Warming of Lake Þingvallavatn
and thermal processes in the lake

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1. Introduction

Climate warming in Iceland has been in line with global warming for the past two centuries (+0.8°C pr. 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 Þingvallavatn, SW-Iceland, over a 55 year period (1962–2017), comprising the most extensive data set on lake T°C available in Iceland.[1]

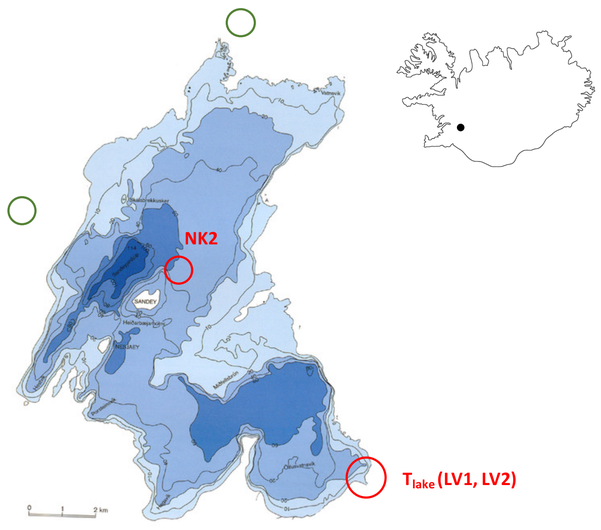

Fig. 1. Lake Þingvallavatn and T°C recording stations. LV1 and LV2 lake outlet, NK2 pelagic station and three T_{air} stations (green circles).

Lake Þingvallavatn is the second largest lake in Iceland, 83 km^2 (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 m^3/s).

2. Data

T_{lake} 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.

T_{air} 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.

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

3. Results

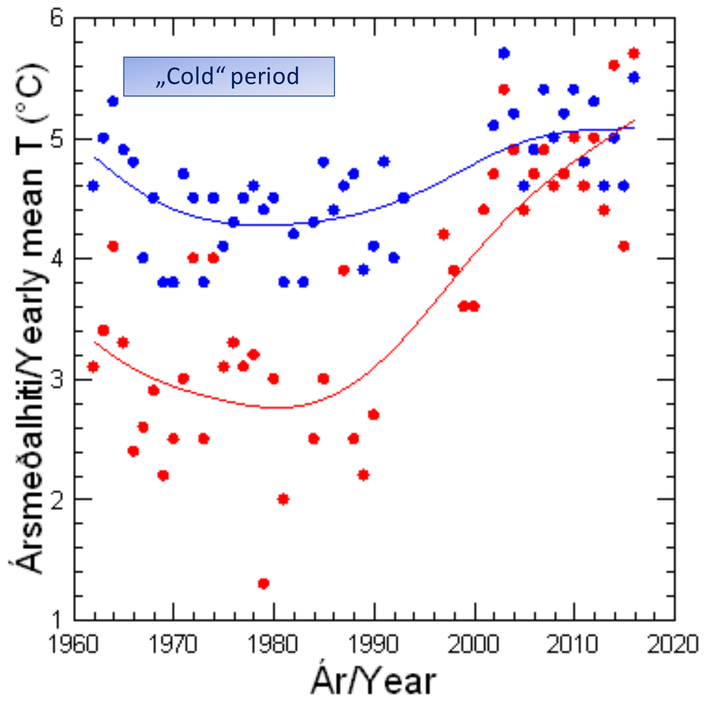

Fig. 2. Yearly mean T°C in Lake Þingvallavatn (blue) and yearly mean T_{air} in the catchment area (red) during 1962–1994 and 2002–2016. DWLS fitted lines.
T_{lake} R=0.999 (P<0.001); T_{air} R=0.735 (P<0.001).

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

T_{lake} 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 Þingvallavatn during 1962–94 and 2000–16. Change *denotes difference in T_{1962}–T_{2016} according to* y = hx + b.

Month	b	h	R	F	p	n	Mean (°C)	Min (°C)	Max (°C)	Change (°C)
January	-26.612	0.014	**0.370**	7.603	**0.008**	50	1.0	0.1	3.1	**0.77**
February	-5.806	0.003	0.129	0.806	0.374	50	0.7	0.1	2.0	0.17
March	4.445	-0.002	0.061	0.178	0.675	50	0.9	0.1	2.4	-0.11
April	-3,217	0.002	0.071	0.241	0.626	49	1.5	0.5	3.2	0.11
May	-19.509	0.011	**0.281**	4.128	**0.048**	50	3.1	1.6	4.9	**0.59**
June	-41.464	0.024	**0.387**	8.261	**0.006**	49	6.2	4.3	9.0	**1.3**
July	-48.331	0.029	**0.418**	9.943	**0.003**	49	9.1	7.0	12.3	**1.57**
August	-49.506	0.030	**0.522**	17.615	**<0.001**	49	9.9	7.9	11.9	**1.62**
September	-20.396	0.015	**0.448**	11.817	**0.001**	49	8.7	7.6	10.0	**0.81**
October	-19.361	0.013	**0.349**	6.532	**0.014**	49	7.0	5.3	8.2	**0.70**
November	-31.603	0.018	**0.410**	11.567	**0.004**	48	4.6	3.0	6.0	**0.97**
December	-38.135	0.020	**0.421**	10.115	**0.003**	49	2.4	0.7	4.3	**1.08**
Whole year:	-24.330	0.015	**0.493**	14.438	**<0.001**	47	4.6	3.8	5.7	**0.81**

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

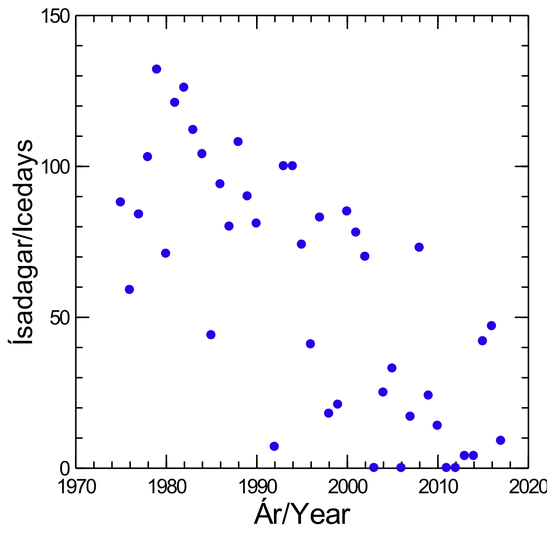

Fig. 3. Number of days with complete ice cover on Lake Þingvallavatn during 1974–2017.

3. Results

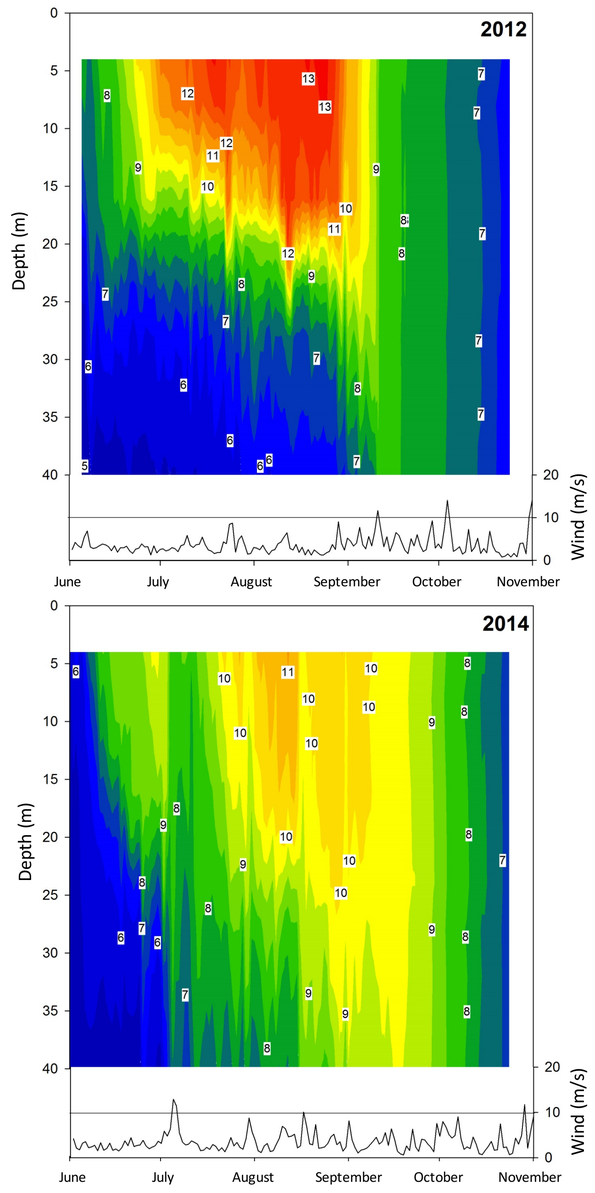

Fig. 4. Isographs of T°C at pelagic station NK2 and mean wind speed at weather station 1596 (Leirur).

In warm and calm summers, as in 2012, a strong thermal stratification develops at 15–25 m depth, with up to 4°C difference between epi- 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 Þingvallavatn 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[2] 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[4], may be the result of warming of Lake Þingvallavatn.

5. References

1 Hilmar J. Malmquist et al. 2020. *Náttúrufræðingurinn* 90 (in prep.)
2 Eydís Salome Eiríksdóttir et al. 2017. Chemical composition of Lake Þingvallavatn 2007–2016. University of Iceland, The Science Institute, (RH-04-2017), Reykjavík. 47 p.
3 Haraldur R. Ingvason et al. 2015. Nat. Hist. Mus. of Kópavogur (*Report no. 1-2015*).
4 Gunnar St. Jónsson. 2017. Phytoplankton studies in Lake Þingvallavatn 2015–2017. Ministry of Environment, Reykjavík. 25 p.