ZOOPLANKTON (Animal Plankton)

Responses of Crustacean Plankton to the Changing Lake Winnipeg Environment

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INTRODUCTION

Pelagic crustacean plankton (offshore zooplankton) communities, because of their central position in aquatic food webs, are among the most reliable indicators of ecosystem response to natural changes and anthropogenic forces affecting lakes and their watersheds.

The zooplankton community of Lake Winnipeg, first observed in 1929 (Bajkov 1930), is providing a valuable long-term perspective on changing environmental conditions in this ecosystem.

Results show evidence of increased abundance of zooplankton within the last 35 years. While this increase is a general indication of nutrient enrichment, the change in zooplankton species structure is the strongest indication of modified environmental conditions in Lake Winnipeg, because individual species are the units that respond to specific habitat changes.

The changes that have occurred over space and time in Lake Winnipeg zooplankton are a reflection of environmental trends and events influencing this ecosystem during the past century, particularly the last quarter.

OBJECTIVES

- To estimate the abundance, composition, and distribution of zooplankton in Lake Winnipeg and to assess the changes in these parameters since 1969.
- To evaluate factors influencing the spatial-temporal dynamics of zooplankton and improve understanding of the biological productivity of Lake Winnipeg.
- To develop the capacity to predict Lake Winnipeg food web and fishery productivity to optimize resource use and management.

METHODS

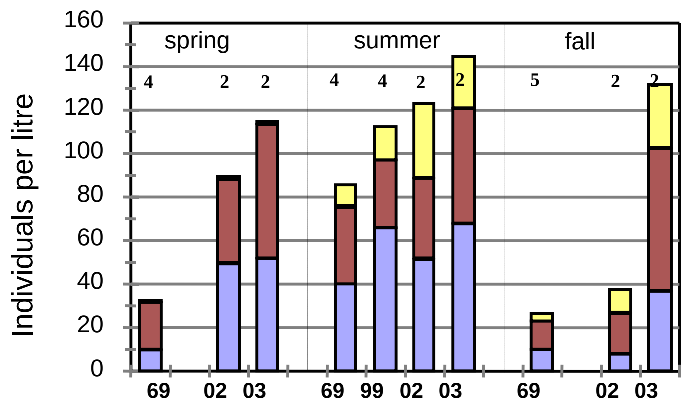
Abundance and distribution of planktonic crustaceans in Lake Winnipeg

- Approximately 150 representative samples from the 6 surveys in 2002 and 2003 were examined microscopically following standard protocols.
- Settled plankton volumes were determined for each of the 360 samples collected in both years (following procedures in Bajkov, 1930).
- Data were tabulated, plotted and evaluated against comparable 1969 data reported by Salki and Patalas (1992) and Patalas and Salki (1992), Salki (1996), Salki (1999) and Stewart et al. (2001).

RESULTS

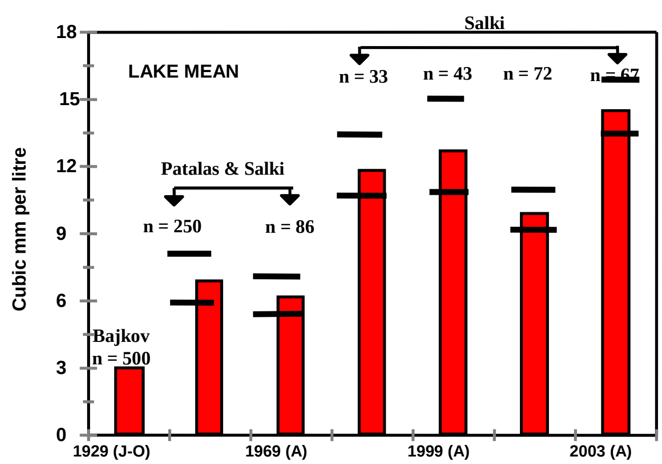
Zooplankton Abundance

The figure below shows that the spring, summer and fall zooplankton abundance in Lake Winnipeg has increased consistently since 1969.



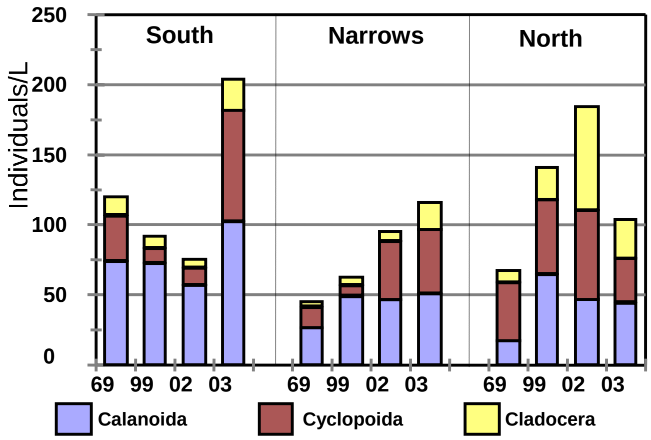
Seasonal Mean Zooplankton Abundance (1969 to 2003)

This pattern was also reflected in the trend of August net plankton volumes (combined zoo- and phytoplankton) retained in 72 micron mesh nets since 1929.



Mid-Summer Settled Net Plankton Volume (1929 to 2003)

The numbers of zooplankton were generally comparable among the South basin, the Narrows and the North basin, but each area displayed individual trends over time.

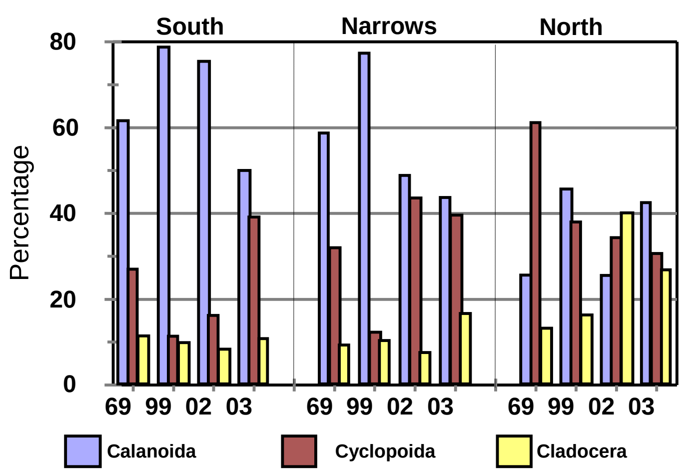


Regional, Mid-Summer Abundance of Zooplankton (1969 to 2003)

Community Composition

The compositional structure of the zooplankton community in Lake Winnipeg, particularly the North basin, has undergone change within the last 35 years. This change is most obvious at the species level.

This figure shows that at the group level, cladocerans are increasing in the North basin while cyclopoids are declining.



Regional Zooplankton Summer Community Composition (1969 to 2003)

While the increase in overall abundance of zooplankton is a general indication of nutrient enrichment, the change in zooplankton species structure is the strongest indication of modified environmental conditions in Lake Winnipeg, because individual species are the units that respond to specific habitat changes. Presented is evidence for change at the species level within each of the three groups, calanoida, cyclopoida and cladocera.

Lake Winnipeg Calanoids

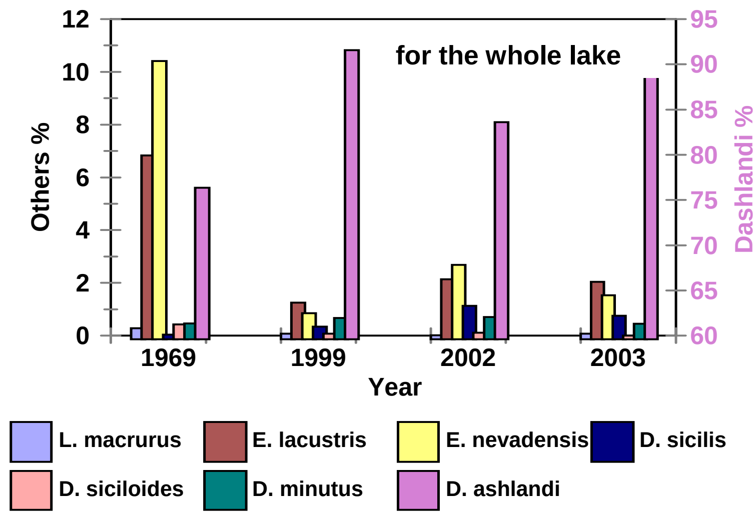
On a lake-wide basis, *Diaptomus ashlandi* now accounts for 85% - 90% of the calanoids, up from 75% in 1969. This was counterbalanced by a decline in each of two *Epischura* species (top figure).

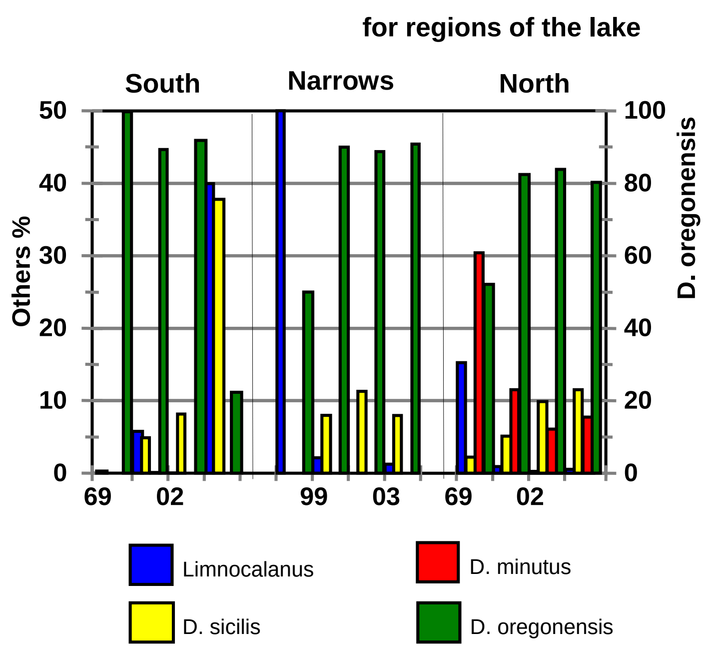
Four other calanoid species exhibited clear trends in the North basin between 1969 and 2003 (bottom figure).

- *Diaptomus minutus* (restricted to the North basin) and *Limnocalanus macrurus* , typically inhabit upper and deeper water layers respectively; both have declined.
- *Diaptomus oregonensis* and *Diaptomus sicilis,* more common to mid-water layers, have increased.

Similar trends were observed in the Narrows region but a different pattern of change was found in the South basin, with the two largest species, *L. macrurus* and *D. sicilis* increasing in abundance.

Relative Abundance of Calanoid Species (1969 to 2003)





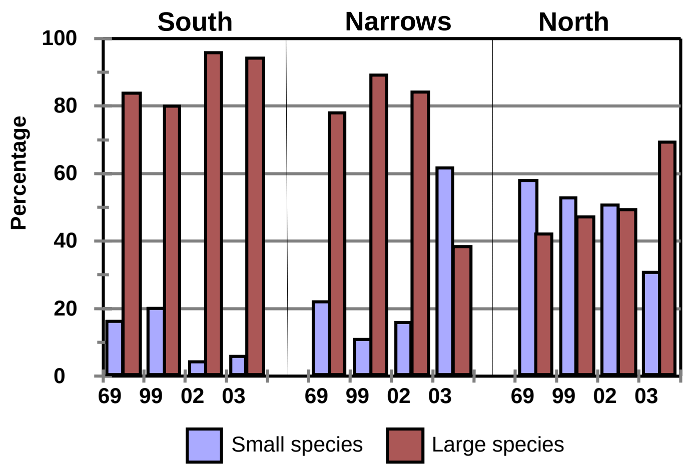
DISCUSSION - Calanoids

The increasing dominance of the herbivore *Diaptomus ashlandi* parallels the growing predominance of blue-greens (cyanophytes) in the phytoplankton community but the functional linkage is still unclear. The declining proportions of *D. minutus* and *Limnocalanus*, however, do appear to have a functional relationship with the proliferation of blue-greens. *D. minutus*, inhabiting the upper waters of the North basin where blue-greens predominate, are not able to sustain growth and reproduction because cyanophytes are essentially inedible.

When cyanophyte blooms collapse, the accumulated algal biomass sinks to bottom water layers where it is decomposed by bacteria. The increasing occurrence of reduced oxygen levels may be limiting development of the deeper dwelling *Limnocalanus* in the North basin. In contrast, the apparent increase of *L. macrurus* and *D. sicilis* in the South basin are likely related to the increase predicted in minimum lake levels (>12”, Manitoba Hydro, 1972) as well as the declining transparency which reduces planktivory.

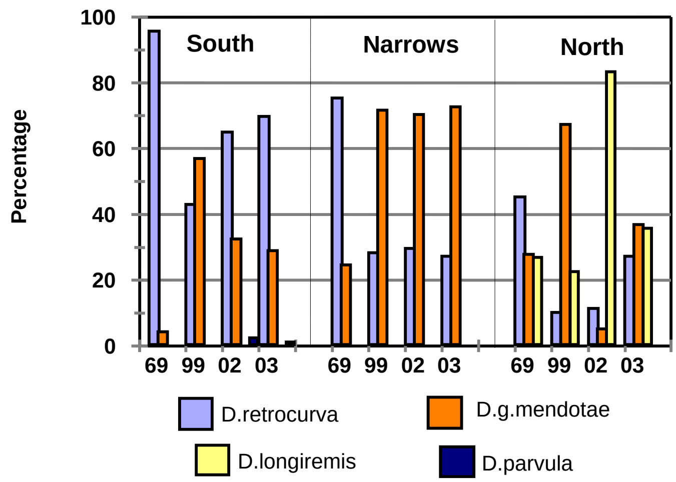
Lake Winnipeg Cladocerans

Among cladocerans, larger-sized species have consistently dominated in the South basin during summer, but appear to be progressively increasing in the North basin.



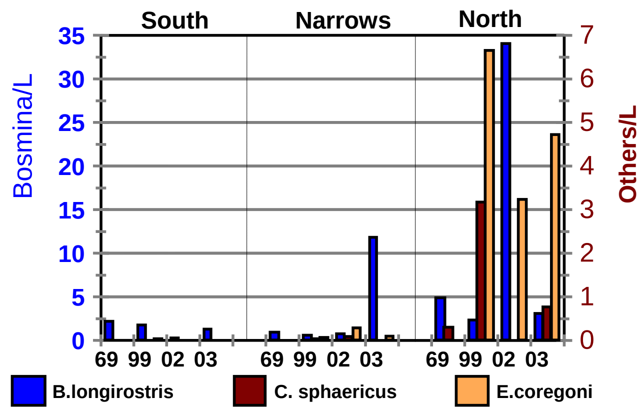
Cladoceran Species Composition Based on Size (1969 to 2003)

Among the daphnids, *Daphnia galeata mendotae*, the largest in Lake Winnipeg, has increased its share in the south and narrows regions since 1969. This is in contrast to the somewhat smaller *Daphnia retrocurva* which has declined in those areas. *D. longiremis* and *D. parvula* continue to be restricted to the north and South basins, respectively.



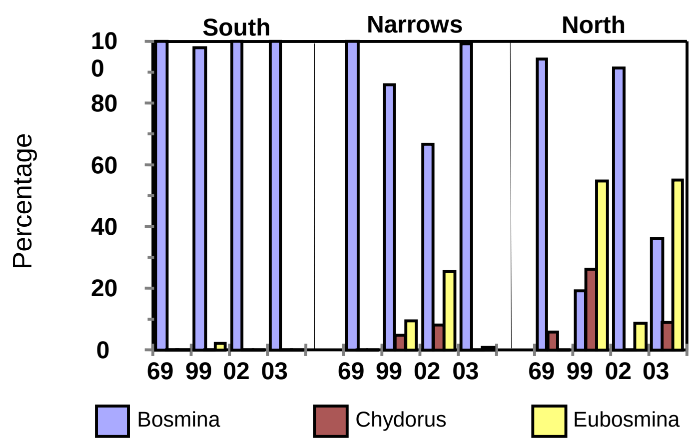
Relative Abundance of Daphnid Species (1969 to 2003)

Three smaller species, *Bosmina longirostris*, *Chydorus sphaericus* and *Eubosmina coregoni*, have increased in the North basin even though their share of the cladocera has diminished.



Relative Abundance of Small Cladocera (1969 to 2003)

Bosmina continues to dominate the smaller cladocerans in the South basin, but in the north its fraction has declined. *Chydorus* and the recent exotic invader *Eubosmina* are increasing.



Small Cladocera Community (1969 to 2003)

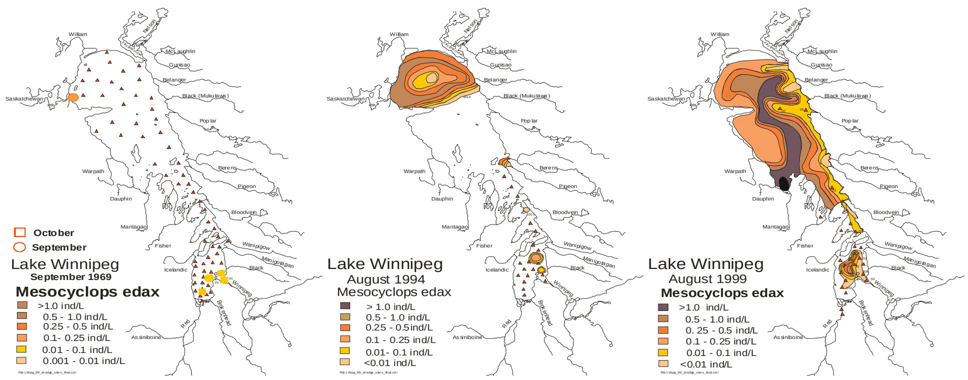
DISCUSSION - Cladocerans

The increasing abundance of cladocerans in the North basin again may be related to increased algal productivity due to nutrient enrichment, but warmer water temperatures generally preferred by cladocera may also be promoting their expansion.

The smaller herbivorous *Chydorus*, *Eubosmina* and *Bosmina*, together with the larger daphnid species are capable of grazing the full size-spectrum of edible algal forms which can promote a competitive advantage to blue-greens. Elser (1999), however, suggests that cyanobacterial dynamics are influenced by food web interactions not only by regulating the rate of grazing mortality but as well by altering the consumer-driven nutrient recycling. Thus, cyanobacteria blooms can be seen as probabilistic events that are the end result of a series of key mechanisms involving nutrient loading, physical mixing conditions, and trophic interactions.

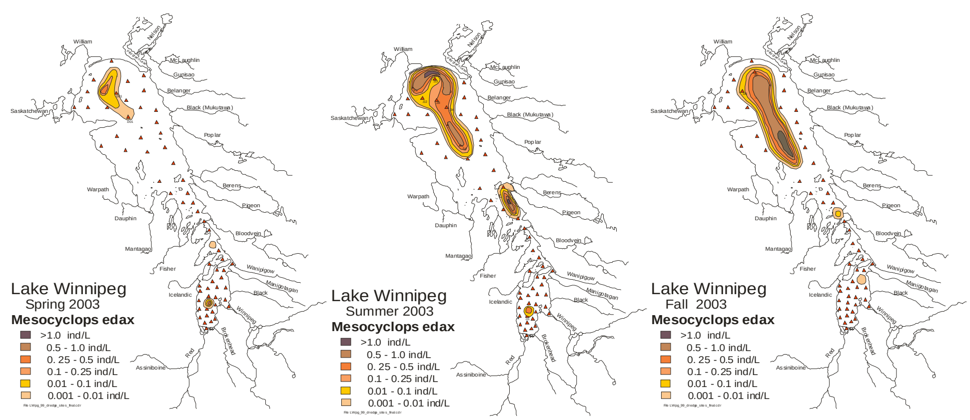
Lake Winnipeg Cyclopoids

The cyclopoid *Mesocyclops edax* demonstrated one of the most significant increases in abundance and dispersal of any species in Lake Winnipeg. In 1969, the species was found only at the mouths of the Winnipeg, Saskatchewan and Red rivers but at least by 1994 (Salki 1996) and thereafter, *M. edax* occurred commonly throughout the lake.



Distribution and Abundance of *Mesocyclops edax* (1969 to 2003)

In 2003, there was a seasonal pattern in the distribution of *Mesocyclops.* This is likely an underestimate of the actual distribution because complete lake-wide data are not yet available.



Seasonal Distribution of *Mesocyclops edax* (2003)

Discussion - Cyclopoids

The factors contributing to the lakewide expansion of *Mesocyclops*, as well as the encroachment of *Tropocyclops prasinus mexicanus* (not shown), in Lake Winnipeg since 1969 have not been determined. Patalas and Salki (1992) hypothesized that several marginal species ("unsuccessful invaders") restricted to inflow areas in 1969 might constitute a potential replacement pool if one or more of the 12 core Lake Winnipeg species were eliminated by changing environmental conditions. Although the composition of core species has remained intact, the relative contribution of each has been modified. Whether this change or other factors (such as less variable water levels or greater heat content and larger lake volume due to warmer August/September temperatures and summer storage) is sufficient to allow establishment of *Mesocyclops* and *Tropocyclops* is uncertain. Prior to 1985, these cyclopoid species were found only in smaller

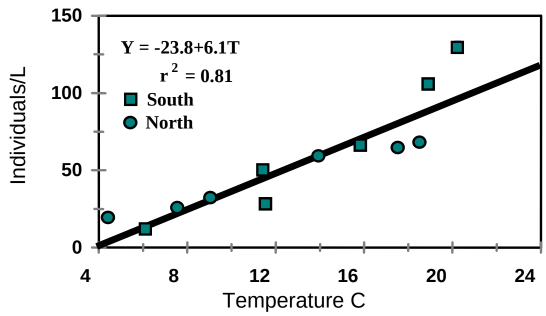
Canadian lakes south of 57° N or the southern Laurentian Great Lakes (Patalas et al. 1994) suggesting a preference for warmer waters. Perhaps their establishment in large Lake Winnipeg signifies climate warming in this region.

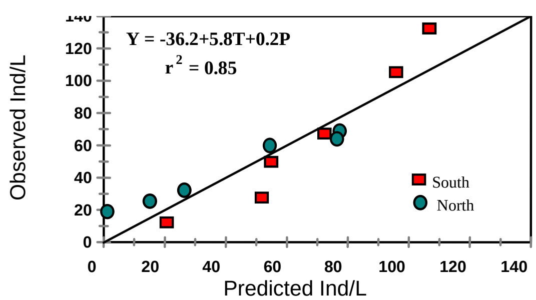
Factors Influencing the Zooplankton Community

The changes that have occurred over space and time in Lake Winnipeg zooplankton are a reflection of environmental trends and events influencing this ecosystem during the past century, particularly the last quarter. Some factors influencing zooplankton abundance and community structure are discussed.

In 1969, variance in Lake Winnipeg zooplankton abundance was largely explained by water temperature alone (see figure below - top) or in combination with in-lake total phosphorus concentration (figure below - bottom).

1969
Relationship Between Zooplankton and Temperature (top)
Zooplankton, Temperature and Phosphorus (bottom)

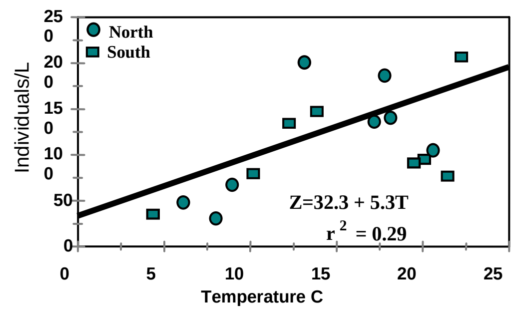


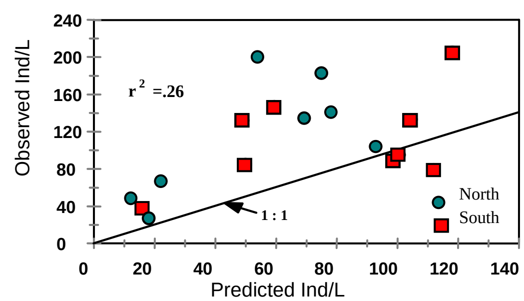


Patalas and Salki (1992) reported an even stronger relationship between zooplankton abundance, temperature and TP when Lake Winnipeg and Laurentian Great Lakes data were combined (r^2 = 0.98) – data not shown.

Presently, zooplankton abundance in Lake Winnipeg cannot be predicted accurately on the basis of either temperature alone (r^2 = 0.29) or together with total phosphorus (r^2 = 0.26).

1994 to 2003
Relationship Between Zooplankton and Temperature (top)
Zooplankton, Temperature and Phosphorus (bottom)





Phosphorus loading: The observed increases in zooplankton abundance and settled plankton volumes, each amounting to more than 300% over the past thirty years, suggest that the actual increase in total phosphorus load to Lake Winnipeg is substantial. Based on the flows and phosphorus concentrations in the Red, Winnipeg and Saskatchewan rivers (over the period 1970 to 2000), the total phosphorus load to Lake Winnipeg has increased by approximately 40%*. This is considerably greater that the 10% estimate reported in the Lake Winnipeg Stewardship Board Interim Report 2005.

*[During this period, total phosphorus concentrations in the Red and Winnipeg rivers each rose by 30% (flow adjusted) while TP concentrations in the Saskatchewan River were unchanged (Jones and Armstrong 2001). Actual flows in the Red, Winnipeg and Saskatchewan rivers were greater by 37%, 4% and 5%, respectively, during the 1990s than on average during the preceding two decades (Hesslein 2005). Based on Hesslein (2005), loads from the Red, Winnipeg and Saskatchewan loads have increased by 60%, 5% and 5%, respectively, over the period 1970 to 2000 and combined, they have increased the TP load to the lake by approximately 40%.]

Temperature: Evaluation of Lake Winnipeg temperature data from the past three decades indicates a slight warming (0.7C°and 0.3 C°) of south and North basin waters, respectively, in mid summer (Salki et al 2005).

Light: Changes in the light regime of Lake Winnipeg during the past three decades appear to be influencing zooplankton community structure. The decrease in water transparency measured in the South basin may be limiting predation by visually-cuing planktivorous fish on larger cladocerans such as *Daphnia* which have increased during this period. Similarly, the reduction in North basin water clarity during the 1990s related to the increasing frequency and predominance of blue green algae blooms may also be responsible for the reduced planktivory on large cladocerans.

Other factors: In combination with temperature and total phosphorus, other factors may also be influencing zooplankton development.

Two events that occurred between 1969 and 1994 – 2003 surveys include

- Hydro regulation - the conversion of Lake Winnipeg into a storage reservoir by the construction of the Jenpeg dam in 1976
- Exotic species - rainbow smelt and *Eubosmina coregoni*, which arrived in 1990 from eastern Canada may be exerting some influence on ecosystem function.

  It is noteworthy that, based on satellite images of Lake Winnipeg (McCullough pers. comm.), the onset of enhanced blue-green algal bloom proliferation in the North basin appears to overlap with the estimated arrival of exotic species in the lake. Grazing by zooplankton and planktivory by smelt may also be influencing blue-green development and may require specific study.

In addition,

- The higher Red River flows during the last decade (Hesslein 2005) are also transporting, in addition to sediment and phosphorus, carbonaceous detritus, a potential food source for cyclopoid zooplankton, into Lake Winnipeg.

PRELIMINARY CONCLUSIONS

Zooplankton abundance during 2002 and 2003 increased beyond any previously observed levels in Lake Winnipeg.

In 1969, zooplankton abundance could be accurately predicted by lake temperature and phosphorus concentrations, but these parameters explain only a small fraction of zooplankton variability currently observed in Lake Winnipeg. Lake management and exotic species may be additional factors presently influencing zooplankton development.

FUTURE RESEARCH - FOOD WEB STRUCTURE AND PRODUCTIVITY

Our ability to predict food web structure and productivity is currently limited by lack of an appropriate Lake Winnipeg ecosystem model. As Lake Winnipeg is unique among world reservoirs (large, shallow, watershed/surface = 40, relatively short water residence time, complex shoreline and geology), a more complete understanding of ecosystem structure and function will only be gained from in-lake studies. Progress on Lake Winnipeg model development will depend on efforts undertaken to address the several research gaps identified during the recent joint federal-provincial meeting at the Freshwater Institute held in late November 2004.