Ecosystem Model of Great Slave Lake to support an ecosystem approach to fisheries management

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Background

An ecosystem is a community of living organisms (plants, animals and microbes) at a particular place or area. Fishing and environmental changes can influence functioning of ecosystems. It is important to determine the relative importance of these impacts. It can be done by the development of ecosystem models which can be used to explore ecosystem response to these changes. Ecosystem models are important to understand the relationship between different type on plants, insects, small animals and fishes living to gather in the ecosystem. Such type of research can be very helpful to predict health, stability, reliability and development stages of the ecosystem and allow for better management. An ecosystem can be healthy when it is in a stable condition, therefore, generally unspoiled ecosystems are considered as healthy and stable ecosystems. We used a computer programme Ecopath with Ecosim (EwE) to make a model of Great Slave Lake ecosystem and study its structure and functioning.

Study area

The main basin of Great Slave Lake (GSL) is comparatively more productive. This productivity may be due to high nutrient and organic matter coming through from the Slave River. The lake is relatively unpolluted and there has not been any introduction of non-native species. Zooplnkton are dominated by Copepoda. Mysid is also an important crustacean (small animals). There are at least 25 fish species in the lake, However, only few species occur in the main lake basin. Five fish species are of commercial importance. The major commercial species are lake whitefish, lake trout, inconnu, Northern pike and walleye. Lake cisco, burbot and longnose sucker are other important species. The eastern arm of GSL supports a trophy fishery for lake trout. The highest sustained catches in GSL are from lake whitefish followed by inconnu. GSL is a shared resource between multiple aboriginal land claim settlement areas and other harvesters. Fisheries in GSL are of many types including commercial fisheries, subsistence or aboriginal fisheries, sports fisheries, domestic fisheries and exploratory fisheries. Fisheries management in Great Slave Lake is focused on a sustainable and balanced commercial, subsistence, and sport fisheries. However, considering the size of commercial fisheries, the other types of fisheries are almost negligible. The fisheries in GSL are co-managed by the community and government departments through the Great Slave Lake Advisory Committee (GSLAC).

Impact of climate change on GSL

Ice free period is increasing in GSL. The longer ice-free period may result in warmer waters and these warmer conditions could force cold-adapted specialists such as lake trout into more restricted habitats. With climate change cold-water habitat for lake trout and lake whitefish will be shifted deeper particularly during the warmer summer months. Therefore, climate related changes might stress lake trout population in the relatively shallow west basin of GSL. However, climate change could also result in a 50% increase in optimal growing season for lake trout in the deep east arm of GSL. Lake whitefish will likely be positively impacted in terms of increased growth, at least in the short term.

Because of warming temperatures, southerly species from the Peace and Athabasca river systems may also colonize or increase in abundance in the GSL via Slave River, which may result in a structural shift of the ecosystem. Under climate change scenarios, seasonal evaporation will increase in GSL. A general decline in precipitation and an increase in air temperature, evaporation, and annual solar radiation will result in decreased flows and longer water renewal times for the basin lakes. A shorter ice-cover period on lakes may increase the nutrient availability in summer. Shorter duration of snow and ice cover may also result in more light availability for photosynthesis and higher primary production.

Ecosystem Modeling

A computer based program Ecopath with Ecosim (EwE) was used to build a model of the GSL ecosystem. EwE is a free modeling framework software program representing the complete biological ecosystem and used extensively for modeling of aquatic ecosystems. We used data mostly from 1980's and 1990's to make this model therefore this model gives a picture of roughly what the GSL ecosystem looked like during the last decades of 20^{th} century. Different functional groups used for GSL ecosystem modeling and their weight square kilometer are of GSL are given in the Table 1. A functional group in Ecopath model can be a species, life stage of a species eg. adult, juvenile or group of ecologically related species. Nineteen functional groups are initially used to represent the GSL ecosystem model. These included one phytoplankton or plant group, two zooplankton groups (very small animals), two benthic invertebrate groups, and thirteen fish groups. Detritus, as a nonliving group, was also included. For the purpose of this report. we only used the fish species, as functional groups, that remain in the lake basin during most of their life cycle and which have an important role in the fisheries and trophic ecology of the lake ecosystem. The important fish functional groups included lake trout, lake whitefish, lake cisco, longnose sucker, Northern pike, Arctic grayling, round whitefish, burbot, walleye, inconnu, lake chub and sculpins. Other important forage fish species, including ninespine stickleback , spottail Shiner and other minnows, were combined together as other fish. Invertebrates were divided into four functional groups, including mysids, amphipods, other benthos (gastropods, insect larvae, chironomids, midges, bivalves, and oligochaetes) and zooplankton. Important groups at 1^{st} trophic level were primary producers and detritus.

Important Results

Overall, average fish biomass density obtained from the GSL ecosystem model is 1.86 $t.km^{-2}$. In terms of biomass, lake whitefish, followed by cisco and sucker, dominate the Great Slave Lake ecosystem. Lake trout is most important group and keystone predator in many Arctic lakes. However, in GSL, the keystoneness index or importance of lake trout was very low compared to other predators. Burbot is the keystone species in GSL. Burbot are known to have an important role in regulating lake ecosystems in other great lakes including Lake Ontario and Lake Michigan. The present study showed that the GSL fisheries require 3 % of the total primary production (energy produced by plants), which is a small proportion of the productive capacity of the ecosystem. It indicates that the fishery during the modeling period was in a sustainable range. In the GSL ecosystem, more energy was required for the harvest of walleye and lake trout while the minimum energy was required for lake whitefish. Much lower energy required for GSL whitefish shows why its fishery is ecologically less expensive and hence much stable and sustainable.

We used ecosystem model to study fisheries impact under different scenario. For example, we reduced the fishing rate in 1990,s to half, which is almost equal to the present rate of fishing in Great Slave Lake. As a result lake trout showed 50% and inconnu showed 28% initial increase in relative biomass. Lake whitefish also showed a 10% increase while Lake cisco showed a 15% reduction, with decreased fishing. During a recent traditional fisheries and environment knowledge survey conducted by the authors (Unpublished), communities along the GSL observed an increase in the lake trout and inconnu populations, while some decrease in the cisco population was predicted by the model. These results shows that this initial model is close to reality and may serve as a background for further development of better more realistic models to inform decision makers. We also did some climate change simulations by increasing and decreasing primary production in the GSL ecosystem model. As a result there was a change in the relative biomass or total weight of functional groups under the increased and decreased primary productivity; however, the scale of the increases was not the same for all groups. Our results showed that change in lake productivity has more impact of lake whitefish and lesser impact on walleye and lake trout.

This preliminary model of GSL ecosystems is an important contribution to use the available data and provide a base on which new data from recent and future studies can be introduced to improve the model results. These initial models serve as a background for further development of a better ecosystem model. There are some knowledge gaps and data limitations and many doubts with this preliminary model. However, the results of this initial model look quite realistic and can be used by management to study basic interactions in the food web, and sustainability. With the availability of new data from ongoing monitoring, this model will be further improved in coming years

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Table 1. Average weight of different fishes and other animals in each square kilometer of Great Slave Lake ecosystem.

Group Name	Biomass (kg/km^2)
Lake trout	38
Pike	89
Inconnu	10
Walleye	7
Burbot	132
Ciscoes	258
Sculpins	223
Lake whitefish	661
Arctic grayling	6
Round whitefish	8
Suckers	250
Chub	2
Other fish	182
Mysids	619
Zooplankton	1465
Amphipods	2380
Other benthos	1670
Primary Production	8200

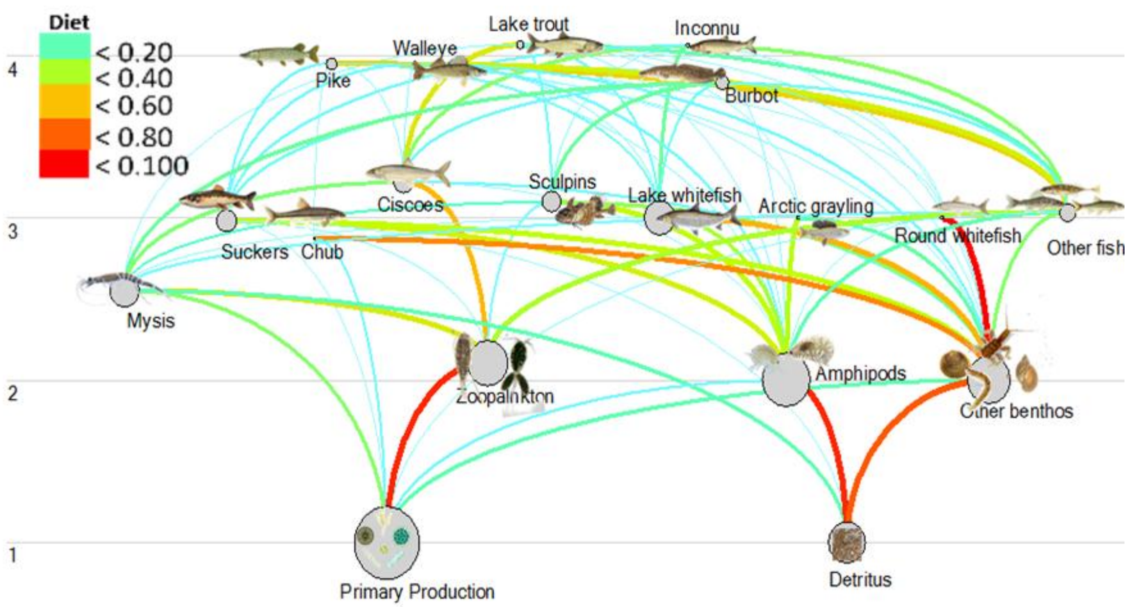

Figure 1: A model of Great Slave Lake food web showing different groups in the ecosystem, therir relative biomass and how much they get their diet from other groups. Forexample a red line connecting two groups shows that the group on top gets its 80-100% diet from the group below attached with that line .

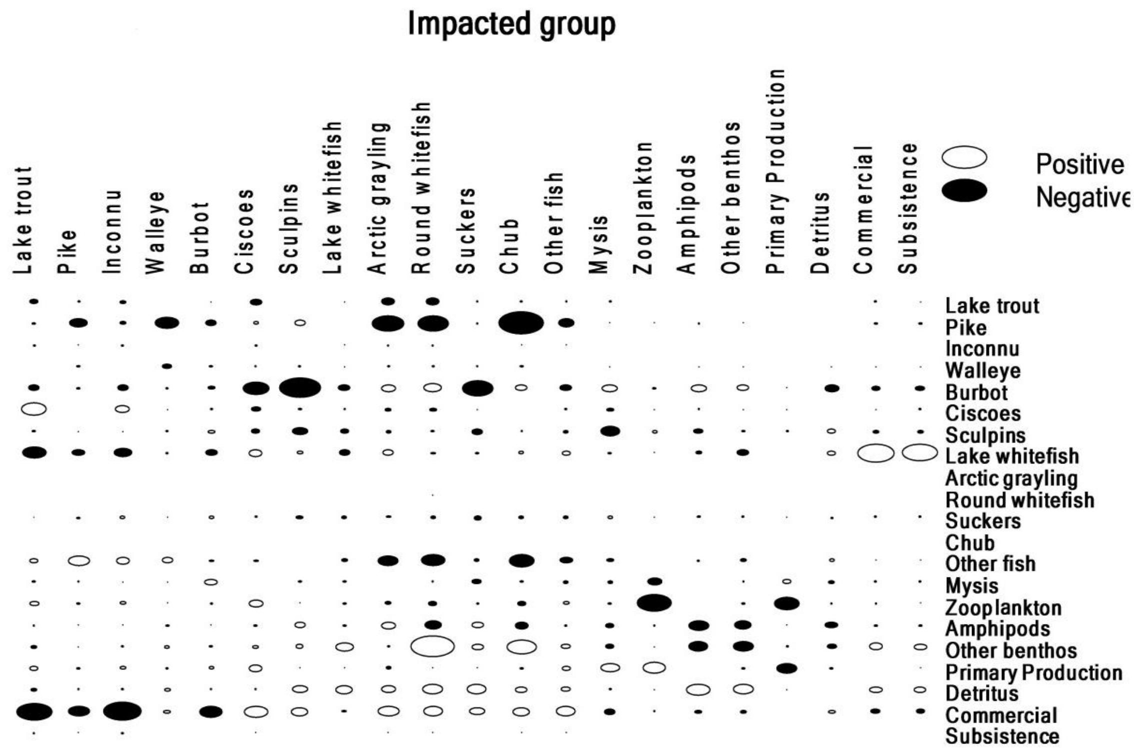

Figure 2: Impact of fishes and other groups (on right side) on the other groups in Great Slave lake. The size of circle shows comparatively, how much a group impact other group. White circles shows positive impact while black circles shows negative impacts.