Global climate change and the Lake Baikal plankton

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Anthropogenic climate change has raised air and water temperatures worldwide (Houghton *et al.* 2001), and environmental warming in Siberia has surpassed estimates of warming elsewhere (Serreze *et al.* 2000, Shimaraev 2002). Here we capitalize on a virtually unknown long–term data set, and describe significant physical and biological changes occurring in Lake Baikal during the past 60 years.

Since 1945 data have been collected at least monthly, generally every 7–10 days, in depth profiles from the surface to 250 m at a single main station in the southern basin approximately 2.7 km offshore from Bol'shie Koty (105°045'02" E, 51°542'48" N) where water depth is approximately 800 m. For analyses here we have used temperatures at 0 m, 25 m, and 50 m. For biological data, we averaged data within the top 50m of the lake, the portion of the water column containing most of the lake's photosynthetic production as well as the summer thermocline (Kozhova & Izmest'eva 1998). To examine long–term trends for Lake Baikal temperature and zooplankton, we averaged data by quarters to create Winter, Spring, Summer, and Fall values. For chlorophyll *a,* only averages of July through August were analyzed here to minimize missing values – the chlorophyll *a* data have only 1 missing value in these months – and we have verified that trends are strong and consistent when more or fewer months are included in analyses. The chlorophyll *a* trends were compared to trends in July–August averages of Secchi depth.

The ice–free season in Lake Baikal is known to have lengthened by 16.1 days over the past 137 years (Magnuson *et al.* 2000) primarily related to later ice onset (Todd & Mackay 2003). Annual mean air temperature in the Baikal area increased 1.2 °C over the past century, a rate twice that of the global average (Shimaraev 2002) and consistent with other reports of intense warming in higher latitudes (Serreze *et al.* 2000). Water temperature within the top 25 m in Lake Baikal increased over the past 60 yr, with changes being most evident in the surface waters (0 m) during summer and fall. Surface waters warmed at an average rate of approximately 0.20 °C decade^{-1}, and the mean temperature at 25 m increased by 0.12 °C decade^{-1} over the 60 year period of observation. This trend was even more dramatic in data segregated by season, where surface waters in summer increased in temperature by 0.38 °C decade^{-1}, and waters 25 m deep in the fall increased by 0.22 °C decade^{-1} on average.

While chlorophyll *a* increased rapidly in the summer over the past quarter century (300% on average since 1979), this increase in algal biomass has not yet caused a significant reduction in mean Secchi depth.

Baikal's longer ice–free season (Livingstone 1999, Magnuson *et al.* 2000) and warmer temperatures during summer correspond with increasing prominence not only of the summer blooming algae but also unique members of the zooplankton community. The

slow–growing copepods show a weak long–term decline and the rotifers have decreased more strongly. However, cladocerans (*Bosmina* and *Daphnia*) have increased dramatically. While copepod and rotifer declines were primarily in the colder months, the cladoceran increase has been evident in the warmest months of summer and fall.

This extraordinary long–term data set from Lake Baikal demonstrates that the planktonic community has responded to environmental change over the past 60 years, as have aquatic systems worldwide (Scheffer et al. 2001, Hays et al. 2005). The maintenance of this monitoring program has defied political and financial obstacles throughout its 60 yr history and now clearly illustrates the value of dedicated monitoring, as the international scientific community debates the allocation of limited funds. For Lake Baikal, such impressive baseline monitoring will be of inestimable value as human activities, such as development of the watershed, proceed against the uncertain backdrop of climate change. Modern climate shifts in Russia – both figurative and literal – underscore the importance of increasing the international awareness of and access to these data from Lake Baikal, as Russia contemplates its scientific and environmental future and as Siberia warms.

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