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Responses to changes in air pollution and climate in Valkea-Kotinen ICP IM catchment – key findings over a 20 year period

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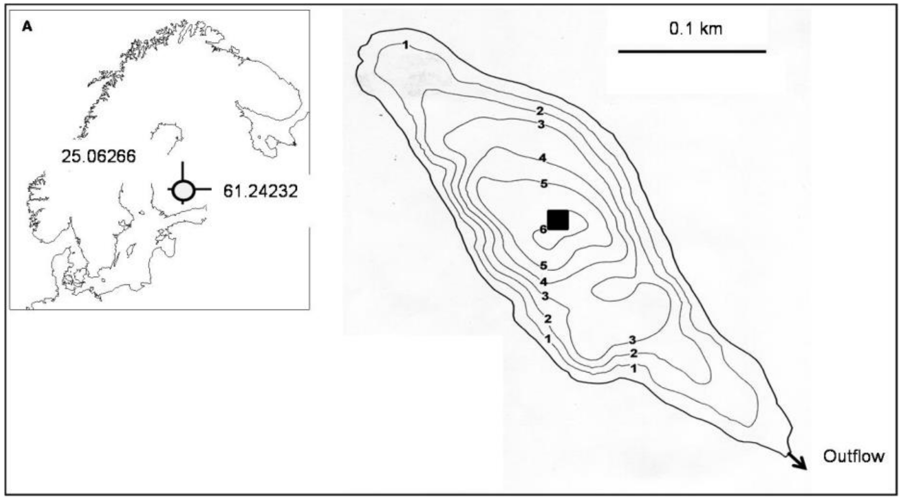
Information for making sustainable choices

Valkea-Kotinen – a forest catchment with a lake



Catchment area (km^2)	0.22
Peatland (%)	14
Mean air temp. 1990-2009 (^oC)	4.6
Mean precipitation ($mm\ a^{-1}$)	628
Mean runoff 1990-2009 ($mm\ a^{-1}$)	198
Lake area (km^2)	0.042
Elevation (m)	156
Maximum depth (m)	6.5
Lake volume (m^3)	103000
Retention time (yr)	1.0

Climate variability and trends in the Valkea-Kotinen region, southern Finland

- ✓ Climatic variables under consideration: air temperature and its indices, precipitation, snow depth, lake-ice cover, wind speed and solar radiation.

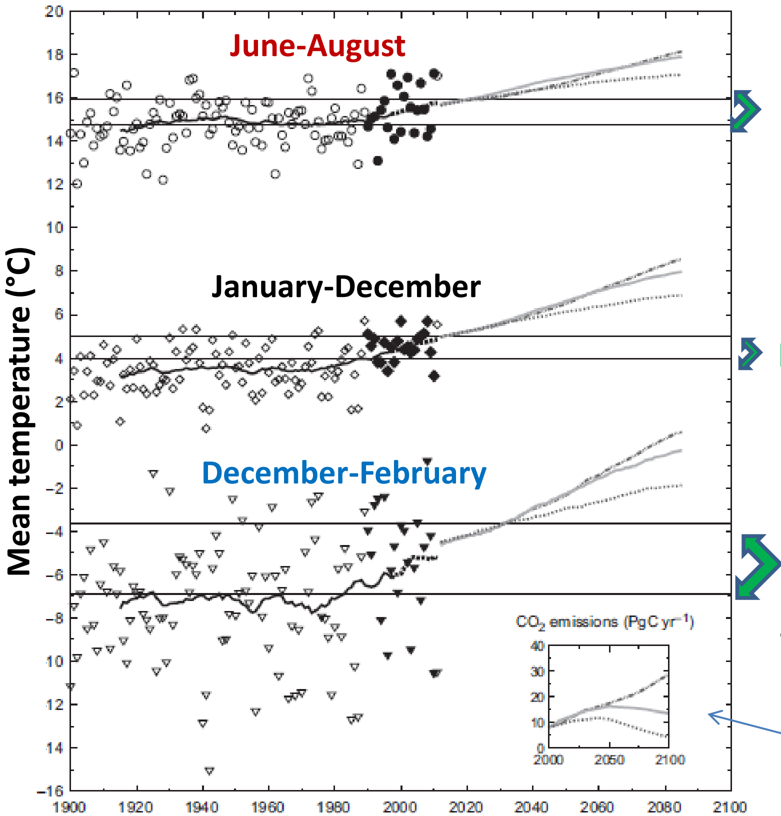
- ✓ The variables were categorized depending on the rate of future climatic changes compared with the variations to which the ecosystems in the Valkea-Kotinen region have been recently exposed.

- ✓ Already currently **significant statistical trends** that are also likely to continue in the future:
  - Increases in annual and spring mean temperature by 0.4 °C / 10 yr
  - A thinning of annual mean snow depth by slightly above 1 cm /10 yr
  - A shortening of the lake-ice season by 15 days /10 yr
  - An advance of ice-off date by six days /10 yr

Jylhä K., Laapas M. Ruosteenoja K., Arvola L., Drebs A., Kersalo J., Saku S., Gregow H., Hannula H.-R. & Pirinen P. 2014. Climate variability and trends in the Valkea-Kotinen region, southern Finland: comparisons between the past, current and projected climates. *Boreal Env. Res*. 19A: 4-30.

Trends in seasonal variability of air temperature

Increases in mean temperature are already (annual and spring) or becoming within the next two decades (other seasons) statistically significant



1900 Observations **2000** Projections **2100**

FINNISH METEOROLOGICAL INSTITUTE

Weather station Lammi-Pappila

Limits of statistical significance

19-model (CMIP3) mean-estimates

Three emission scenarios for CO_2:
SRES A2 (top)
A1B (middle)
B1 (bottom)

Jylhä et al. (2014), Figure 2

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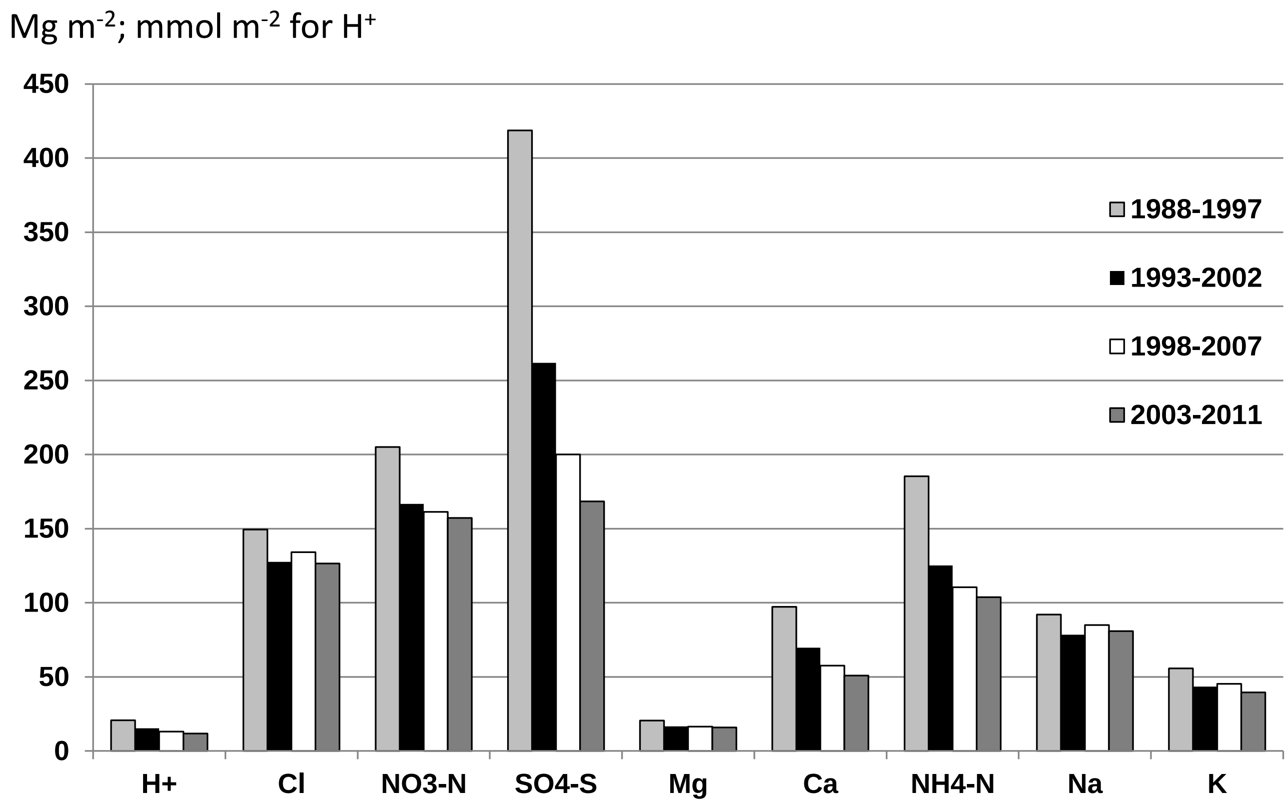
Temporal trends in the bulk deposition and atmospheric concentration of acidifying compounds and trace elements

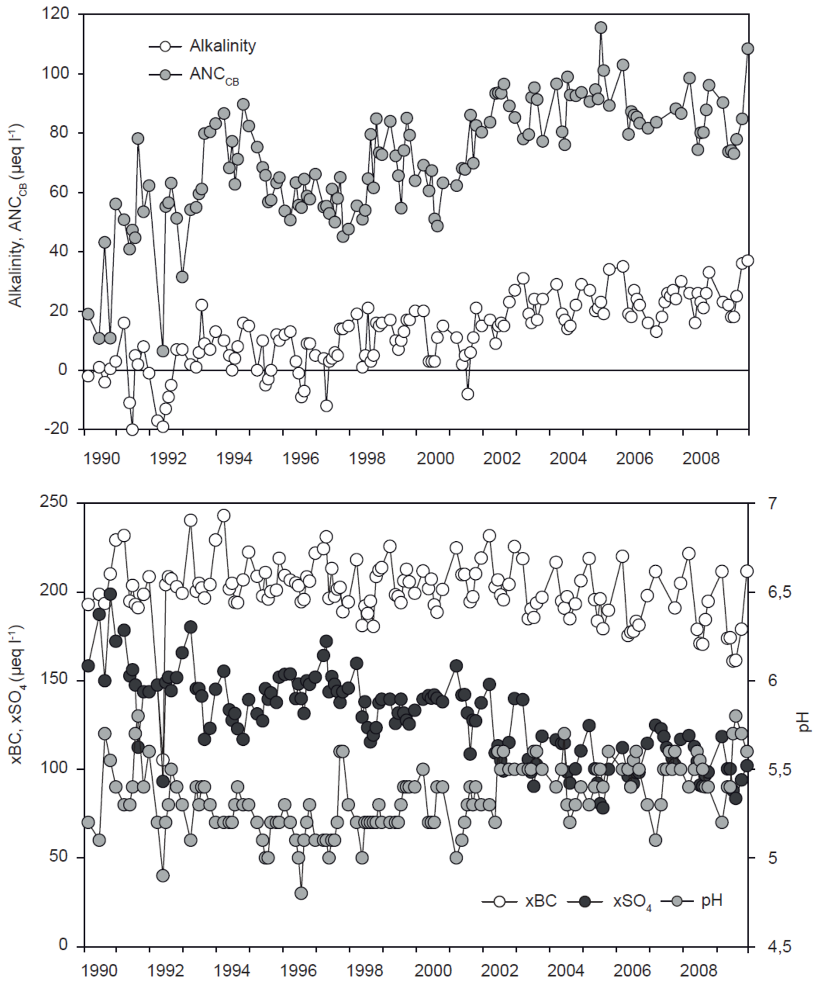
- The precipitation chemistry of almost 30 acidifying compounds, base cations and trace elements monitored in the Valkea-Kotinen IM catchment during 1988-2011
- A significant downward trend in the bulk deposition of all main ions detected during the first decade of monitoring
- Decreases also in the bulk deposition of trace elements, except for Cd
- Slow decrease and wide year-to-year variation in the bulk deposition of nitrate – during 2002-2008 even an increasing trend
- The dominating directions of transport of air masses to Valkea-Kotinen area from southwest, west, northwest and north

Ten-year annual mean values for the bulk deposition of the main anions and cations at Valkea-Kotinen.



Ruoho-Airola T., Hatakka T., Kyllönen K., Makkonen U. & Porvari P. 2014. Temporal trends in the bulk deposition and atmospheric concentration of acidifying compounds and trace elements in the Finnish Integrated Monitoring catchment Valkea-Kotinen during 1988–2011. *Boreal Env. Res*. 19A: 31-46.

Water quality in Lake Valkea-Kotinen: key acidification parameters in 1990-2009

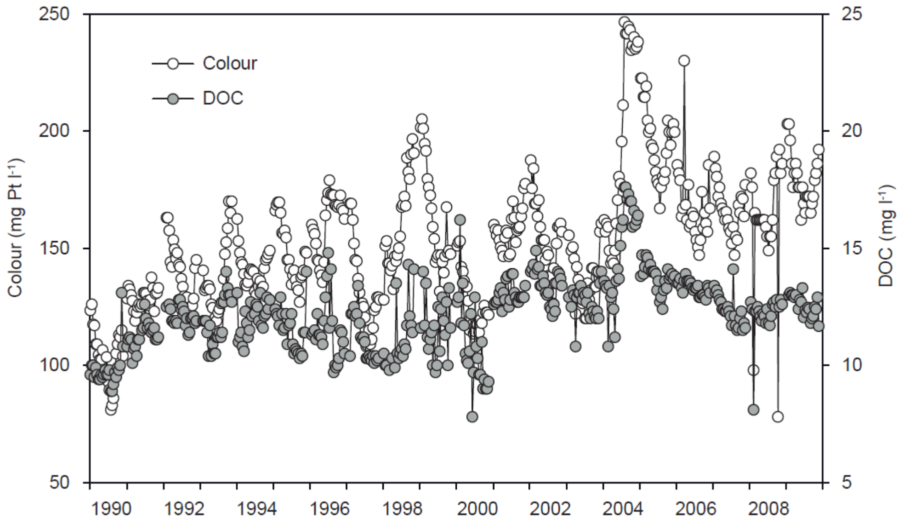


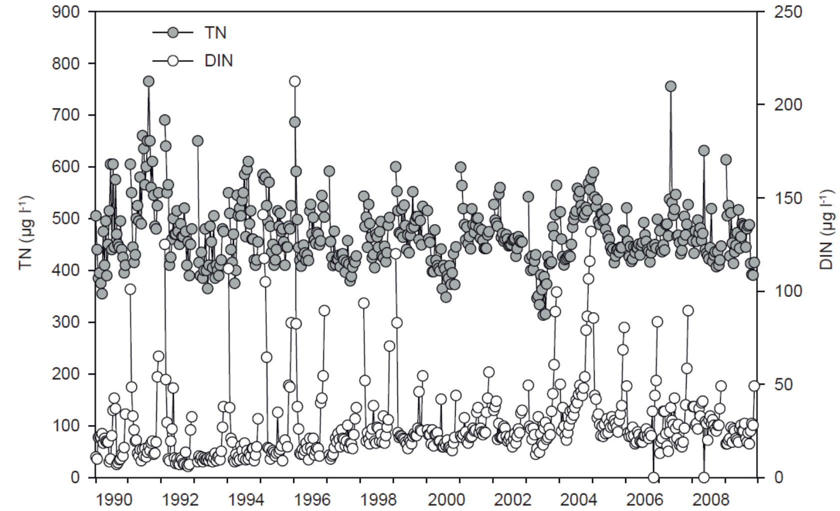
Recovery from acidification is proceeding in L. Valkea-Kotinen

- A clear decrease in sulfate and increase in alkalinity took place in early 2000s, about 5-10 years later than observed in clear water lakes in south Finland.
- Retention and release processes of sulfate in peaty soils of the catchment may have affected the recovery processes in the lake.
- Effects of episodic organic acidity may have also delayed the recovery of buffering capacity in the highly humic lake

Vuorenmaa J., Salonen K., Arvola L., Mannio J., Rask M. & Horppila P. 2014. Water quality of a small headwater lake reflects long-term variations in deposition, climate and in-lake processes. *Boreal Env. Res*. 19A: 47-65.

Water quality in Lake Valkea-Kotinen: DOC, colour and nitrogen in 1990-2009





DOC and water colour: significant increase

- Recovery from acidification an important driver behind the increase.
- Short-term fluctuations in runoff modify the load of organic matter to the lake
- Increase in DOC may also be related to meteorological factors (increased temperature)

DIN: significant increase – TN not trend

- Due to in-lake processes….?
- From N limitation to P limitation?
- Higher primary production in the 1990s
- Hydrology - wetter conditions in the 2000s than in the 1990s….

Effects of a changing climate on the hydrology of a boreal catchment and lake DOC — probabilistic assessment of a dynamic model chain

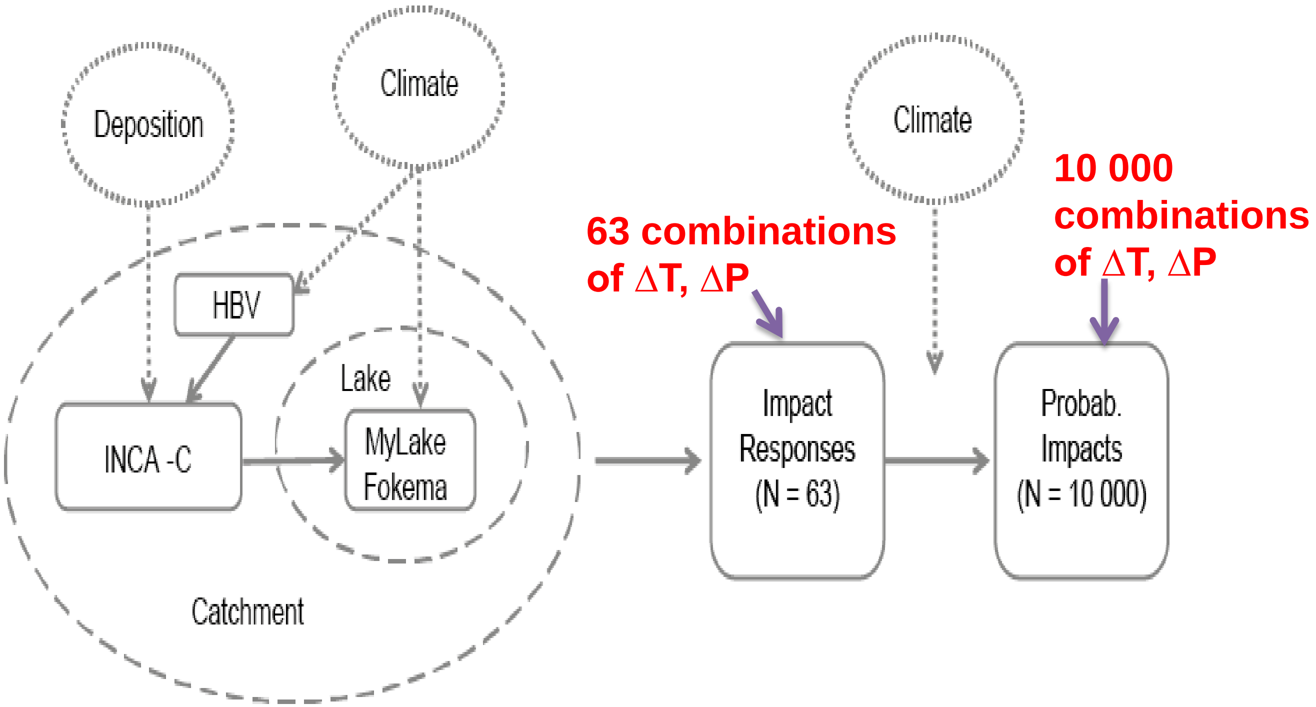
Impact response surface analysis was applied to quantify the likelihood of climate change induced hydrological responses in Valkea-Kotinen IM catchment

Summary

- Seasonal pattern in AET and runoff
- Annual runoff may decrease or increase (-10% to +5%)
- Drier soils (SMD +12% to +25%)
- DOC in lake may decrease slightly (6%)
- Shorter snow period
- Shorter lake ice period (15 days per decade)
- Earlier onset of stratification (April 22nd, not May 12th)

Holmberg, M., Futter, M.N., Kotamäki N., Fronzek, S., Forsius, M., Kiuru, P., Pirttioja, N., Rasmus, K., Starr, M.& Vuorenmaa, J. 2014. Boreal Env. Res. 19A: 66-82

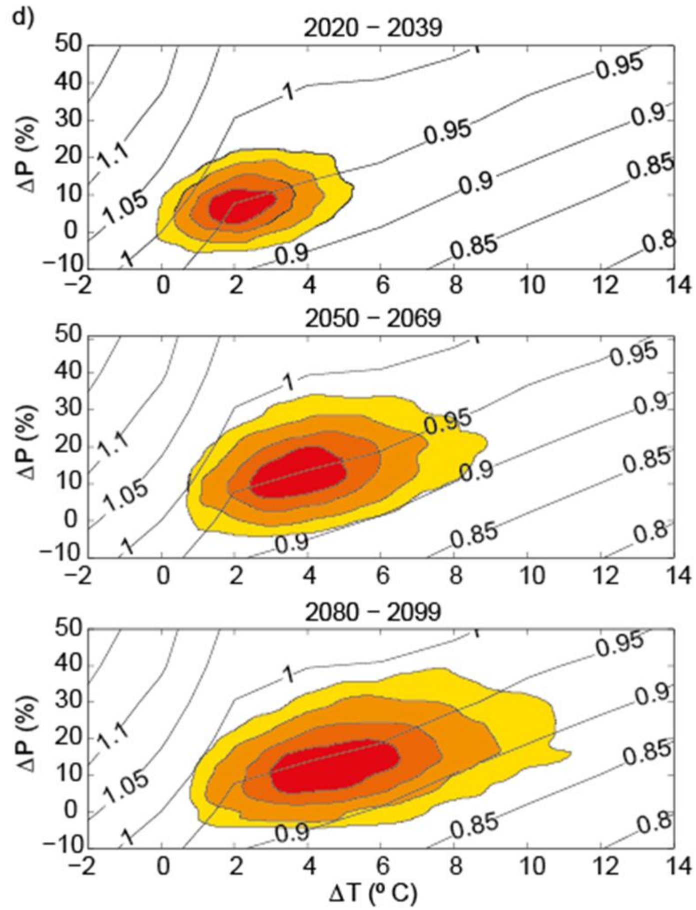
Probabilistic assessment of a dynamic model chain: *HBV – INCA-C – MyLake/Fokema*



INCA-C + HBV: Futter et al. 2008, 2009; MyLake: Saloranta et al. 2010;

MyLake/FOKEMA – estimated *DOC* concentrations in lake, relative to reference

- Lake DOC 14.3 mg L^{-1} in reference conditions
- Low sensitivity to climate change
- Slight decrease with time



Harris, G.R., Collins, M., Sexton, D.M.H., Murphy, J.M. & Booth, B.B.B. Probabilistic projections for 21st century European climate. Nat. Hazards Earth Syst. Sci. (2010) 10: 2009-2020

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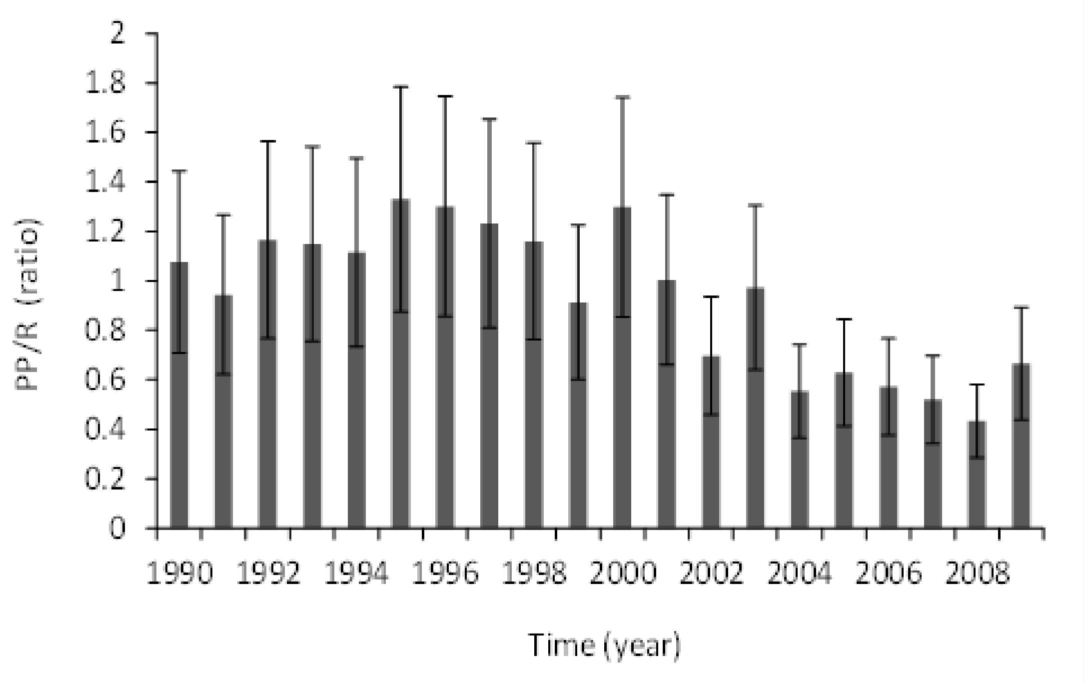
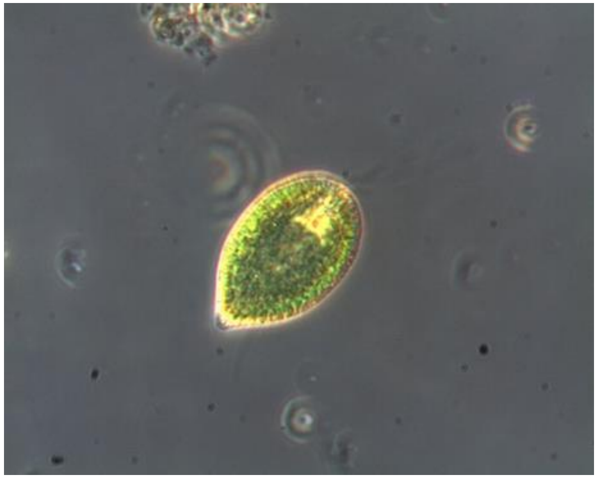
Plankton metabolism and sedimentation

- Significant decreasing trend in primary production of phytoplankton – decreased light conditions due to increased DOC as main reason
- No trend in the respiration of plankton – increasing heterotrophy
- Significant decrease in sedimentation of organic matter



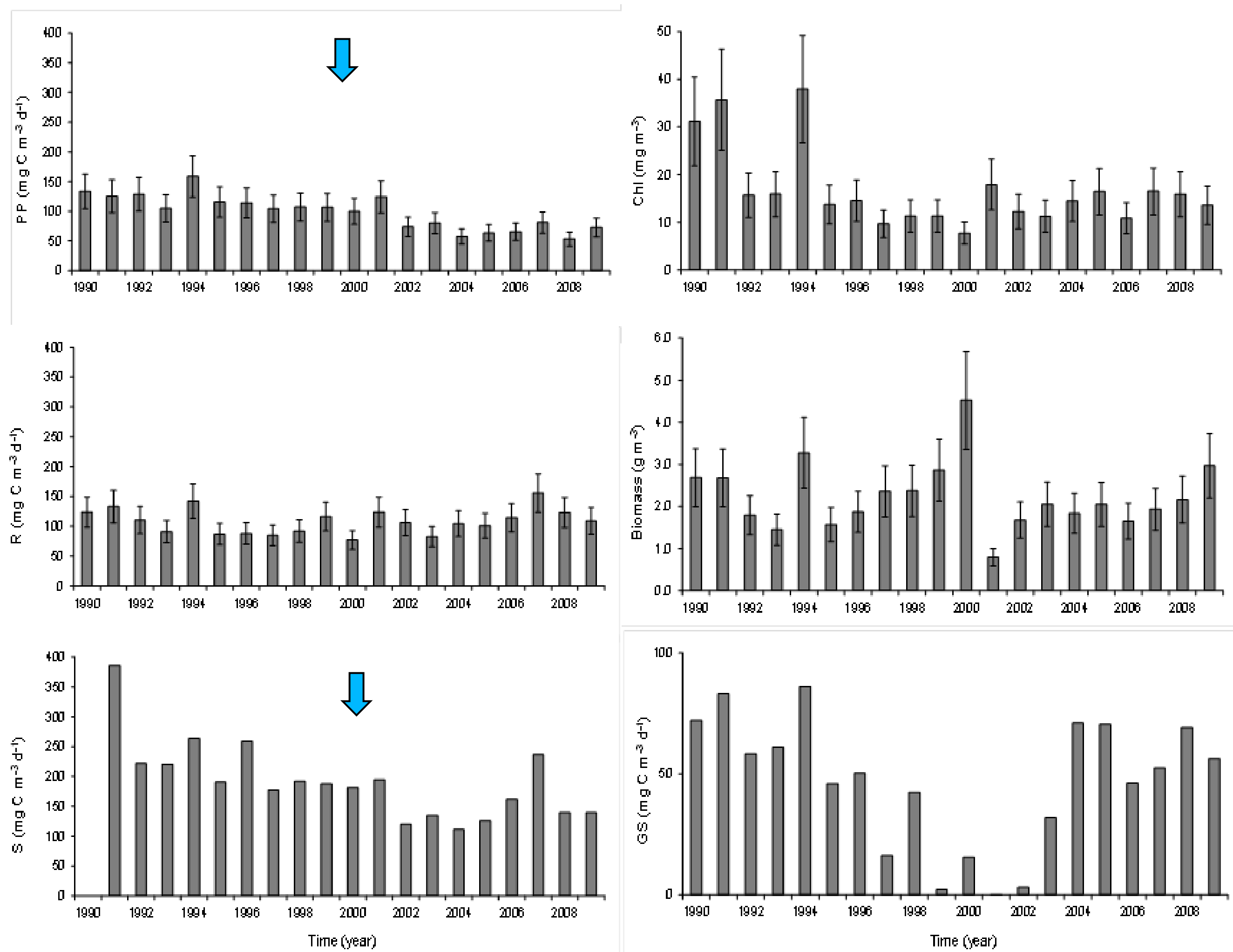
The ratio between mean annual primary production and respiration (PP/R) of plankton



Gonyostomum semen, a rapidophycean alga

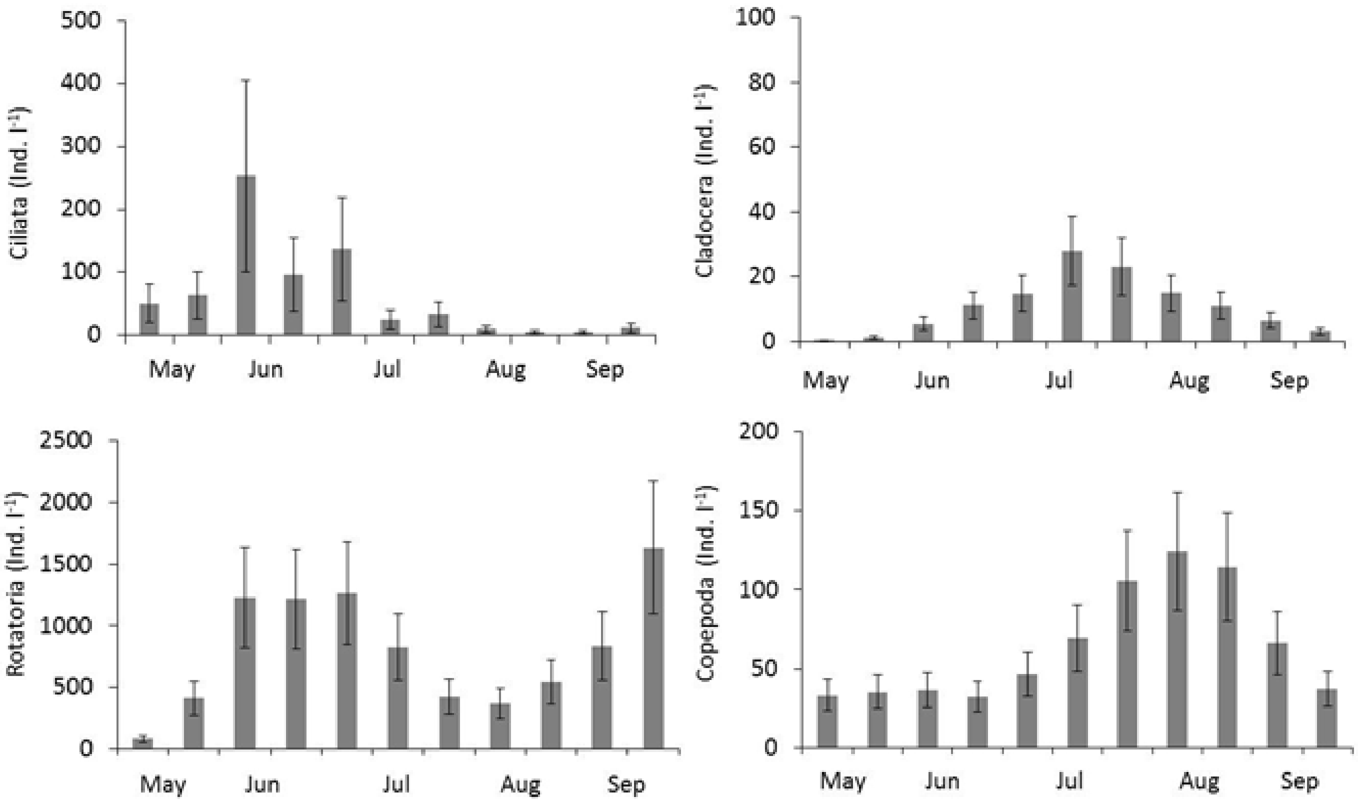
Arvola L., Salonen K., Keskitalo J., Tulonen T., Järvinen M. & Huotari J. 2014. Plankton metabolism and sedimentation in a small, boreal lake – a long term perspective. *Boreal Env. Res*. 19A: 83-96.

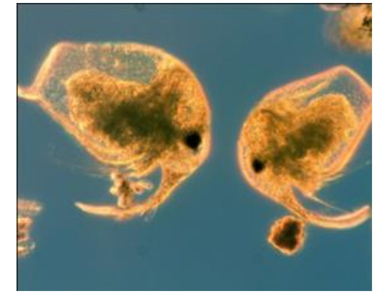
Plankton metabolism and sedimentation - processes



Zooplankton – seasonal patterns

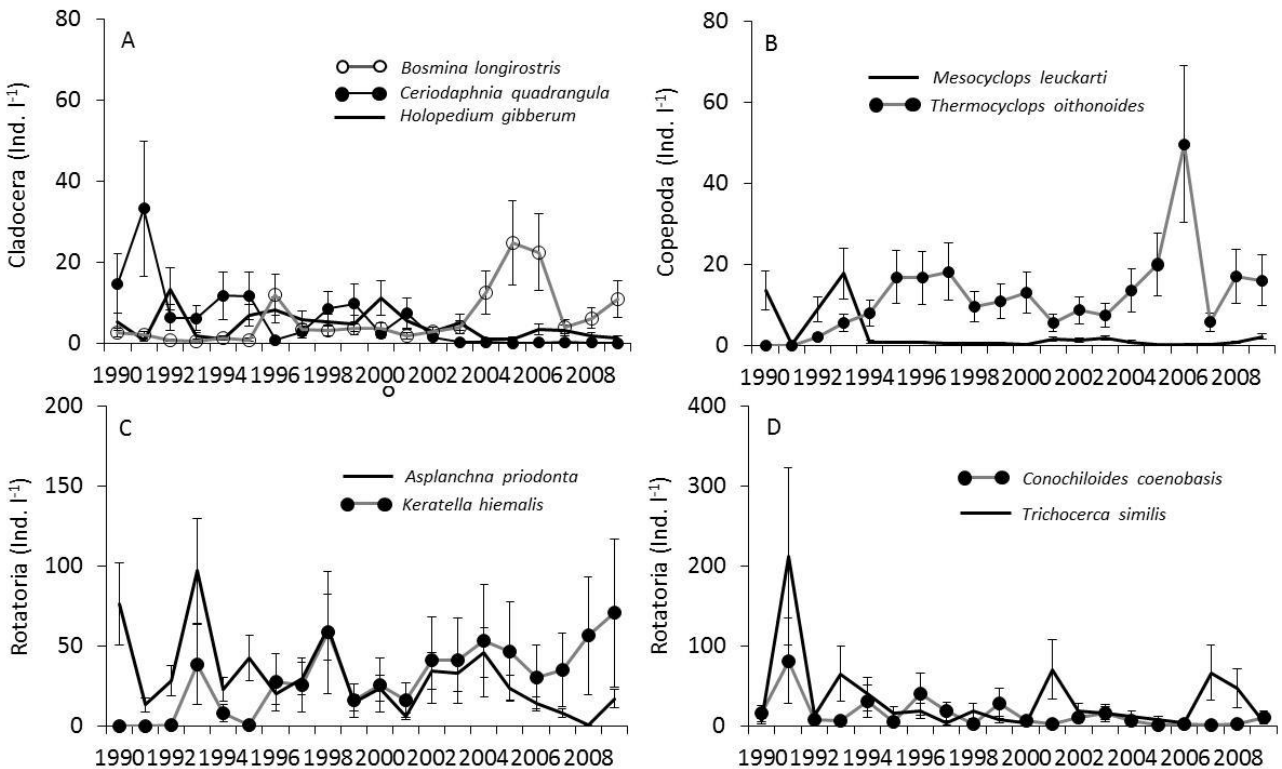
- Regular seasonal dynamics appeared in the occurrence of major zooplankton groups (protozoans → rotifers → cladocerans → copepods). Data (mean ± SD) for 1990-2009, rotifers 1996-2003.





Zooplankton – long-term trends

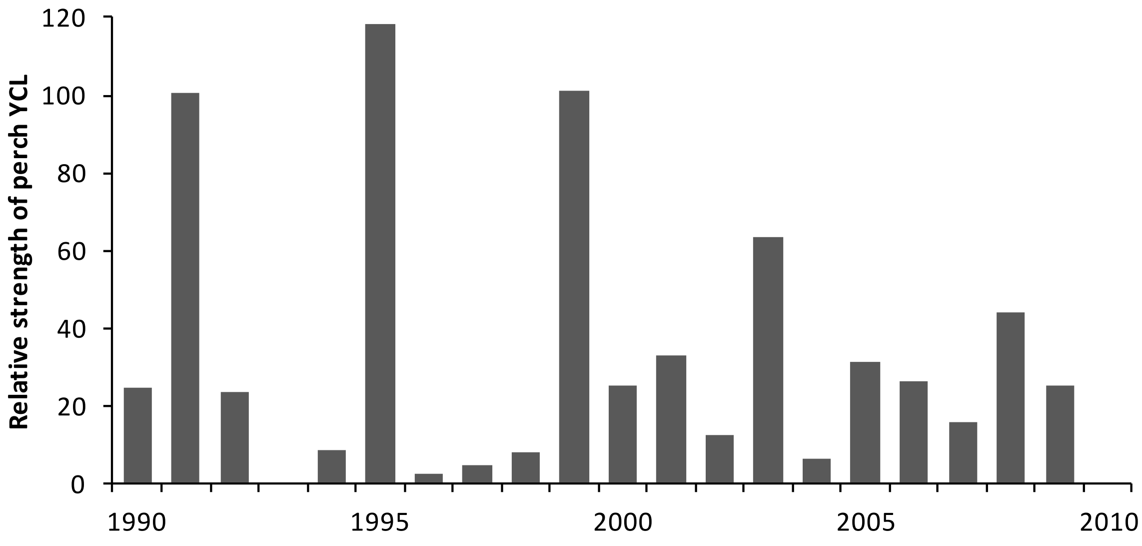
- Significant long-term changes in the abundance of dominating crustacean species but not of rofifers
- RDA analysis: Long-term pattern in zooplankton was mainly associated with abiotic factors like colour, phosphorus and alkalinity



Lehtovaara A., Arvola L., Keskitalo J., Olin M., Rask M., Salonen K., Sarvala J., Tulonen T. & Vuorenmaa J. 2014. Responses of zooplankton to long-term environmental changes in a small boreal lake. *Boreal Env. Res.* 19A: 97-111.

Population dynamics of perch

- Strong year-classes of perch appeared at a four-year interval during the first half of the monitoring period – no more in the second half
- → Acidification did not affect the reproduction and population dynamics of perch



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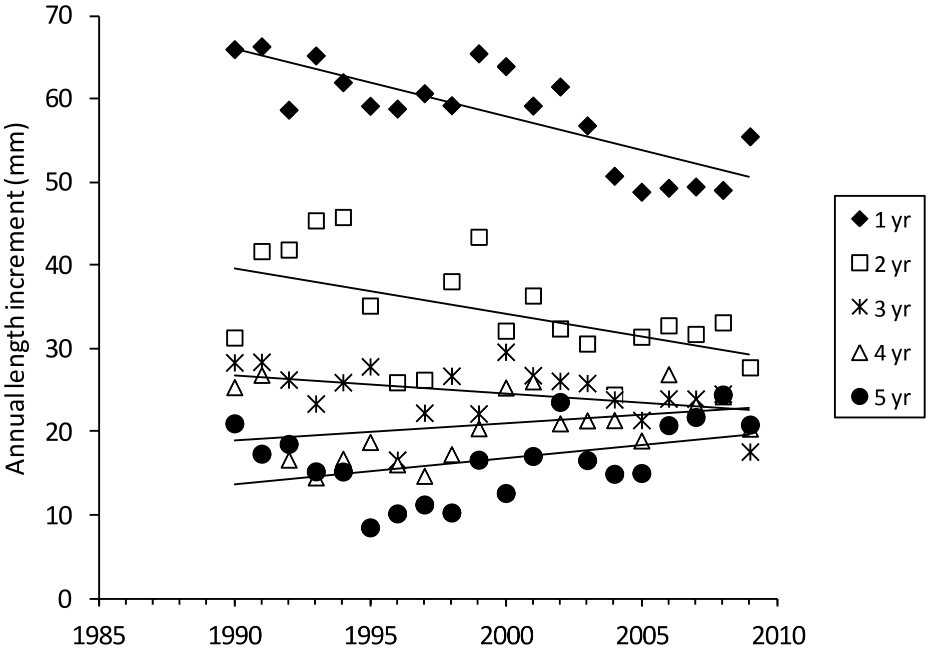
Decreased growth of young perch

- Significant decrease in the growth of young perch – not of old ones
- Increased water colour → decreased biological productivity → decreased food production → intraspecific food competition
- These changes outweighed the expected positive effect of increasing temperature for young perch but not for the older perch.



Rask M., Sairanen S., Vesala S., Arvola L., Estlander S. & Olin M. 2014. Population dynamics and growth of perch in a small, humic lake over a 20-year period — importance of abiotic and biotic factors. *Boreal Env. Res.* 19A: 112-123.

Concluding remarks

- The present results from Valkea-Kotinen IM catchment highlight the value of protected head water catchments for environmental monitoring.
- In such sensitive sites 20 years may be a sufficient time period to show abiotic and biotic responses to air pollution and climatic change.
- The results clearly demonstrate the complexity of boreal nature and the interactions within and between the aquatic and terrestrial ecosystems and atmosphere.
- Further, these studies strongly emphasize the importance of integrated long-term monitoring of physical, chemical and biological variables for detecting the variety of impacts of changing environmental conditions on ecosystems.