

TOWARDS A MANAGEMENT PROGRAM FOR SUNFISH LAKE:

THE ALGAL COMPOSITION AND DISTRIBUTION

by

DOUG TURNBULL HAMILTON

Queen's University

Kingston, Ontario, Canada.

April, 1980

## PREFACE

Due to the similarity of much of the subject matter of my thesis and the thesis of Graeme Black (1980), most of the introduction and methods and materials of both theses are the same and were written by both of us as a joint effort.

## ABSTRACT

Before developing a management program for Sunfish Lake, a small, meromictic, highly productive lake in southern Ontario, the essential elements required for the program's development must be studied. The composition and seasonal and spatial distribution of the phytoplankton in Sunfish Lake was studied between July 19, 1979 and November 25, 1979. The importance of the algae in Sunfish Lake as a base in the food chain may be outweighed by their importance in oxygen production and thus in maintaining the high oxygen concentrations found in the lake. The spatial distribution of the algae indicates stratified blooms of algal species (*Oscillatoria agardhii*, R.S.) are present in the summer and early fall. As well, one algal genera (*Gomphosphaeria*) clearly exhibits seasonal succession amongst three species. Some evidence supporting the possible role of *Oocystis* as the major contributor to the super-saturation of oxygen in the upper hypolimnion of the lake is presented, however further studies are necessary for verification.

The trends of the major algal species are presented, however, subsequent studies are required in order to indicate what factors are most influential in the causation of these trends. As well a study incorporating  $^{14}\text{C}$  or Winkler techniques should be performed to measure the actual rates of oxygen evolution by the phytoplankton.

## ACKNOWLEDGMENTS

I wish to express my gratitude to my supervisor, Dr. S.R. Brown, for his guidance and tolerance in the research and composition of this thesis. I would also like to thank Mr. J. Hutchison for his help in the data collection and his much appreciated companionship during some foul weather.

## TABLE OF CONTENTS

ABSTRACT .....	ii
ACKNOWLEDGMENTS .....	iii
TABLE OF CONTENTS .....	iv
INTRODUCTION .....	1
Study Site Description .....	5
The Meromictic Lake and Terminology .....	6
METHODS AND MATERIALS .....	15
RESULTS .....	17
DISCUSSION .....	24
LITERATURE CITED .....	29
APPENDIX .....	31

## INTRODUCTION

Sunfish Lake is a small meromictic lake situated in rolling farmland eight kilometers west of Waterloo Ontario. It is a deep kettle lake with a wooded and steeply rising shoreline. The lake is surrounded by cottage lots averaging around 400 foot frontage. Originally these were summer cottages, however, they have evolved into substantial dwellings some of which are now permanent residences and are accessible year round.

Very few studies have been conducted on the lake itself, however, several paleolimnological investigations have studied the sediments of Sunfish Lake (Sreenivasa and Duthie, 1973). These paleolimnological studies are of considerable interest because they are investigating the fossil record of possibly the earliest deglaciated area in Ontario, and it was these studies which first brought Queen's limnologists to Sunfish Lake. The "cottagers" became interested in, (and were soon actively co-operating) with the Queen's study. With an increasing awareness of the health of their lake, the cottagers soon developed a deep concern for the future of the lake as a residential and recreational area.

The cottagers' concern stemmed from subjective evidence of heavy algal production and increasing growth of aquatic macrophytes in the littoral zone which are two of the symptoms of eutrophication most commonly associated with the deterioration of a lake. This concern was heightened when a biologist who is a social or business contact of one of the cottagers expressed an opinion that Sunfish Lake will become



worthless for recreational purposes within fifty years. However, in this assessment two mitigating factors have been overlooked. First is that thriving fish populations apparently continue to exist in the lake, and the second is that the lake's present meromictic condition probably operates to retard the processes of eutrophication. Thus, since the determination of the current status of the lake is important to the paleolimnological study as well as to the cottagers, a unique opportunity exists for the integration of a study in basic science and its practical application in the development of a lake management program. The long-term aims of this management program would be to maintain or increase fish population levels by maintaining the present high hypolimnetic oxygen levels as well as the existing food base. The oxygen concentration present in the hypolimnion of a lake represents a balance between the oxygen being produced by algal photosynthesis and the oxygen being utilized by the decomposition of dead organic material in the lake. Sunfish Lake represents a unique situation because it is both highly productive and meromictic. Large oxygen concentrations are present in the hypolimnion because large amounts of oxygen are being evolved photosynthetically, however, little of this oxygen is being utilized in the decomposition process because a large proportion of the decomposition occurs below a chemical density barrier termed the chemocline and consequently does not utilize any of the oxygen from the mixolimnion.

The development of a lake management program for Sunfish Lake requires such a large volume of data gathering and analysis that in order to be accommodated in the scope of thesis projects it must be divided into at least four or five projects.

The essential elements to be studied are a) the composition and distribution of algal populations; b) the pelagic zooplankton; c) the aquatic macrophytes; d) the benthos; and e) the fish populations present in Sunfish Lake. This thesis deals only with the phytoplankton but the framework of the overall study is explained in the following paragraphs.

The composition, and spatial and seasonal algal distributions are important parameters for the determination of the productivity of a lake. Both quantity and quality of the phytoplankton in lakes are used as indicators of the lake's trophic status. The importance of the algae in Sunfish Lake as a base in the food chain may be outweighed by their importance in oxygen production and thus in maintaining the high oxygen concentrations found in the lake. High levels of primary production are normally associated with hypolimnetic oxygen deficits. However, this does not occur in Sunfish Lake probably because the phytoplankton mineralization is mainly occurring in the monimolimnion. To obtain an accurate measure of the algal oxygen evolution in the lake, analysis by the  $^{14}\text{C}$  or Winkler method (Lind, 1974) should be done.

Another element essential to the development of a lake management program is a knowledge of the composition, and spatial and seasonal distribution of the zooplankton. The importance of zooplankton as algal grazers means that some correlation should be made between the zooplankton and algal distribution. Pelagic zooplankton are also important food sources for certain species of adult fish such as alewife (Larkin and Northcote, 1969). Due to the high productivity of Sunfish Lake, information regarding the trophic sequence of the lake is not critical to the



development of a management program due to the abundance of alternate food sources. Thus, there is no necessity that all the feeding relationships be studied.

The benthic invertebrates contribute differently in the food chain than do the zooplankton. Amphipods, isopods and aquatic insects are all important in providing a food base for all the fingerling fish (Wetzel, 1975). Thus, the benthic composition and productivity should be studied.

A study of the macrophyte composition, and spatial and temporal distribution is also essential to the development of a management program. The aquatic macrophytes provide a habitat for the benthic invertebrates which are important sources of food for the fingerlings in the lake. The decomposition of dead macrophytic growth contributes to nutrient cycling as well as to the reduction of oxygen concentrations in the littoral zone. Thus, the harvesting of macrophytes can be advantageous in removing nutrients and maintaining higher oxygen tensions, however, the rate of removal must be controlled because too large a removal could drastically reduce the benthic food base in the lake as well as increase competition for fish spawning sites.

Various aspects of the fish populations should be analyzed. The most important is the resource division which occurs between fish species. Fish have been shown to demonstrate a marked tendency to concentrate their feeding on different invertebrates as they successively become abundant in the environment (Keast, 1965). Keast (1965) showed that interspecific competition between fish species in Lake Opinicon in southern Ontario was less than it first appeared. This was due to the

ecological separation of the fish species by food preference or specialization. Thus, a study should be done much like Keast's 1965 study which investigated a fauna of cohabiting fish species to determine 1) diets and patterns of utilization of food resources in the environment; 2) the relationship between numerical changes in invertebrates and their occurrence in fish stomachs; 3) to what extent specific items are selected by species; 4) the extent to which there is food overlap and/or competition between fish species and age classes of species; 5) mechanisms for reducing interspecific competition; and 6) the potential of the different fishes for utilizing alternative foods.

#### Study Site Description

Sunfish Lake (43° 28N, 80° 35W) is a small, deep kettle lake, located approximately eight kilometers west of Waterloo, Ontario (figure 2). The lake is located in a small poorly drained depression surrounded by sandy kames over a bedrock of shale, salt and gypsum (P.F. Karrow, from Duthie and Carter, 1970). Selected morphological and physical data obtained by Duthie and Carter are given in Table 1.

Macrophytic growth in Sunfish Lake is restricted to a very narrow littoral zone due to the remarkably deep mean depth (10.4 m) for a lake of such a small surface area (8.3 ha). The main inlet and outlet are situated in the northern corner of the lake (figure 1). Flow is intermittent and sometimes bypasses the lake completely. Local residents have reported the presence of several subsurface springs, however, these reports are unconfirmed.

Paleolimnological data has been obtained from an investigation of the diatom stratigraphy in a sediment core from Sunfish Lake (Sreenivasa and Duthie, 1973). Sreenivasa and Duthie interpreted the samples as demonstrating that around 850 years ago Sunfish Lake made the transition from an oligotrophic to a eutrophic lake, and that the lake became meromictic about 140 B.P. at a time when the local forest was cleared to produce agricultural land.

#### The Meromictic Lake and Terminology

Two types of stratification are found in a temperate, meromictic lake; thermal stratification, and chemical stratification. Thermal stratification arises from the exponential absorption with depth of light from the sun (Wetzel, 1975). This creates a warm surface layer (epilimnion) and a cooler bottom layer (hypolimnion). The transition zone between these two layers is referred to as the metalimnion. Due to the increase in density associated with a decrease in temperature, the metalimnion acts as a density barrier, inhibiting mixing between the layers during the summer months. However, during the spring and fall, complete mixing through the entire water column (overturn) occurs as the thermal stratification breaks down.

Chemical stratification can be considered more stable than thermal stratification. The bottom water (monimolimnion) forms through an accumulation of dissolved organic and inorganic material. The density difference between the upper layer (mixolimnion) and the monimolimnion often reaches a difference of 1-2 percent (Wetzel, 1975). The transition zone between these two layers is termed the chemocline. The chemocline



is marked by a rapid decrease in oxygen levels with increasing depth and a significant increase in the specific conductivity; a measure proportional to the total dissolved solids. Because this chemocline occurs at greater depth than the ~~meta~~limnion, a greater energy input from the wind is required at overturn to mix the mixolimnion with the monimolimnion. Often, such energy levels are not attained, at which point, a state of permanent meromixis exists. The existing stratification for Sunfish Lake is schematized in figure 5.

The stability of the monimolimnion can have a major influence on the flora and fauna in a meromictic lake. This layer can be regarded as a "cesspool" which traps nutrients and particles settling through the water column. If the density gradient formed at the chemocline is sharp enough to create a condition of permanent meromixis, nutrients would be permanently trapped in the monimolimnion, and thus would be unavailable to the primary producers. Thus, a state of stable meromixis can suppress primary production, and in Sunfish Lake one of the goals of a management program would likely be to stabilize this meromictic condition. As well, because much of the algal decay occurs below the chemocline, there is less stress placed on the mixolimnion oxygen budget.

Duthie and Carter (1970) state that partial mixing of the monolimnion in Sunfish Lake regularly occurs once every year or two. This conclusion was arrived at by analyzing seasonal oxygen changes. However, increased oxygen was observed occasionally in the monimolimnion during mid-summer with no apparent explanation. The observed mixing may have been an artifact of the experimenter's equipment or methodology,

rather than an actual occurrence. More recent data accumulated by Hamish MacIntosh (unpubl.) indicates mixing of the monimolimnion with the mixolimnion to be a much rarer event than was previously suspected; with complete mixing probably occurring no more frequently than once every fifteen years.