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The Mongolian LTER: Hovsgol National Park

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ABSTRACT: The Government of Mongolia approved establishment of the Mongolian LTER network in December 1997. In June 1998, a seminar was organized by the Mongolian Academy of Sciences to initiate the program. Dr. James Gosz of the US LTER program keynoted the seminar. A Mongolian LTER Steering Committee was established to organize the network and to develop guidelines for its management. This Committee designated Hovsgol National Park in northern Mongolia as the first Mongolian LTER network site. Other potential sites are presently being considered, including study sites in steppe grassland and desert locations. The primary goals of the Mongolian LTER Network are to study human impacts on Mongolia's environment; with a focus on short-term impacts of nomadic grazing on terrestrial and aquatic ecosystems and long-term climate change impacts on more pristine environments in the protected areas. There are at least two additional goals: to provide information and advice on how best to protect Mongolia's pristine environments, and to train Mongolian students to work on environmental problems to encourage the growth of expertise for making sound environmental decisions.

Key Words: Fire, Grazing, Lake Hovsgol, Mongolia, Permafast.

HOVSGOL NATIONAL PARK LTER

Lake Hovsgol and its watershed were designated a national park in 1992. The Park now includes the complete watershed of the Lake (Fig. 1), and the Hor'dal Sor'dag Mountains to the west: almost 900,000 ha of taiga forest, grassland, tundra, and Lake Hovsgol. This area is unique because it has had minimal impacts to the region other than nomadic grazing by livestock herds in stream valleys. Forest cutting, at times severe, has allowed grassland areas to increase. There has never been commercial fishing on the Lake. Thus, "bottom up" and "top down" ecosystem structuring remains as it has been historically. There has been a recent increase in poaching of wildlife, though there still are brown bear (*Ursus arctos*), Argali (*Ovis ammon*), Ibex (*Capra siberica*), reindeer (*Rangifer tarandus*), musk deer (*Moschus moschiferus*), and some indications that snow leopards (*Uncia uncia*) may survive in the mountains west of the Lake. The biological communities of the forests, grasslands, streams, wetlands and Lake remain similar to those that have co-evolved up to and following the time nomadic herdsman first came to Hovsgol from the Steppe grasslands. Lake Hovsgol contains almost 70% of the surface freshwater of Mongolia, a clean dependable water source in an otherwise arid and semi-arid land.

There are two towns on the Lake, Hatgal at the southern end near the lake's outlet to Egiin Gol, and Khanck, at the northern end and close to the Russian border. Historically, these two towns were shipping ports to support the import/export trade with Russia. After the breakup of the Soviet Union and the decline of trade, the number of people living in the towns decreased.

Lake Hovsgol is a sister lake to Baikal; both developed in tectonic depressions created during the formation of the Baikal Rift System during the late Tertiary Period. Hovsgol is estimated to be between 2 and 3 million years old but has not been dated using isotopic techniques. Very few lakes are this old (perhaps ten) and none are this pristine; until now, the Lake and its watershed have absorbed major geological and human impacts. The lake is large, 136 km long and between 20 and 40 km wide and has a surface area of 2760 km^2 (Table 1). The maximum depth is 262 m, and the mean depth is 136 m. The area of the basin is 4920 km^2. There are 96 small tributary streams entering the Lake. Hovsgol's

Table 1. Geographic areas and morphometric characteristics of Hovsgol National Park and Lake Hovsgol (Mongolia)

Morphometric Characteristics	Hovsgol
Area of Hovsgol National Park	9000 km^2
Area of taiga forest	2507 km^2
Area of the lake	2760 km^2
Volume of lake water	380.7 km^3
Maximum depth of lake	262.4 m
Length of lake	136 km
Maximum width of lake	36.5 km
Lakes surface altitude	1645 meters a.s.l.
Highest point in the watershed	3491 meters a.s.l. (Mynk Sardag, northeast end of lake)

outlet river, Egiin Gol, initially flows south and then eastward to join the Selenga River, the largest source of water entering Lake Baikal. The cold continental climate of latitudes 50° to 52° N, and high elevation (the lake's surface is at 1645 m above sea level), combined with very low productivity, makes it a harsh environment and difficult for more cosmopolitan species to invade the lake.

GEOLOGY OF THE BASIN

Limestones (primarily dolomites) with phosphorite deposits compose the major part of the lithology along the south and southwestern regions of the lake's watershed (Tuvan-Mongolian superterrane or microcontinent) (Tumurtogoo 1999). To the north of this there are smaller tectonic blocks with Precambrian poly-metamorphic rocks intruded by Paleozoic granitoids and covered by Pleistocene alluvium in stream channels.

The northern and southeastern shores of the Lake consist of ophiolites, Early Paleozoic volcanogen-turbidite deposits and Paleozoic granitoids. Finally, the lithology of the northeastern shore is composed of Early Precambrian and Early Paleozoic zonal metamorphic groups with intrusions of various aged Paleozoic granitoids and most of the eastern side of the lake consists of olivine basalt from the late Miocene and Pliocene volcanism.

The extensive dolomite sedimentary rock layers of the watershed have a strong influence on the chemistry of the lake water and sediments, producing carbonate-rich alkaline lake water with extensive marl sediment deposits, produced when $CaCO_3$ is precipitated. Basalt from the volcanic lava deposited along the eastern shore of the Lake is sub-alkaline. Water entering the lake from tributary streams along the eastern shore first passes through vegetation-rich wetlands or shallow ponds. In some tributaries the water may be colored brown by humic acids, producing a slightly more acidic water that reduces the pH.

ECOLOGY AND BIODIVERSITY

Scientists from the National University and the Mongolian Academy of Sciences working in cooperation with the Russian Academy of Sciences organized scientific expeditions to Lake Hovsgol between 1970 and 1990. The studies focused on climate, hydrology, ecology and economic resources of the basin (Kozhova *et al.* 1989). In 1995, American scientists joined the Lake studies, and Japanese scientists joined in 1996. More emphasis was placed on understanding biodiversity of tributary streams, physical dynamics of the Lake, and increased student training in biodiversity and ecological research.

Some conclusions and observations resulting from these studies to date include:

1. The Siberian larch (*Larix siberica*) dominates the forest and the lake is surrounded by continuous permafrost.
2. There are numerous rare plant and animal species living in the forested watershed.
3. Hovsgol and its tributary streams have many endemic taxa, some formerly thought restricted to Baikal. The level of endemism ranges from 10 to 20% of the taxa in several phyla, but most taxonomic groups are not well studied.
4. Endemic taxa compose most of the animal biomass of the Lake. The endemic copepod (*Diaptomus kozhovi*) makes up 55% of the zooplankton biomass. 70% of the biomass of benthic communities consists of endemic taxa of Amphipoda, Mollusca, Oligochaeta and Trichoptera (Kozhova *et al.* 1989 and recent studies).
5. Based upon phytoplankton biomass and primary production measurements, Hovsgol is an ultra-oligotrophic lake.
6. Because of the very low productivity, larch leaf detritus may be a primary source of food for benthic invertebrates. Detritus can be carried deep into the lake by thermal density currents that mix the water in the spring from the shoreline areas.
7. The tributary streams are important spawning sites for the lake's fishes.

LONG-TERM DATA SETS

The long-term data sets that are presently available or that we are trying to obtain for the region and the Lake include the following (C:

Continuous, D: Discontinuous, H: Hatgal, K: Khanck, L: Lake, W: Watershed):

1. Meteorological			
a. Temperature	H/K	C	1963-Present
b. Precipitation (rain/snow)	H/K	C	1963-Present
c. Wind direction and speed	H/K	C	1963-Present
d. Solar energy	H/K	C	1963-Present
e. Barometric Pressure	H/K	C	1963-Present
f. Lake ice cover	H/K	C	1963-Present
2. Hydrological			
a. Lake level	H/K	C	1967-Present
3. Permafrost			
a. Temperature	H	D	1980-90s
b. Active zone depth	H	D	1980-90s
4. Land cover	W	D	1940s/90s
5. Biological (Lake)			
a. Species distribution	L	D	1970-90s
b. Phytoplankton biomass	L	D	1970-90s
c. Zooplankton biomass	L	D	1970-90s
d. Benthic biomass	L	D	1970-90s
e. Primary production	L	D	1970-90s

LONG-TERM MONITORING PROGRAMS

Meteorological and hydrological data are continuously collected at Hatgal and Khanck by the Meteorological Institute of the Ministry of Nature and the Environment. The National Park has a chemistry laboratory and has monitored water chemistry of the Lake. In 1999, with the help of a grant from USAID, new equipment was purchased for analysis of water samples, and an improved water quality monitoring program was developed, which included study of the major tributary streams entering the Lake.

Scientists of the Mongolian Academy of Sciences and the National University are presently developing a proposal to study forest changes and the impact of grazing on the watershed streams and the Lake.

SHORT-TERM IMPACTS

Grazing

The Hovsgol watershed primarily consists of taiga forest, but there are steppe grasslands bordering high alpine tundra in the west, and on south-facing slopes of mountains, and in stream valleys. These areas have been grazed for centuries. Stream valleys are generally a combination of steppe vegetation and wetlands. Recently, the number of livestock in the valleys has increased because the loss of trade with Russia has limited the ability of the herdsman to sell their animals. This appears to be having an impact on tributary streams of the Lake. When grazing livestock move into grasslands they dramatically alter stream conditions. The erosion of stream banks is beginning to occur as grazing sheep, yaks, cows and goats move into or across streams. Some stream channels are covered with sediments, smothering biotic habitats, and this can destroy spawning sites of fishes. Corrective action needs to be taken as soon as possible to reduce the impacts of grazing.

After clearcutting or forest fires, local plant species are replaced by species of steppe plant communities, and this encourages herdsman to move animals into the Park. Unmanaged and irregular grazing of domestic animals will have a negative impact on the regeneration of larch stands; goat and sheep eat larch seedlings, shoots and bark (Dugarjav 1980). As grazing increases, grazing animals have a negative impact on plant cover, soils and permafrost. In limited areas, cattle are affecting stream channels by breaking down stream banks, causing erosion of soils into streams that covers the rocks that are critical habitats for aquatic insects, the primary foods of fishes.

Forest fires

Natural fires now cause 10% of major fires in Mongolia and Siberia (Goldammer and Furyev 1996); 90% of fires are due to human carelessness, or are deliberately set to expand grazing lands or to drive wild animals out of the forest for poaching. The consequence of increased fire recurrence on larch is unknown. Frequent forest fires change the course of plant succession in different ways, depending on topography, soil texture and moisture (Sheshukov 1996). Small trees less than 10 cm diameter and trees with high resin content are killed by even moderate fires. Large trees with thick bark have positive growth increments following fires of either moderate or high intensity (due to nutrient release from burned vegetation; Yevdokimenko 1996). This phenomenon selects for the mature stands of trees observed in northern Mongolia.

LONG-TERM IMPACTS

Average annual air temperatures at Hatgal have increased by 1.44℃ since 1963, as estimated by time-series analysis (0.043℃ per year; SE = 0.011; $P < 0.001$; Durbin-Watson = 2.03); virtually identical with estimates made by NOAA from a general review of warming for southern Siberia. Present measurements and predictions of climate warming and atmospheric circulation models indicate that boreal regions will be most affected by global warming, northern Mongolia lies within the greatest impact zone. Precipitation has increased slightly (by 50 mm), but this may not be significant.

HNP represents the southern boundary of the Siberian taiga forest, much of which lies in the zone of continuous permafrost. Forest loss in northern Mongolia is widespread. The taiga forest as a whole is under similar threat. This is a serious global issue, the Siberian forest represents 20% of the forestry resources of the World. It is a major carbon "sink" for the whole Northern Hemisphere (Dixon *et al.* 1996). Understanding and managing this phenomenon is crucial because the forest grows on permafrost soils (Hilbig 1995) that are being degraded by climate warming. Permafrost soils are high in humus content: loss of permafrost and warming of soils increases the rate of decomposition of humus, increasing the rate of release of carbon dioxide and methane, further increasing greenhouse gas levels in the atmosphere. It is very likely that local permafrost conditions exist because the forest cover insulates soils. Maintaining forest cover is critically important to protect permafrost.

THE TAIGA FOREST

The southern taiga has a cold boreal, semi-arid climate with low precipitation levels (250 to 500 mm/yr). Taiga forests of Mongolia and western Siberia are dominated (60 to 70%) by larch (*Larix siberica*) with Siberian pine, Scotch pine and birch less common (Matveev and Usoltzev 1996, Dixon *et al.* 1996, Ahlback 1999). Larch grows well on rocky permafrost soils (Hilbig 1995, Yevdokimenko 1996), apparently because of a greater efficiency in obtaining and conserving moisture relative to other gymnosperms (Gower *et al.* in press). The tree's roots spread horizontally between the soil surface and the permafrost layer. Root response to permafrost melt is unknown. In Mongolia, larch are primarily found in high mountain zones in the taiga forest or the high mountain tundra, extending between 1400 ~ 2250 m a.s.l. South of HNP, trees grow on north-facing slopes and comprise a forest/steppe transition zone. Much of the forest consists of mature trees with an average age of 130 years, and heights of 15 to 20 meters and more than 20 cm diameter.

Experimental forestry work conducted in central Khangai in the 1980's, showed that clearcutting of trees altered the daily air temperature, increasing the temperature in logged areas by 3.7℃, and the temperature of the soil surface increased 12~14℃ over soil temperature of undisturbed forest areas, and surpassed 40℃ in July (Dugarjav 1980).

Forests in HNP now covers 250,706 ha, about 30% of the total Park area, the remainder includes the lake, grassland meadows and high-mountain tundra. Large areas of forests and nearby grasslands are affected by forest fires, illegal cutting and intense grazing. In 1999, an outbreak of the Siberian Silk Worm (*Loxostege sticticalis*) occurred at the southern end of the Park, but did not extend beyond the Hatgal area. This insect normally has large population explosions two to three years after a major fire. Its impact on trees has not been assessed.

Detailed forestry resource maps are available for Hovsgol from 1947 that we are now digitizing to compare with new land cover maps being prepared from recent satellite images to incorporate in a GIS format (Goulden *et al.* in review). Combined with ground observations, these maps will enable us to determine locations of former forests, how much has been lost and the cause (cutting or forest fires). We will also define corresponding increases in grassland meadows, and can later evaluate how these areas are being used today.

In HNP, characteristic soils include mountain tundra soils, mountain permafrost soils, mountain forest dark colored soils, chernozems, boggy soils, meadow soil, soddy soils, dark chestnut and chestnut soils, and saline soils. These soils have a surface layer of non-decomposed plant material and a thick layer of humus with 8 to 12% organic content. Below these layers the B transition horizon consists of gravel, large stones and below this, permafrost. The thickness of the active zone is between 50 to 60 cm in the mountain forest soils.

PERMAFROST MELTING IN BOREAL REGIONS

In nearby Kazakstan, the depth of the melted active zone has increased by 30% due to climate warming. Forest fires cause melting of permafrost, increasing the depth of the active zone 0.3 to 0.4 m in the Trans-Baikal area near Mongolia (Rylkov 1996). Melt of permafrost decreases soil moisture, leaving vegetation on dryer soils more susceptible to fires. With expected levels of climate warming, permafrost soils with temperatures of −1 to −2℃ will melt. There is a time lag between air and soil temperature changes because of insulation by vegetation. Deforestation removes the vegetated insulating layer that protects permafrost (Wein and de Groot 1996).

As permafrost melts, warmer temperatures will cause soil organic matter content to decompose more rapidly, releasing CO_2 to the atmosphere. It is essential to know the full impacts of deforestation and warming due to climate change on permafrost conditions of the region. To develop predictions on how the depth of the active zone will change and affect land cover vegetation, present permafrost thermal regimes, depth, and plant cover must be measured. Insulation by vegetation will slow the melting of permafrost as climate warms. Insulation depends upon vegetation type, which is affected by the frequency of forest fires, forest defoliation (insects), cutting and grazing. We do not know which factor contributes most to permafrost melt, but it is clear that all are influencing factors, and their relative importance needs to be defined in order to prioritize efforts to slow permafrost melt.

Results of bore-hole studies in Hatgal indicate that permafrost is composed mostly of gravel containing a great deal of sand and ice, with a temperature of −1.5 to −1.6℃, a thickness of 60 ~90 meters and a depth of seasonally thawing ground of 3.5~4.5 meters. On Mt. Artag, west of the lake, permafrost is 90 m thick and has a temperature of −1.8℃. Permafrost phenomena such as frost mounds (pingos), thermokarst, frost cracking and solifluction are observed in the Darkhad depression, west of Hovsgol. Pingos have a height ranging from 2~3 m and diameters of 200~300 m, and form as a result of long term freezing. Permafrost melting is evident by thermokarst forming on top of pingos and solifluction on hill slopes, all appearing during the last 50~60 years.

At Hatgal, preliminary studies indicate that the active zone depth has increased by 0.2~0.3 m, and permafrost temperature has increased by 0.1 to 0.2℃ in the last 20 years (Tumurbaatar 1999). However, more frequent measures are needed to determine this accurately. Several concrete and brick buildings in Hatgal, including the main school building, collapsed during the late 1980s and early 90s due to permafrost melt.

CONCLUSIONS

Despite the recent establishment of the Hovsgol LTER site, long-term data sets do exist that provide an important baseline for future studies. We are attempting to pull these data sets together and hope to have them available through publications and on a web site. The Mongolian LTER program is interested in encouraging foreign scientists to visit and consider developing programs within the context of the MLTER. MLTER scientists are also interested in cooperative research programs that will expand opportunities for foreign and Mongolian scientists to work together in comparative studies. Contacts can be made with the authors of this paper.

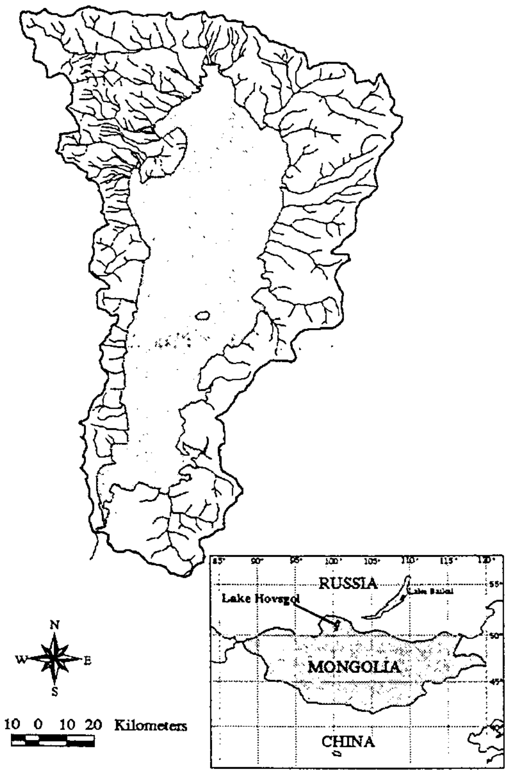

Fig. 1. Location and watershed map of Lake Hovsgol, Mongolia.

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