Inlay Lake, had higher ammonium concentration.

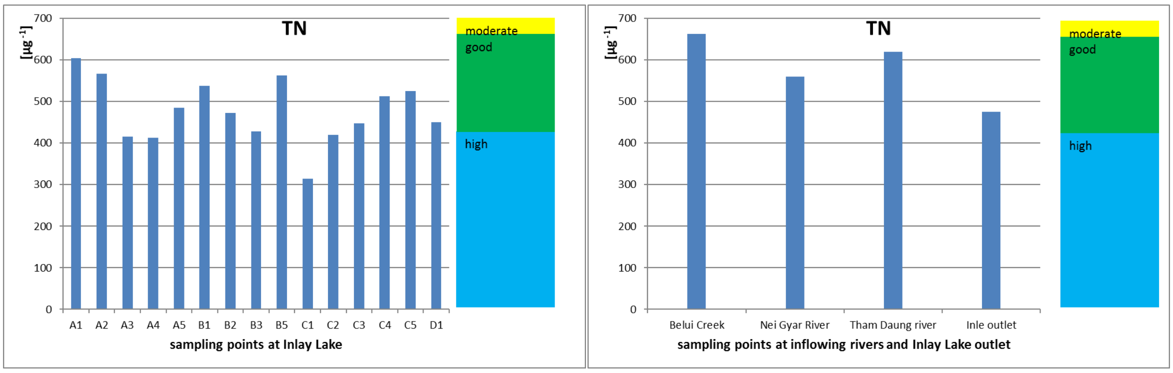


Figure 4.1. Total nitrogen (TN) concentrations in Inlay Lake (left), and tributaries Belui (Belu), Tham Daung (Nant Latt) and Nei Gyar (Ye Pae), and outlet river (right) (sampling points, see Figure 3.1). The graphs are based on average total nitrogen concentrations (Table 4.2-4.4), while the classifications are exemplified based on Norwegian boundaries in Table 3.3.

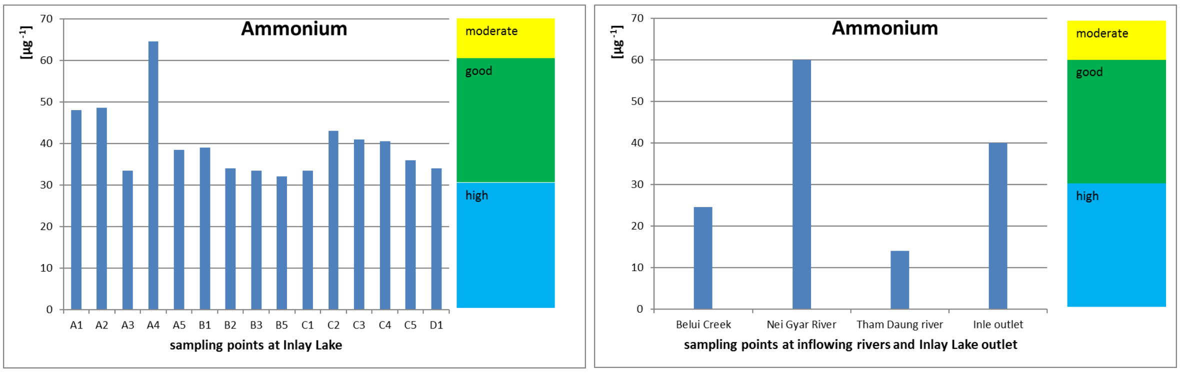


Figure 4.2. Ammonium concentration in Inlay Lake (left), and tributaries Belui (Belu), Tham Daung (Nant Latt) and Nei Gyar (Ye Pae), and outlet river (right) (sampling points, see Figure 3.1). The graphs are based on average ammonium concentrations (Table 4.2-4.4), while the classifications are exemplified based on Norwegian boundaries in Table 3.5.

Total phosphorus

Total phosphorous (TP) concentration was low in most parts of Inlay Lake (Figure 4.3), and the sampling points A2-4 and B2-3 in the lake can be characterised by very good and good status according to Norwegian boundaries. All sampling points close to the shore and the sampling points in the C transect are had high TP concentrations. The reasons for the high TP-concentrations are the influence of the floating gardens and the domestic wastewater from the villages, especially in the southern part of the lake. It is also most likely that higher amounts of TP are stored in the sediments of Inlay Lake, and in the large stands of aquatic macrophytes that cover the lake bottom.

The inflowing rivers are transporting TP into the lake. All investigated rivers are characterised by high TP-concentrations characterising them in a moderate to bad status. The high TP values originate from erosion and use of fertilisers in the catchment area and wastewater from settlements.

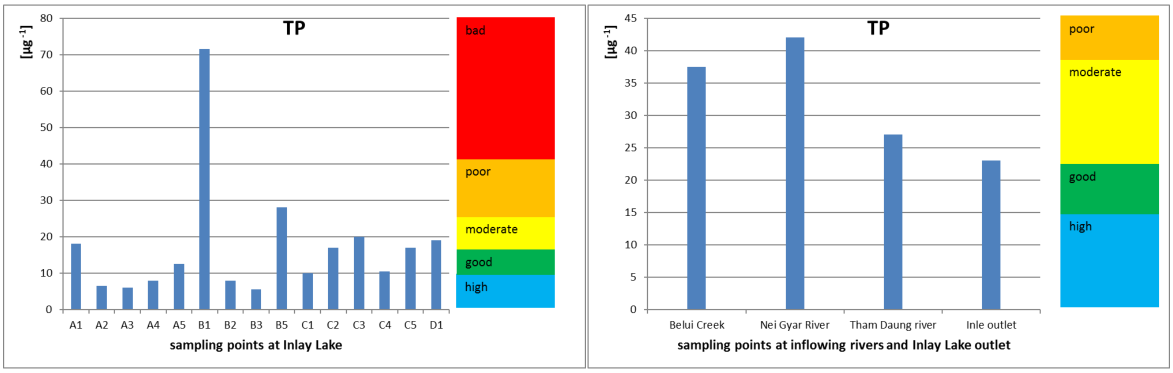


Figure 4.3. Total phosphorus (TP)concentrations in Inlay Lake (left), and in tributaries Belui (Belu), Tham Daung (Nant Latt) and Nei Gyar (Ye Pae), and outlet river (right) (sampling points, see Fig. 3.1). The graphs are based on average total phosphorus (TP)-concentrations (Table 4.2-4.4), while the classifications are exemplified based on Norwegian boundaries in Table 3.3 and 3.5.

4.3 Phytoplankton

4.3.1 Species diversity and abundance

The phytoplankton composition and biomass are influenced by the availability of nutrients, especially phosphorous and nitrogen compounds. The three sampling points A3, B3 and C3, located in the centre of the three selected transects, were analysed for phytoplankton composition and its abundance. During the three field sampling episodes in November 2014, February 2015 and November 2015 altogether 140 phytoplankton taxa were identified at the three sampling locations A3, B3, and C3. The phytoplankton taxa and their abundance based on a semi-quantitative scale are depicted in Appendix B. As number of taxa could be determined to genus level only, the number of taxa present in Inlay Lake is supposed to be higher. Furthermore, the additional sampling points in the A, B and C transect, which will be analysed at a later stage, will most likely increase the number of taxa in Inlay Lake. The phytoplankton biomass ranged from 0.44 to 1.85 mg/l, which indicate good to moderate status of the Inlay Lake phytoplankton, see Figure 4.4.

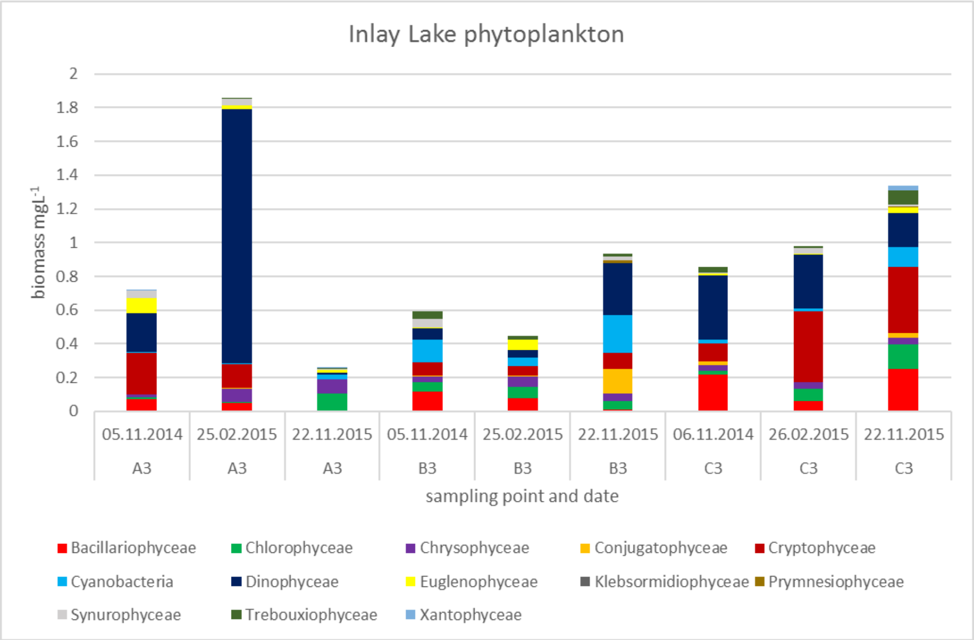


Figure 4.4. Phytoplankton composition and biomass at three sampling points and sampling locations in Inlay Lake in 2014 and 2015.

At the stations A3 and C3 diatoms (Bacillariophyceae), Cryptophyceae and Euglenophyceae were the dominating groups. Green algae (Chlorophyceae) were found at B3 and C3 in relative higher amounts. Cyanobacteria were present at all locations but higher biomasses were found only at the stations B3 and C3. However, the biomass of Cyanobacteria was always in a range still indicating good water quality. It is to note that the cyanobacterial species *Microcystis aeruginosa* was found in low amounts at all three sampling points. Using enzyme linked immunosorbent assay (ELISA), hepatotoxic microcystins were identified in cultures *of M. aeruginosa* isolated from Inlay Lake. Figure 4.5 shows *Microcystis aeruginosa,* isolated from Inlay Lake.

The nutrient concentrations found in Inlay Lake in 2014 and 2015 suggest that a more extensive growth of phytoplankton, and in particular potential toxic cyanobacteria like *M. aeruginosa* (Figure 4.5), can occur.

Inlay Lake, however, is a very shallow and clear lake with a water depth not exceeding 4 m. These conditions support a strong growth of aquatic macrophytes. The macrophytes compete with phytoplankton for available nutrients and are so far preventing a massive growth of phytoplankton and especially nuisance cyanobacteria. Removal of aquatic macrophytes from Inlay Lake would probably lead to an increased growth of phytoplankton and have very negative effects for the water quality of the lake.

Figure 4.5. Colony of the microcystin-producing cyanobacterium *Microcystis aeruginosa* isolated from Inlay Lake.

4.3.2 Ecological status of Inlay Lake based on phytoplankton

Based on the phytoplankton biomass and composition, and the trophic index PTI (without chlorophyll), and with Norwegian boundaries (see Table 3.7), we have exemplified the ecological status of Inlay Lake in the years 2014 and 2015 (Figure 4.6). According to this, the phytoplankton at all three central sampling stations A3, B3 and C3 in Inlay Lake could be classified as good, both in November 2014 and in February 2015. In November 2015, however, the status could be classified as moderate. This indicate a deterioration of the water quality of Inlay Lake in 2015. It is to note that the other sampling points are still under evaluation and the results will be integrated in the final report.

Inlay Lake is dominated by intensive growth of aquatic macrophytes, and most likely, a large amount of the available nutrients (TP and TN) is stored in the macrophyte biomass, and not available for phytoplankton growth. The relatively low phytoplankton biomasses found in Inlay Lake in 2014 and 2015 are therefore probably associated with the massive macrophyte growth. Without aquatic macrophytes the phytoplankton biomass would most likely be much higher, and lead to a poorer evaluation of Inlay Lake.

Most phytoplankton taxa are more or less globally distributed. The use of indicator values, indices and boundaries from Norway seem to be suitable also for assessments in Myanmar, at least in this first phase. However, the indices and boundaries have to be evaluated and further developed when more data from Myanmar are available.

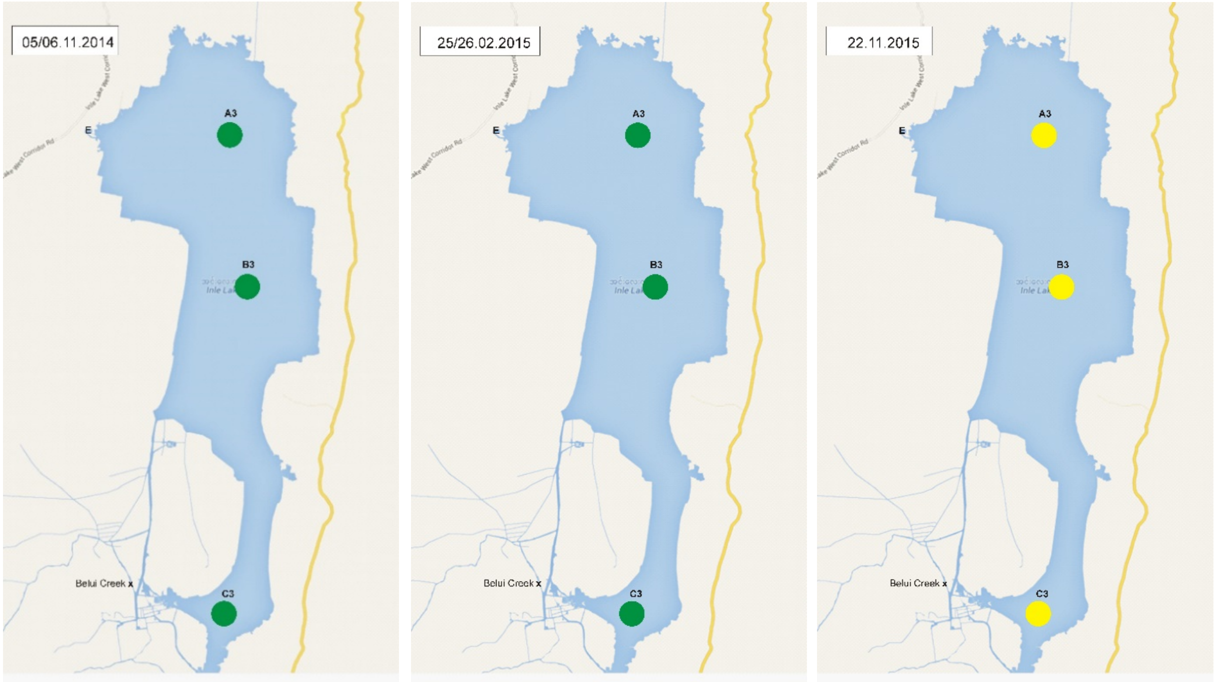


Figure 4.6. Ecological status of Inlay Lake using phytoplankton biomass, PTI index and cyanobacteria biomass. The classification is based on phytoplankton data from Inlay Lake 2014-2015, and exemplified based on Norwegian boundaries in Table 3.7. The evaluation is based on Table 3.1 using the lake type: lowland, calcareous, clear, shallow. Green =good status, yellow= moderate status.

4.4 Aquatic macrophytes

4.4.1 Species diversity, frequency and abundance

The description and analyses of the aquatic macrophytes are based on species lists and semi-quantitative scores form the 14 main localities (Figure 3.1).

The species diversity of aquatic macrophytes is high in Inlay Lake, compared to other lakes in Europe and Asia of similar size and type. In 2014-2015, a total number of 25 species of aquatic macrophytes are recorded in the lake. Among these, 13 elodeids, 6 nymphaeids, 5 lemnids and one charophyte were identified (total species list in Appendix B).

Species frequency (%) and abundance (sum of all semi-quantitative scores) differed from season to season, and from year to year. However, in both years and seasons, the elodeids *Nechamandra alternifolia* and *Potamogeton lucens,* and the lemnid *Eichornia crassipes* dominated the aquatic macrophyte vegetation (Figures 4.7 and 4.8).

In temperate areas, including Norway, the growing season for most of the aquatic macrophytes only 6-7 months. The climate in the rest of the year is often too strong for supporting macrophyte growth. In these areas, survey once a year is generally enough to get an overview of the diversity and abundance of aquatic macrophytes. In tropical areas, where the climate support macrophyte growth the whole year, the growing season can vary between species, and some of the less frequent species are absent or have small abundance in part of the year. To get a good overview of the diversity and abundance of aquatic macrophytes in tropical eutrophic lakes it seems to be necessary to survey twice a year, and several years in a row.

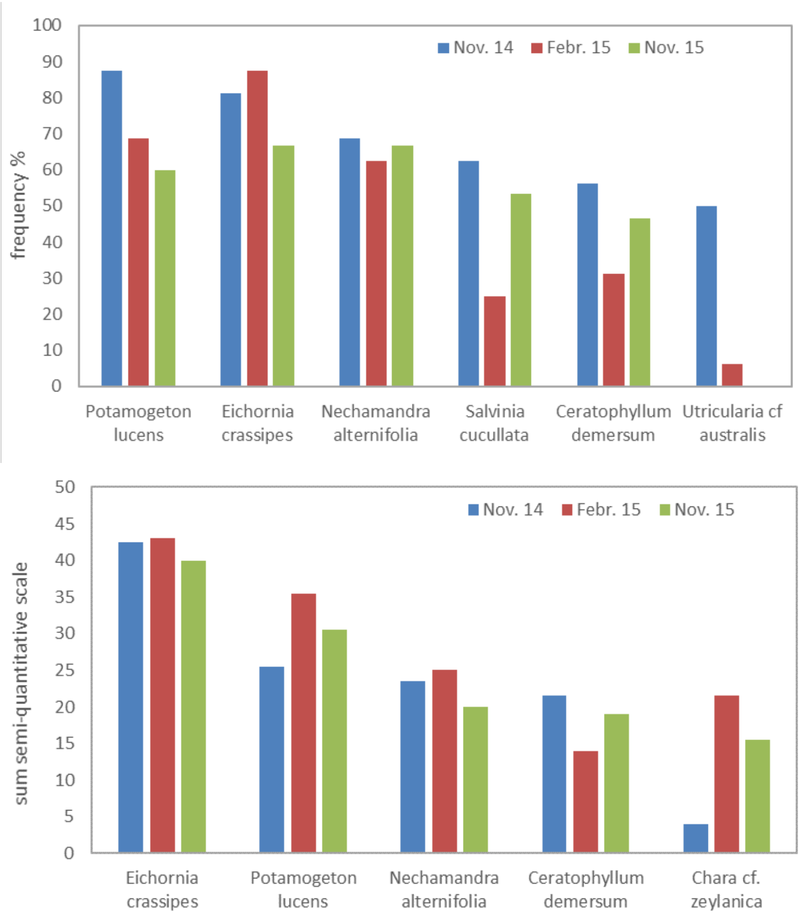


Figure 4.7. Frequency (%) and abundance (sum semi-quantitative scores) of dominating species in Inlay Lake in 2014-2015.

The number of species in the different lifeform groups vary among transects and localities, and between year and seasons (Figure 4.9). In general, the localities in the middle of the lake, especially the localities B3 and B4, have fewer free-floating species (lemnids), mainly because of wind stress.

In February 2015, the number of species was low compared to November 2014 and November 2015. It is obviously that the macrophytes are in better condition after the wet season (i.e. November), compared to the dry period (February). In February 2015 and March 2017 (not shown here), the coverage of periphyton algae on sediment and plants was higher than in November.

In addition, most localities had lower species number in November 2015 compared to November 2014. Also the number and abundance of sensitive species show a small, but not significant, decrease from 2014 to 2015.

Figure 4.8. The dominating species in Inlay Lake. Upper left: the lemnid *Eichornia crassipes*, upper right: the elodeid *Potamogeton lucens*. Lower picture: the elodeid *Nechamandra alternifolia*. Photos: Andreas Ballot.

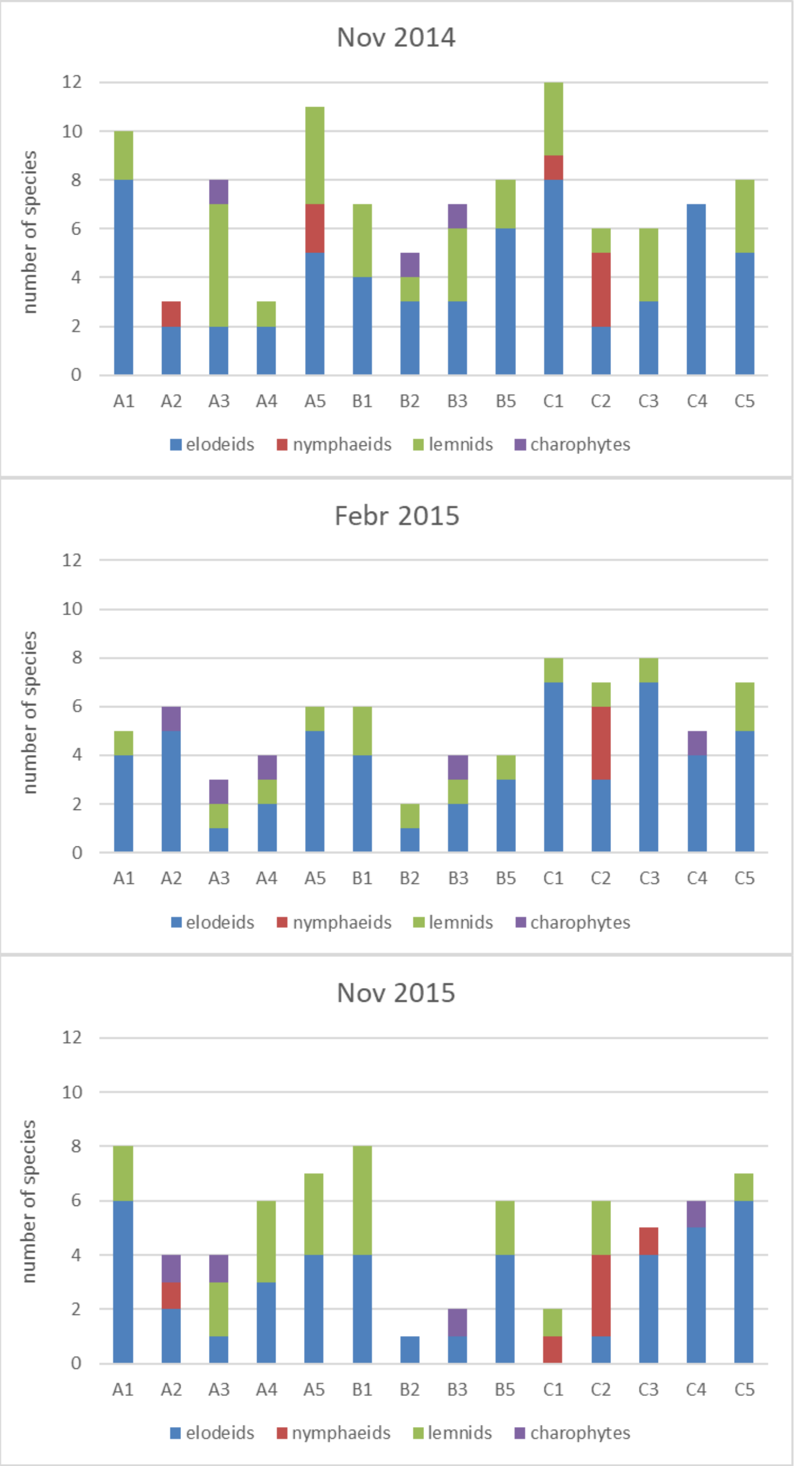


Figure 4.9. Aquatic macrophytes at the different localities and dates in Inlay Lake. Number of species within each lifeform group.

4.4.2 Ecological status of Inlay Lake based on aquatic macrophytes

In this chapter, we present the ecological status of aquatic macrophytes in Inlay Lake, based on the three possible indices, suggested by Mjelde et al (2017), also see chapter 3.2.3. These indices and boundaries are used here as examples of ecological status assessments. And as shown, the ecological status of Inlay lake varies considerably, depending on the various indices. Therefore, their usefulness in Myanmar lakes have to be evaluated by Myanmar experts, and indices and boundaries for Myanmar have to be developed further when more data from the country are available.

Norwegian trophic index - TIc
Based on the preliminary species sensitivity for Myanmar species, and using the suggested Norwegian trophic index and boundaries, the status of aquatic macrophytes in Inlay Lake are classified as poor (Table 4.5). In addition, the status seems to become worse from November 2014 to November 2015, however, still in the same status class.

Table 4.5. Ecological status of aquatic macrophytes in Inlay Lake in 2014 and 2015
Based on the TIc-index and the boundaries in Table 3.9. Inlay Lake is lake type 301:
high alkalinity, clear. Orange = poor status.

Period	TIc value	Status
November 2014	-13,0	poor
February 2015	-15,0	poor
November 2015	-21,1	poor

The TIc-index indicates that the aquatic macrophytes in Inlay Lake are dominated by tolerant species, which give a negative value, and poor status (based on Norwegian boundaries). The result from this index is uncertain due to the fact that it is based on preliminary species sensitivities and that Norwegian boundaries are used. If such an index is chosen for Myanmar assessment, the species sensitivity has to be further developed and boundaries exclusively for Myanmar lakes has to be developed.

Relative abundance index (RA index)
Based on the suggested relative abundance metrics (average of the three metrics), the status of aquatic macrophytes in Inlay Lake was classified as poor in November 2014 and moderate in February and November 2015, see Table 4.6.

Table 4.6. Ecological status of aquatic macrophytes in Inlay Lake in 2014 and 2015.
Based on a RA-index (relative abundance), see Table 3.10. Yellow = moderate status,
orange = poor status.

Period	RA value	Status
November 2014	2,4	poor
February 2015	2,8	moderate
November 2015	2,5	moderate

This relative abundance index includes the sensitive lifeform group charophytes and the tolerant group lemnids. It is an overall agreement of the sensitivities of these lifeform groups, which make such an index more robust than the TIc-index, and more suitable for Myanmar assessment at this stage. However, if this index or a similar one is chosen, it has to be further developed and boundaries exclusively for Myanmar lakes has to be developed.

Submerged macrophyte coverage index (SMC index)
Based on submerged macrophyte coverage, the status of aquatic macrophytes in Inlay Lake was classified as good status in all sampling periods, see Table 4.7.

Macrophytes cover, particularly in shallow lakes like Inlay lake, are important for maintaining the clear water state. Since the nutrient input to the lake are high, decreased macrophyte cover will lead to an increased phytoplankton biomass and decreased water clarity. For shallow lakes, we therefor suggest to emphasize the submerged cover index (SMC, see Table 4.7), may be in combination with the RA index. And again, if this index is chosen, it has to be evaluated and boundaries exclusively for Myanmar lakes has to be developed.

Table 4.7. Ecological status of aquatic macrophytes in Inlay Lake in 2014 and 2015
Based on a SMC-metric (submerged macrophyte coverage), see Table 3.10
Green = good status.

Period	SMC value	Status
November 2014	3,9	good
February 2015	4,4	good
November 2015	4,1	good

Conclusion
The distribution of aquatic macrophytes in different lake types in Myanmar is poorly known, and no agreement of sensitivities for the species appearing in the Inlay Lake exist. In this first phase, we therefor suggest to continue developing the Submerged cover index (SNC-index) and the Relative abundance index (RA index).

4.5 Conclusion remarks on ecological status assessment in Inlay lake

In the chapter 4.1-4.4 we have presented some physico-chemistry and biological data conducted from Inlay lake in 2014-2015. We have tested some ecological status indices, suggested by Mjelde et al. (2017), with data from Inlay lake.

When indies and boundaries for Myanmar lakes are established, this chapter will include a final ecological status in the lake, based on the different indices for the biological elements, and the supporting physico-chemical elements, and following the ‘one-out, all-out’ principle (i.e., the worst status of the biological elements used in the assessment determines the final status of the water body). The supporting physico-chemical elements can only influence the status down to moderate, while only biological elements can determine poor or bad status.

However, on this stage the ecological assessments presented here is just an example, and final ecological status for the lake cannot be determined. Establishing a correct classification system for Myanmar requires information about species distribution in country, and their sensitivity to pressures, in addition to data about existing lake types and water chemistry. We highly recommend starting the collection of data from other lakes in different regions of Myanmar. The chosen lakes should represent different lake types (natural lakes and reservoirs, high and low alkalinity lakes, etc.) with expected different biodiversity of phytoplankton and aquatic macrophytes, and representing different water quality. Data from these additional lakes will give important information about the distribution of species along the main gradients, such as alkalinity, nutrient, latitude, altitude, etc. Together with data from Inlay Lake, these data will be essential to establish indices and boundaries for assessing ecological status for phytoplankton and aquatic macrophytes in lakes in Myanmar.

5. Suggested monitoring programme for Inlay Lake

5.1 Quality elements and frequency

For the monitoring programme in Inlay Lake we recommend to continue with the biological elements phytoplankton (including chlorophyll) and aquatic macrophytes (Table 5.1).

In addition, the following physico-chemical parameters should be included: oxygen, pH, conductivity, calcium, colour, turbidity, total phosphorous (TP), PO_4, total nitrogen (TN), NO_3, NH_4, and total organic carbon (TOC).

To detect pollutants from the floating gardens, we suggest sampling for organic pollutants once a month; but *only* during months when farmers spray with pesticides. Knowing the type of pesticide will facilitate the accuracy of the analysis. Samples should be sediment samples rather than water samples since organic pollutants tend to accumulate in sediment and/or biota and may not be detectable in water. To monitor effects from small industries, sampling close to the outlet and downstream the industries for the analysis of metals is needed (see also chapter 3.2.1 on Priority Substances). Sewage from villages will mainly refer to nutrient and bacteria impact. Monitoring of bacteria levels need to occur regularly, but more frequent in the dry, summer season when particularly high levels of bacteria can be expected (Presentation Taungyi university 2016).

Monthly water level measurements should be included. In addition, a bathymetric map (showing the depths of the lake) should be created.

Table 5.1. Recommended quality elements and frequency for surveillance monitoring in Inlay Lake. The elements and frequency are in accordance with the EU WFD suggestions.

Quality elements	Frequency	Repetition
Phytoplankton - Chlorophyll a (µg/l) - Total algal biomass (mg/l) - Species composition - Cyanobacterial biomass (mg/l)	every month in a 2-year period	after 3 years
Aquatic macrophytes - abundance - species composition	twice a year in a 2-year period	after 3 years
Fish - abundance - species composition	in later phase	-
Hydrology morphology:		
-water level measurements	every month in a 2-year period	after 3 years
-depth measurements	once in a 2-year period	-
Physical-chemical elements	every month in a 2-year period	after 3 years
Priority substances	Depend on the specific industries and pressures in the lake.	Depending on industrial or other use of substances.

In flowing rivers to Inlay Lake

In addition, we suggest water samples for physico-chemical analyses from the main inflowing rivers and the lake outlet every month in a 2-year period, according to Table 5.2. At the same time, water flow measurements should be included.

Suggested physio-chemical parameters are: oxygen, pH, conductivity, calcium, colour, turbidity, total phosphorous (TP), PO_4, total nitrogen (TN), NO_3, NH_4, and total organic carbon (TOC).

Table 5.2. Recommended monitoring in the inflowing rivers to Inlay Lake.

Quality elements	Frequency	Repetition
Macroinvertebrates	in a second phase	
Fish	in a later phase	
Periphyton	has to be decided later	
Physical-chemical elements	every month in a 2-year period	after 3 years
Priority substances	has to be decided later	to be decided
Hydro-morphology: -water flow	every month in a 2-year period	after 3 years

5.2 Localities

The original number of 14 sampling localities (Figure 5.1) can be reduced to 6 for water chemistry and phytoplankton. The distribution of aquatic macrophytes can vary between the localities, depending on the character and condition of the local habitats. All the original sampling localities should be maintained for aquatic macrophytes.

Figure 5.1. Suggested localities for surveillance monitoring programme in Inlay Lake. In total 14 localities for aquatic macrophytes and 6 localities for phytoplankton and water samples (red circles).

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Appendix A.

Normative definitions for high, good and moderate status for phytoplankton and macrophytes in lakes.
From: DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000: Establishing a framework for Community action in the field of water policy

Status	Phytoplankton	Aquatic macrophytes
High	The taxonomic composition of phytoplankton corresponds totally or nearly totally to undisturbed conditions. The average phytoplankton abundance is wholly consistent with the type-specific physio-chemical conditions and is not such as to significantly alter the type-specific transparency conditions. Planktonic blooms occur at a frequency and intensity which is consistent with the type-specific physicochemical conditions	The taxonomic composition corresponds totally or nearly totally to undisturbed conditions. There are no detectable changes in the average macrophyte abundance.
Good	There are slight changes in the composition and abundance of planktonic taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth of algae resulting in undesirable disturbances to the balance of organisms present in the water body or to the physio-chemical quality of the water or sediment. A slight increase in the frequency and intensity of the type-specific planktonic blooms may occur.	There are slight changes in the composition and abundance of macrophyte taxa compared to the type-specific communities. Such changes do not indicate any accelerated growth resulting in undesirable disturbances to the balance of organisms present in the water body or to the physio-chemical quality of the water or sediment.
Moderate	The composition of planktonic taxa differs moderately from the type-specific communities. Abundance is moderately disturbed and may be such as to produce a significant undesirable disturbance in the values of other biological and physio-chemical quality elements. A moderate increase in the frequency and intensity of planktonic blooms may occur. Persistent blooms may occur during summer months.	The composition of macrophyte taxa differs moderately from the type-specific community and is significantly more distorted than at good status. Moderate changes in the average macrophyte abundance are evident.

Appendix B. Species lists

Appendix Table B1. Phytoplankton composition in Inlay Lake in Inlay Lake in November 2014, and February and November 2015

Appendix Table B2. Aquatic macrophytes in Inlay Lake in November 2014, and February and November 2015.

Appendix Table B1. Phytoplankton composition in Inlay Lake in Inlay Lake in November 2014, and February and November 2015.Legend: + = sporadic, ++ = frequent, +++ = dominant.

Taxon	A3 05112014	A3 25022015	A3 22112015	B3 05112014	B3 25022015	B3 22112015	C3 06112014	C3 26022015	C3 22112015
Domain Eubacteria									
Division Cyanobacteria (Cyanoprokaryota									
Aphanocapsa spp. C. Nägeli	+		++	+++	+++	+++	+++	+++	+++
Aphanothece sp. C. Nägeli		++	++			+++		+	+++
Chroococcus sp. Nägeli				++	++	++			
Chroococcus limneticus Lemmerm.								+	
Cylindrospermopsis curvispora M.Watanabe									+
Dolichospermum (Ralfs ex Bornet & Flahault) P.Wacklin, L.Hoffmann & J.Komárek		+				+	+		++
Limnothrix redekei (Goor) Meffert		+				+			
Merismopedia punctata Meyen	++		+	+++	+	++	+		++
Merismopedia tenuissima Lemmermann	+		+	+++		+++	++		+++
Merismopedia warmingiana (Lagerheim) Forti						+++			+++
Microcystis aeruginosa (Kützing) Kützing	++			++		+++	+	++	++
Planktolyngbya cf. *brevicellularis* G.Cronberg & Komárek		+	+	+++	++	++	++		
Planktothrix pseudaghardii Suda et al.									
Pseudanabaena sp. Lauterborn	+		+		+			+	+
Pseudanabaena limnetica (Lemmermann) Komárek						+			
Rhabdoderma Schmidle & Lauterborn									++
Sphaerospermopsis (Forti) Zapomelová, Jezberová, Hrouzek, Hisem, Reháková & Komárková		+						+	
Synechococcus C.Nägeli	+++								
Synechocystis C.Sauvageau	+		+++						

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Domain Eukarya									
Class Bacillariophyceae									
Achnanthes Bory		+	+						+
Amphora sp. Ehrenberg ex Kützing	+								+
Aulacoseira granulata (Ehrenberg) Simonsen							+		++
Aulacoseira granulata var. angustissima (Otto Müller) Simonsen									++
Aulacoseira italica (Ehrenberg) Simonsen	+								
Cocconeis sp. Ehrenberg							+		
Cyclotella (Kützing) Brébisson				++	+	+	+	+	+++
Cymbella sp. C.Agardh		+	+		+				
Epithemia Kützing								+	
Fragilaria sp. Lyngbye						+		+	+
Fragilaria ulna (Nitzsch) Lange-Bertalot									+
Gomphonema sp. Ehrenberg	+	+	+			+	+	++	
Navicula Bory	+			+		+			
Nitzschia acicularis									+
Nitzschia palea (Kützing) W.Smith								+	
Nitzschia Hassall		++					+		+
Pinnularia sp. Ehrenberg				+				+	
Surirella Ehrenberg								+	
Surirella cf. elegans Ehrenberg				+			+		
Class Conjugatophyceae									
Closterium spp. Nitzsch ex Ralfs				+		+			
Cosmarium Corda ex Ralfs				+	+	+	++		+
Cosmarium pachydermum P.Lundell # COSMARIZ		+				+			
Staurastrum spp. Meyen ex Ralfs				+		+			+

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Class Chlorophyceae									
Ankistrodesmus Chorda				+					
Carteria Diesing	+							+	
Chlamydomonas sp. Ehrenberg	++	++	+	++	++	+		++	++
Coelastrum microporum Nägeli			+						
Coelastrum polychordum (Korshikov) Hindák				++	+				
Coelastrum reticulatum (P.A.Dangeard) Senn			+			+			+
Coenochloris hindakii Komárek						+			+
Coenochloris Korshikov						++			+
Desmatractum delicatissimum Korshikov					++				
Desmodesmus quadricauda (Turpin) Brébisson	+	+		+	+	+		+	+
Golenkinia brevispina Korshikov	+		++			+	+	+	+++
Golenkinia radiata Chodat					++	+			
Kirchneriella dianae (Bohlin) Comas Gonzalez									+
Kirchneriella microscopica Nygaard				+					
Monoraphidium circinale (Nygaard) Nygaard	+	+	++		+			+	+++
Monoraphidium contortum (Thuret) Komárková-Legnerová			+	+++	+	+	++		+
Monoraphidium convolutum (Corda) Komárková-Legnerová	+								
Monoraphidium griffithi									++
Monoraphidium komarkovae Nygaard	+		+						
Monoraphidium minutum (Nägeli) Komárková-Legnerová			+	+	++	++		++	++
Pediastrum simplex Meyen		+	+	+	+	+			+
Pediastrum simplex var. *echinulatum* Wittrock					+				+
Pediastrum tetras (Ehrenberg) Ralfs						+			
Scenedesmus Meyen				++	+			+	
Scenedesmus acutus Meyen						+			

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Scenedesmus calyptratus Comas						++		+	+++
Scenedesmus ecornis (Ehrenberg) Chodat	+	+	+	++	++	+++	+	+	+
Scenedesmus verrucosus Y.V.Roll				+			+		
Schroederia planctonica (Skuja) Philipose						+			
Spermatozopsis exultans Korshikov									++
Tetraedron caudatum (Corda) Hansgirg		+		++		+		+	++
Tetraëdron mediocris Hindák					+				
Tetraedron minimum (A.Braun) Hansgirg				++	+	+	+	+	++
Tetrastrum komarekii Hindák					+	+		+	++
Tetrastrum triangulare (Chodat) Komárek				+			+		
Treubaria triappendiculata C.Bernard			+						+
Willea vilhelmii (Fott) Komárek	+				+	+			+
Class Trebouxiophyceae									
Actinastrum gracillimum G.M.Smith							+++		
Actinastrum hantzschii Lagerheim						+			+
Botryococcus terribilis Komárek & Marvan		+							
Crucigenia tetrapedia (Kirchner) Kuntze			+	++			+		+
Crucigeniella pulchra (West & G.S.West) Komárek							+		
Crucigeniella crucifera (Wolle) Komárek						+			++
Dichotomococcus Korshikov, 1928						+			
Dictyosphaerium Nägeli						+			
Franceia javanica (C.Bernard) Hortobágyi				+++					
Geminella Turpin									++
Golenkiniopsis solitaria (Korshikov) Korshikov				++					
Golenkiniopsis parvula (Woronichin) Korshikov							+		++

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Lagerheimia chodatii C.Bernard							+		
Lagerheimia ciliata (Lagerheim) Chodat					+				
Lagerheimia genevensis (Chodat) Chodat						+			
Lagerheimia subsalsa Lemmermann				++	+		+	+	+
Nephrocytium agardhianum Nägeli					+				+
Nephrocytium limneticum (G.M.Smith) G.M.Smith						+			
Nephrocytium Nägeli				+					+
Oocystis sp Nägeli ex A.Braun			++	+		++	+	++	+++
Tetrachlorella incerta Hindák							+		
Class Klebsormidiophyceae									
Elakatothrix viridis (J.W.Snow) Printz					+				
Class Cryptophyceae									
Cryptomonas Ehrenb spp.	+++	+++	+++	+++	++	+++	++	+++	+++
Class Dinophyceae									
Ceratium hirundinella (O.F.Müller) Dujardin		+				+		+	
Gymnodinium F.Stein		+					+		+
Gymnodinium simplex (Lohmann) Kofoid & Swezy	++	+++							+
Peridiniopsis Lemmermann	+++	+++	++			+			++
Peridinium Ehrenberg				+	+		+	++	
Peridinium brevipes Paulsen	+	+++				++			+
Class Euglenophyceae									
Euglena acus (O.F.Müller) Ehrenberg	+								
Euglena spp. Ehrenberg	+	+	++	+	+		+		+

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Lepocinclis constricta Matvienko									+
Lepocinclis cf. *ovum* (Ehrenberg) Lemmermann		+							
Lepocinclis Perty				+				+	
Phacus longicauda (Ehrenberg) Dujardin	+		+	+					+
Phacus tortus (Lemmermann) Skvortzov				+					
Phacus sp. Dujardin	++		+						+
Trachelomonas Ehrenberg	+								+
Trachelomonas volvocina (Ehrenberg) Ehrenberg		+							
Chrysophyceae									
Bitrichia chodatii (Reverdin) Chodat	+		++						
Chromulina L.Cienkowsky 3x2	++	+++	+++		+++	+		++	++
Chrysococcus G.A.Klebs						++	+++		++
Dinobryon bavaricum Imhof		++			+	++			+
Dinobryon crenulatum West & G.S.West			+	+	+	++	+		
Dinobryon divergens O.E.Imhof	+	++			+++	++			
Dinobryon sociale (Ehrenberg) Ehrenberg				++			+		
Dinobryon sertularia Ehrenberg	+	+	+			++		+	+
Ochromonas Vysotskij spp.	+	+++	+		++	++	+++	+	++
Kephyrion Pascher						+			
Pseudokephyrion Pascher		+++							
Class Prymnesiophyceae (Haptophyceae)									
Chrysochromulina parva Lackey		+	+			+++			+++
Class Synurophyceae									
Mallomonas cf. *elegans* Lemmermann	+								

Appendix Table B1. (cont.).

Taxon	**A3 05112014**	**A3 25022015**	**A3 22112015**	**B3 05112014**	**B3 25022015**	**B3 22112015**	**C3 06112014**	**C3 26022015**	**C3 22112015**
Mallomonas elongata Reverdin		+							
Mallomonas schwemmlei Glenk									+
Mallomonas sp. Perty	+	+	+	+		+	+	+	+
Class Xanthophyceae Eustigmatophyceae									
Centritractus belonophorus (Schmidle) Lemmermann			+				+		+
Centritractus ellipsoideus Starmach	+		+						
Ophiocytium capitatum Wolle # OPHI CAP									+
Goniochloris fallax Fott			+						

Appendix Table B.2. Aquatic macrophytes in Inlay Lake in November 2014, and February and November 2015. Abundance score; based on a semi-quantitative scale, where 1 = rare, 2 = scattered, 3 = common, 4 = locally dominant and 5 = dominant. -1: occurrence (no score), +: drifting specimen

Localities in transect A:	**A1**			**A2**			**A3**			**A4**			**A5**		
Latin names	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15
ELODEIDS															
Ceratophyllum demersum	2		2									1	4	3	4
Hydrilla verticillata															
Myriophyllum cf spicatum	2														
Myriophyllum verticillatum	5	5	5		2										2
Najas indica	2	4	4	2	3										
Nechamandra alternifolia	2	3	1		3	2	5	5	5	5	3-4	5	3	2-3	3
Potamogeton crispus	2												1		
Potamogeton lucens	2	1	2	5	5	4	2			+	3-4	5	2	2	2
Potamogeton nodosus															
Potamogeton cf. pusillus															
Stuckenia pectinata															
Utricularia cf australis	2												2	-1	
Utricularis sp 2			1		1									-1	
NYMPHAEIDS															
Nelumbo nucifera													+		
Nymphaea nouchali															
Nymphaea pubescens															
Nymphaea sp															
Nymphoides indica															
Ottelia alismoides				2		2							1		
LEMNIDS															
Eichornia crassipes	3	3	2				5	5	5	3	2	5	4	4	3
Lemna trisulca							1								
Pistia stratiotes							1-2					2	1		1
Spirodela polyrhizza							1						1		
Salvinia cucullata	2		1				3		2			2	1		1
CHAROPHYTES															
Chara cf. zeylanica					4-5	5	3	4-5	5		3-4				
total number of species	**10**	**5**	**8**	**3**	**6**	**4**	**8**	**3**	**4**	**3**	**4**	**6**	**11**	**6**	**7**

Appendix Table B.2. (cont.)

Localities in transect B:	**B1**			**B2**			**B3**			**B5**		
Latin names	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15
ELODEIDS												
Ceratophyllum demersum	4-5	3	4	2						2		3
Hydrilla verticillata										1		
Myriophyllum cf spicatum												
Myriophyllum verticillatum										3	+	1
Najas indica							-1					
Nechamandra alternifolia	2	1	+				+	3		2	+	1
Potamogeton crispus												
Potamogeton lucens	2-3	2-3	2	2	4		-1	4-5	4-5	3	4	4
Potamogeton nodosus			+									
Potamogeton cf. pusillus												
Stuckenia pectinata												
Utricularia cf australis	2			1						2		
Utricularis sp 2		1				+						
NYMPHAEIDS												
Nelumbo nucifera												
Nymphaea nouchali												
Nymphaea pubescens												
Nymphaea sp												
Nymphoides indica												
Ottelia alismoides												
LEMNIDS												
Eichornia crassipes	5	4-5	5	4	2		4	2		5	2	4
Lemna trisulca												
Pistia stratiotes	2		3				+					
Spirodela polyrhizza			1									
Salvinia cucullata	2	1	1				+			2		1
CHAROPHYTES												
Chara cf. zeylanica				2			-1	5	2-3			
total number of species	**7**	**6**	**8**	**5**	**2**	**1**	**7**	**4**	**2**	**8**	**4**	**6**

Appendix Table B.2. (cont.)

Localities in transect C:	**C1**			**C2**			**C3**			**C4**			**C5**		
Latin names	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15
ELODEIDS															
Ceratophyllum demersum	2	2					-1	4	3	4	2		2		2
Hydrilla verticillata	4	4		1				4		1					
Myriophyllum cf spicatum															
Myriophyllum verticillatum	3	1		+	2	5								3	1
Najas indica	5	5						5		1		2	1		5
Nechamandra alternifolia	1						-1		1					3	1
Potamogeton crispus		4			3			2						1	
Potamogeton lucens	3	4					-1		4	3	5	3	+	1	
Potamogeton nodosus	2	3			3			3	5			5	1		
Potamogeton cf. pusillus												1			
Stuckenia pectinata								5		2	3	2			1
Utricularia cf australis										2					
Utricularis sp 2	1							3		1	3		1	1	2
NYMPHAEIDS															
Nelumbo nucifera				2	3	4									
Nymphaea nouchali															
Nymphaea pubescens			2	3		3									
Nymphaea sp															
Nymphoides indica					2										
Ottelia alismoides	2			1	3	2			2						
LEMNIDS															
Eichornia crassipes	3	4	4	2	4	4	-1	1					3-4	3-4	5
Lemna trisulca															
Pistia stratiotes							-1						1		
Spirodela polyrhizza	1														
Salvinia cucullata	2					2	-1						3	2	
CHAROPHYTES															
Chara cf. zeylanica											4	3			
total number of species	**12**	**8**	**2**	**6**	**7**	**6**	**6**	**8**	**5**	**7**	**5**	**6**	**8**	**7**	**7**

Appendix Table B.2. (cont.)

Localities in transect D&E:	**D**			**E1**			**E2**		
Latin names	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15	Nov.14	Feb.15	Nov.15
ELODEIDS									
Ceratophyllum demersum									
Hydrilla verticillata	-1					-1			
Myriophyllum cf spicatum			3		4			3	
Myriophyllum verticillatum				4					4
Najas indica									
Nechamandra alternifolia	-1	+		+	2	-1	+		+
Potamogeton crispus									
Potamogeton lucens	-1					-1			
Potamogeton nodosus									
Potamogeton cf. pusillus									
Stuckenia pectinata									
Utricularia cf australis	-1				4	-1			
Utricularis sp 2		+					+		
NYMPHAEIDS									
Nelumbo nucifera			5	5				5	5
Nymphaea nouchali				1					1
Nymphaea pubescens				2					2
Nymphaea sp	-1	1				-1	1		
Nymphoides indica			1-2	2	4			1-2	2
Ottelia alismoides	-1	2		2		-1	2		2
LEMNIDS									
Eichornia crassipes	-1	4	2	3		-1	4	2	3
Lemna trisulca									
Pistia stratiotes	-1	2				-1	2		
Spirodela polyrhizza									
Salvinia cucullata	-1	2	1	2-3		-1	2	1	2-3
CHAROPHYTES									
Chara cf. zeylanica									
total number of species	**9**	**7**	**5**	**9**	**4**	**9**	**7**	**5**	**9**

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