Ecology of Eurasian boreal and Arctic lakes. Effect of climate change on seasonal hydrological and ecological cycle.

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Boreal Lakes

- Boreal lakes - are the most numerous of any lake type on Earth.
- There are probably at least 2 million of them, ranging in size from small ponds to Lake Superior, Lakes Ladoga and Onego.
- Softwater boreal lakes may contain 80% or more of the world's unfrozen freshwater.

Outline

- Hydrological and ecological cycle in Eurasian boreal and Arctic lakes.
- Role of ice in seasonal hydrological and ecological cycle.
- Impact of climate change on Ice cover and hydrological and ecological processes in lakes.

Hydrological Cycle

- Inflows:
  - Precipitations
  - Surface water inflow
  - Groundwater inflow
- Outflow
  - Surface water outflow
  - Groundwater outflow
  - Evaporation
  - Evapotranspiration

Hydrologic Cycle

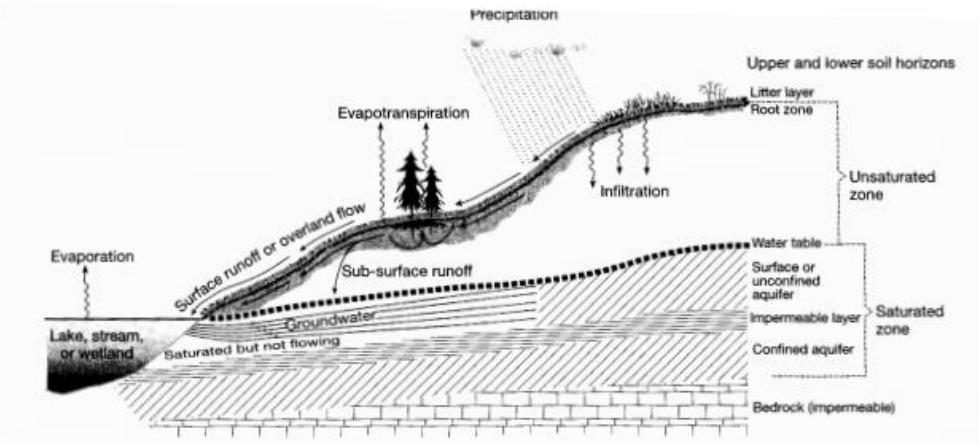


Figure 5–1 Schematic view of water movement in and on catchments, including the flow of groundwater into lakes, streams, or wetlands. Agriculture and other human activities contribute plant nutrients, organic matter, pesticides and other contaminants to runoff and groundwater. *(Greatly modified after Gibbs 1987.)*

Hydrometeorological regime

- Most boreal lakes occur in continental climates → spring and autumn transitions are rapid BUT: variable & unpredictible.
- Max of surface water inflow:

- small rivers in spring (corresponding with snowmelt)
- larger – later

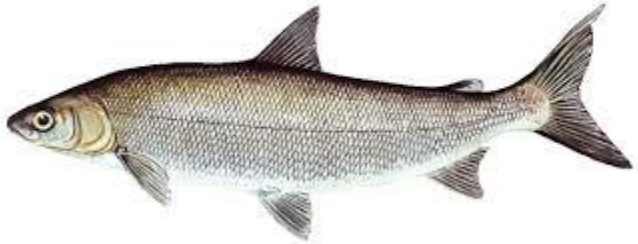
- Min – late fall & winter
- Covered with ice in wintertime;

Boreal Lakes Ecosystems

- Boreal freshwaters contain few species → very vulnerable to perturbations
- Lakes are unproductive (0.01-1 animal/1000 m2 of lake area)
- Most boreal aquatic communities probably contain no more than a few hundreds of readily identifiable species on any single date.
- Poor tolerance of warm temperatures or low oxygen.

“Cold stenotherms”

Lake Whitefish (Coregonus clupeaformis)



- In more southerly boreal lakes, such organisms survive by staying below the thermoclines of lakes during summer months.

Ice cover

Most boreal lakes have ice cover at least some part of the year (excluding geothermal lakes and very deep or salty lakes)

Role of ice cover

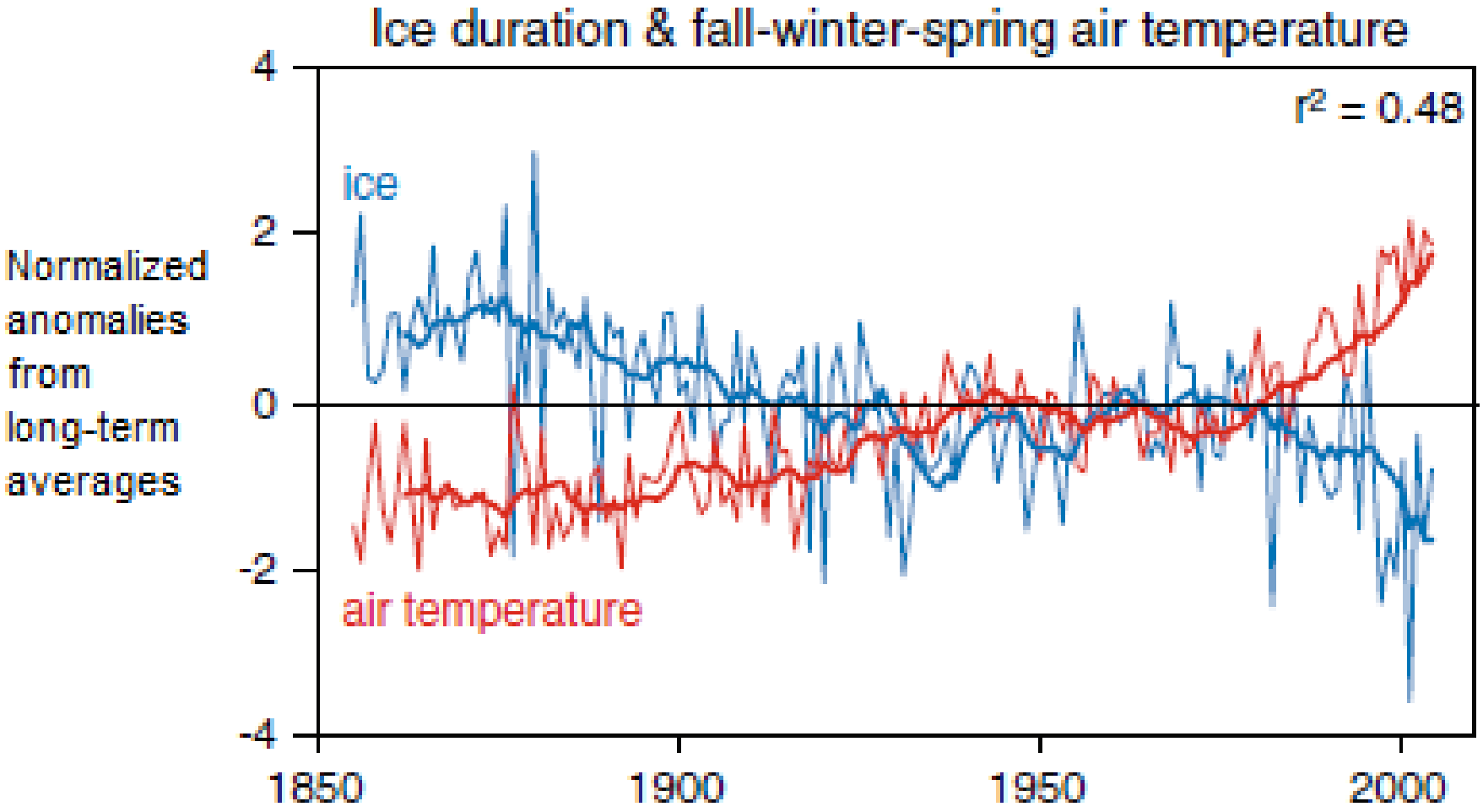
Ice insulates the lake from atmosphere:

- prevents wind from driving currents → less circulation
- no gas exchange between the lake and atmosphere → less oxygen in the water
- less light in the water (with snow cover even less)

Role of ice cover

- Primary production in lakes reduced in wintertime
- Snow on top of ice also insulates heat effectively
- Predicted warmer winters and more snowfall -> changes in the composition of ice?

The most basic way of monitoring ice coverage in lakes is to keep track of autumn freeze up and spring break up dates of ice. Before the time of remote sensing, these time series are the best indicator of changes in lake ice coverage.

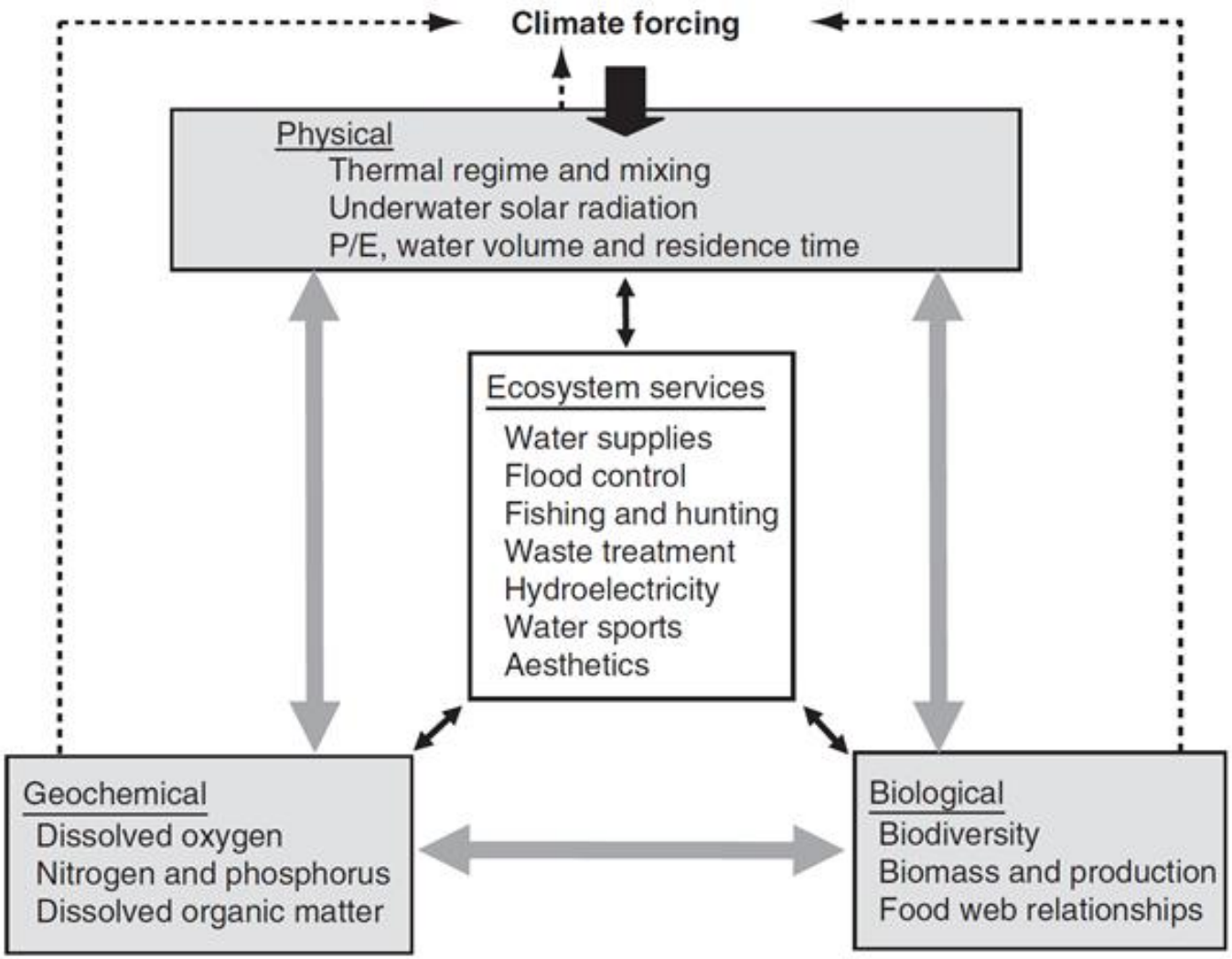


Benson et. al, 2011.

Climate change

- Lakes have always been subject to the impacts of climate change.
- Application of paleolimnological methods in which lake sediment cores are dated and analyzed to infer climate impacts in the past.
- Studies of present-day lakes of different ages are also providing valuable insights into the consequences of climate change.
- Knowledge about climate impacts: modeling and experiments, combined with multi- decade, regional analyses of lakes that are currently experiencing shifts in temperature and precipitation .

Changes in air temperature and precipitation have direct effects on the physical, chemical, and biological characteristics of lakes



Lake properties	Response variables	Processes or mechanisms	Climate-related drivers
Hydrology	Water level	Runoff, dilution, and transport of elements, Evapotranspiration	• precipitation • air temperature • water temperature • cloud cover • relative humidity
Temperature	Duration of Summer Stratification	Shifts in the timing of spring and fall mixing Events	• air temperature • water temperature • cloud cover • relative humidity
	Depth of the thermocline	As thermal stability: A product of the opposing effects of turbulent kineticenergy	• air temperature • water temperature • cloud cover • relative humidity

Lake properties	Response variables	Processes or mechanisms	Climate-related drivers
Ice phenology	Ice-out	Thawing in spring	• precipitation • air temperature • water temperature • cloud cover • relative humidity
	Ice duration	Single or multiple occurrences of ice-on and ice-off	• air temperature • water temperature • cloud cover • relative humidity
Chemistry	Oxygen	Ice, mixing, metabolism	• air temperature • water temperature
	Conductivity or salinity, pH or alkalinity	Dilution, evaporative concentration	• atmospheric deposition • precipitation • air temperature • water temperature • cloud cover • relative humidity

Conclusions

- Northern aquatic ecosystems are a rich resource of enormous ecological value;
- These waters are now undergoing rapid changes in their physical, biogeochemical and biological properties;
- There are a lot of parameters of climate system which effect hydrological and ecological cycle of boreal lakes;
- BUT the connections between different parameters are complicated and need more detailed research.