Warming of Lake Pingvallavatn and thermal processes in the lake

Hilmar J. Malmquist1, Finnur Ingimarsson2, Haraldur R. Ingason3, Stefán Már Stefánsson2 and Póra Hafnsdóttir1,2

1 Icelandic Museum of Natural History, Brynjólfsgata 5, 107 Reykjavík, Iceland – nmsi.is
2 Natural History Museum of Kópavogur, Hamraborg 6a, 200 Kópavogi, Iceland – natkop.is

1. Introduction

Climate warming in Iceland has been in line with global warming for the past two centuries (>0.8 °C per century).

Because of warming, changes in ecosystem structure and function are taking place, as evidenced in particular by glacial melting and retreat, and changes in marine species abundance and distribution.

In this study we account for the thermal evolution of a freshwater ecosystem, Lake Pingvallavatn, SW-Iceland, over a 55 year period (1962–2017), comprising the most extensive data set on lake T°C available in Iceland.1

Fig. 1. Lake Pingvallavatn and T°C recording stations. LV1 and LV2 lake outlet, NK2 pelagic station and three T°C stations (green circles).

Lake Pingvallavatn is the second largest lake in Iceland, 83 km² (2900 Gl), with a mean depth of 34 m and fed primarily by cold (3–4°C), spring-water inlets, amounting to ca. 90% of the total inlet (100 m³/s).

2. Data

Tlake at LV1 and LV2 was provided by the National Power Company of Iceland, with a min of 1–4 records/day during 1962–94 and 24–48 recs./day during 2000–17.

Tlv was provided by the Icelandic Met. Office.

Reliability of T°C at the lake outlet as an indicator of whole lake T°C was tested by regression analyses of LV2 on T°C at pelagic station NK2. A highly significant correlation was observed between T°C at LV2 and NK2 measured simultaneously at 4 m, 8 m and 16 m depth at all 4 seasons.

Tlake at NK2 was recorded by data loggers every hour at 8–10 different depths during June–November 2011–2016.

3. Results

Fig. 2. Yearly mean T°C in Lake Pingvallavatn (blue) and yearly mean Tlw in the catchment area (red) during 1962–1994 and 2002–2016. DWLS fitted lines. Tw: R=0.999 (P<0.001); Tlw: R=0.735 (P<0.001).

T°C of Lake Pingvallavatn has increased significantly for the past 30 years, congruent with a rise in Tw in the catchment area (Fig. 2). Annual mean Tlake has risen on average by 0.15°C per decade, similar to warming observed in other large, deep lakes in the northern hemisphere.

Tlake has risen in all months, except February–April (Table 1), with most profound warming in June-August.

Table 1. Linear regressions on monthly mean T°C in Lake Pingvallavatn during 1962–94 and 2000–16. Change denotes difference in Tslate-Tlake according to y = bx + a.

<table>
<thead>
<tr>
<th>Month</th>
<th>b</th>
<th>a</th>
<th>r</th>
<th>p</th>
<th>ΔT°C</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>April</td>
<td>0.20</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>May</td>
<td>0.15</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>June</td>
<td>0.17</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>July</td>
<td>0.15</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>August</td>
<td>0.08</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>September</td>
<td>0.15</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>October</td>
<td>0.07</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>November</td>
<td>0.04</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
<tr>
<td>December</td>
<td>0.02</td>
<td>-1.07</td>
<td>0.96</td>
<td>0.004</td>
<td>0.031</td>
<td>(0.002, 0.058)</td>
</tr>
</tbody>
</table>

Freezing of the lake occurs much less frequently nowadays than before, with thinner ice and shorter duration (Fig. 3).

Fig. 3. Number of days with complete ice cover on Lake Pingvallavatn during 1974–2017.

Fig. 4. Isotherms of T°C at pelagic station NK2 and mean wind speed at weather station 1596 (Leirur).

In warm and cloudy summers, as in 2012, a strong thermal stratification develops at 15–25 m depth, with up to 4°C difference between epil- and hypolimnion (Fig. 4). In colder and more windy summers, as in 2014, the thermocline is weak or absent and the lake is mixed from top to bottom.

4. Conclusions

Temperature of Lake Pingvallavatn has risen significantly for the past 30 years in line with and due to climate warming.

Warming of the lake, along with increased nitrogen loads observed in the inlet water may already have affected primary producers in the pelagic zone, as observed lately by increase in phytoplankton biomass, especially in autumn.3

Recent, unprecedented changes in species abundance and composition of principal diatoms in the lake, may be the result of warming of Lake Pingvallavatn.

5. References