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Effects of decreased freshwater ice cover duration on biodiversity

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Ice cover is an important component of northern freshwater ecosystems influencing numerous physical, chemical, and biological processes in standing-water (lentic) and running-water (lotic) systems [1]. The duration of Arctic lake and river ice is determined by the dates of autumn freeze-up and spring break-up, the timing of which is strongly controlled by climate [e.g., 2, 3]. The broad extent of lakes and rivers throughout the northern high-latitudes provides good spatial coverage necessary to make the timing of lake and river ice freeze-up and break-up an effective indicator of climate change, and how such change might be affecting these important aquatic ecosystems.

Population/ecosystem status and trends

Records of lake and river ice duration are available for the Arctic from a variety of sources covering different time periods, from remote sensing and direct ice-observing programs to historical archives and sediment cores. Changes in the taxa buried in lake and pond sediments have been used by many researchers to identify warming trends and the historical presence/absence of ice cover on northern lakes [e.g., 4–9]. In general, such evidence points towards warming temperatures and shorter ice durations since the end of the Little Ice Age around 1850, with greater changes observed in northernmost areas when compared to more temperate locations [8]. Ground-based observation and remote sensing are being used to quantify shorter-term trends. These studies are revealing a number of key temporal trends in Arctic lake and river ice cover.

Over the last 150 years lake and river freeze-up dates in the northern hemisphere have become later at an average rate of 5.8 days per century and break-up dates have become earlier at a rate of 6.5 days per century (Figure 15.1) [10]. Overall, this is an average reduction in ice-cover duration of almost two weeks per century. Further reductions have been observed in ice cover duration from a small number of records that began as early as the 16th century, although rates of change increased after approximately 1850 [10].

In many trend analyses, there have been various attempts to link changes in the timing of freeze-up and break-up with climatic variables. Although ice events result from a complex set of variables, particularly in the case of river ice [e.g., 11], the primary focus has been on simple air temperature. Specifically, air temperatures one to three months preceding the events have been most strongly correlated with their timing [e.g., 1, 10, 12, 13]. Strong correlations have been shown between the timing of freeze-up and break-up events, and that of spring and autumn 0° isotherm dates over Canada for various lake and river ice processes in the last century [14].

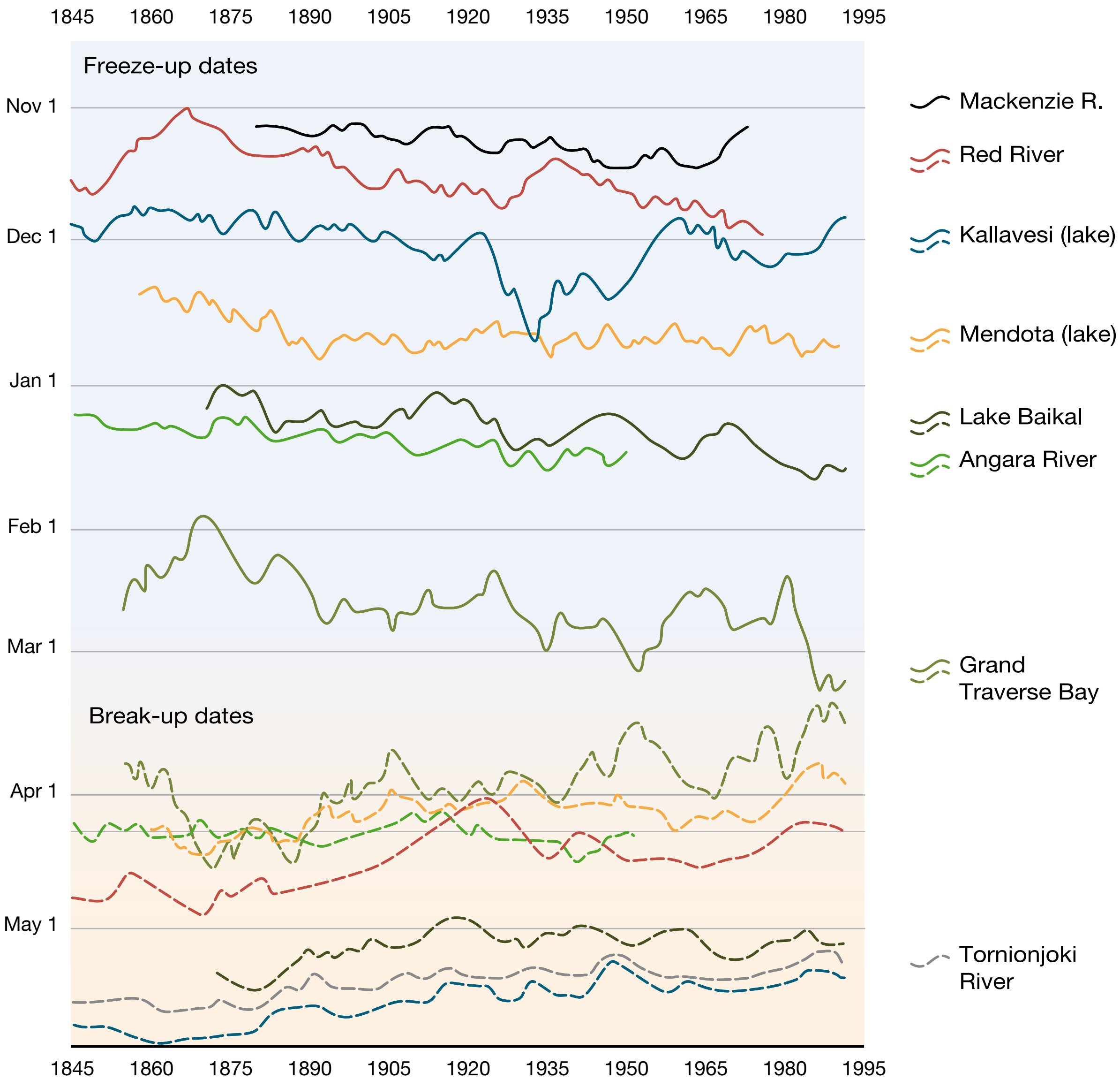

Figure 15.1: Time series of freeze-up and break-up dates from northern hemisphere rivers and lakes, 1846–1995. Data were smoothed with a 10-year moving average [10].

Concerns for the future

Given the strong association of lake and river ice freeze-up and break-up timing, as well as winter duration, significant concern has been raised about future changes that might occur in ice-covered systems [15–17]. It is generally accepted that as climate warms, earlier break-up dates will be seen in northern areas and longer open-water conditions will prevail [18]. Such changes will affect sensitive northern ecosystems, as well as human activities. It will, for instance, directly affect traditional and subsistence lifestyles of northern peoples that have relied on lake and river ice covers, such as in the case of fisheries [19–21].

In addition to simply affecting access to fisheries, ice-induced changes in primary production are expected to affect all trophic levels, the effect on Arctic fish populations being one example. Increased temperature and light availability, from reduced ice duration or changes in ice composition, will favor productivity [e.g., 16, 22, 23]. Other related changes may, however, produce negative effects. For example, the increased abundance of food available for fish in river systems, and the increased habitat availability with less ice (e.g., lack of freezing to the lakebed), may cause otherwise migratory species to remain in rivers year round. Feeding at sea has been linked to larger sizes in fish and larger populations, thus the increased productivity may ultimately lead to decreased fish yields [20].

The increased ultraviolet radiation that will reach aquatic ecosystems as a result of changing snow and ice cover may also cause pigmentation changes in both plankton and fish, and may render some food sources inedible or less nutritious and may possibly affect their immune systems [16]. For Arctic lakes that have been perennially ice and snow covered, orders-of-magnitude increases in ultraviolet exposure are projected to occur – increases greater than those due to moderate stratospheric ozone depletion [23, 24].

Some changes in ice cover may reduce the available habitat for cold-water organisms, forcing some fish to seek refuge in deeper areas [20]. Planktonic species, on the other hand, will benefit from the increased light availability and warm temperatures in the upper layer associated with lake stratification [22]. One of the more obvious effects of warming on fish populations is the fact that certain species are very close to their tolerance limits. Some fish living in sub-Arctic environments may move northwards resulting in competition for native species while for other fish the temperature stresses may prove fatal [20].

Changes in the duration of river ice is also reason for concern, particularly as it relates to the dynamics of hydrologic events, such as spring break-up floods. These events are of special importance to the ecosystem health of riparian ecosystems, especially to the major Arctic river deltas and their associated vast array of lakes [17]. Reduced ice-cover duration will be accompanied by thinner ice covers, ice thickness being one of the major physical controls on the frequency and severity of ice-jam flooding [e.g., 25, 26]. In particular, if accompanied by other climate-induced changes such as sea-level rise or reduced snowmelt runoff, reduced ice cover is likely to seriously impair the aquatic function of these critical Arctic ecosystems [e.g., 27, 28]. Moreover, such changes will also affect the traditional practices of the indigenous peoples that rely on such delta ecosystems for subsistence fisheries or harvesting of aquatic mammals [20, 21, 29].

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