PREDICTION AND INTERPRETATION OF RATES OF HYPOLIMNETIC OXYGEN DEPELETION

by

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PREFACE

The format of this thesis is similar to most in that various sections of work are presented as individual chapters. Each chapter is presented as a scientific paper suitable for publication. Chapters are presented and referenced as papers. Some of these have been published previously. Only the table and figure numbers, and minor syntax errors have been changed from the original papers. References to Cornett and Rigler (1983) refer to various chapters in this thesis.

ABSTRACT

The areal hypolimnetic oxygen deficit model (AHOD) developed by Strom (1931) and Hutchinson (1938) was tested by examining the predictions which the model makes and by testing the assumptions which were made during the formulation of that model. The model was found to be incorrect. Rates of hypolimnetic oxygen depletion are strongly influenced by the morphometry and temperature of the hypolimnion. Lake morphometry influences at least two processes which affect oxygen concentrations. Significantly more oxygen is turbulently transferred into the hypolimnia of shallow lakes than deep lakes. However the maximum rates of vertical transport are always less than 15% of the observed rate of oxygen depletion. The morphometry of the hypolimnion exerts a much stronger influence upon the amount of respiration which occurs within the hypolimnetic water column. The amount of respiration measured in the water column increases as the thickness of the hypolimnetic water column increases. In oligotrophic lakes with shallow hypolimnia, less than 20% of the total amount of oxygen consumed in the hypolimnion is respired in the water column. In deep lakes more than 60% of the total amount of oxygen consumed is respired within the water column. Measured rates of water column respiration are strongly correlated with the temperature and amount of particulate organic matter present in the water column.

The rate of oxygen consumption within the hypolimnion is constant throughout the period of thermal stratification. Respiration does not depend upon the ambient concentration of oxygen present within the hypolimnion. Changes in oxygen concentration within any stratum of the hypolimnion of a lake can be predicted from a knowledge of the retention of phosphorus by the lake's sediments (Rp), the average temperature of the stratum during the period of

thermal stratification (T), and the ratio of the volume of the stratum to the area of lake sediments horizontally contiguous to the stratum (V:SA). A simple statistical model developed from published estimates of rates of oxygen consumption (VOD $mg/m^3/day$) predicts that

$$VOD = -6.6 + .0081T*Rp + 11.07T - 2.32T*Ln(V:SA).$$

The predictions of this equation agree very well with rates of oxygen depletion measured in 12 lakes which possess a diversity of physical and chemical characteristics. During the period of stratification, hypolimnetic oxygen concentrations can be estimated from the predicted rate of oxgyen depletion and an estimate of the initial oxygen concentration within the hypolimnion at the onset of stratification.

RÉSUME

La formule pour calculer la déficience en oxygène d'une région hypolimnétique, developpee par Strom (1931) et Hutchinson (1938), a été mise à l'essai en examinant les prévisions qui résultent de la formule et en mettant à l'essai les présomptions faites au cours de l'élaboration de ladite formule. Nous avons trouvé la formule inexacte. Les taux d'épuisement d'oxygène hypolimnétique sont fortement affectés par la morphométrie et la température de l'hypolimnion. La morphométrie des lacs répercute sur au moins deux (2) procédés qui affectent les modifications sur la concentration de l'oxygène. D'une facon très marquee, plus d'oxygène est violemnent transférée dans l'hypolimnia des lacs de hauts fonds que dans les lacs profonds. Toutefois, les taux maxima de transport vertical sont toujours de 15% moindre que le taux calibré d'epuisement en oxygène. La morphométrie de l'hypolimnion exerce une beaucoup plus forte influence sur la quantité de respiration qui se produit en deçà de la colonne d'eau hypolimnétique. La quantité de respiration mensurée dans la colonne d'eau s'accroît à mesure que l'épaisseur de la colonne d'eau hypolimnétique augmente. Dans les lacs oligotrophiques, avec hypolimnia peu profondes, moins de 20% du montant global de l'oxygène consommée dans l'hypolimnion est respirée dans la colonne d'eau. Dans les lacs profonds, plus de 60% du montant global d'oxygène consommée est respirée en deçà de la colonne d'eau. Les taux mensurés de la respiration de la colonne d'eau correspondent fortement avec la temperature et la quantité de matière organique particulaire présente dans la colonne d'eau.

Le taux de consommation d'oxygène à l'interieur de l'hypolimnion est constant durant toute la période de stratification thermique. La respiration ne dépend pas de la concentration d'oxygène ambiante présente à l'interieur de

l'hypolimnion. Les modifications dans la concentration d'oxygène dans toute couche donnée de l'hypolimnion d'un lac peuvent être prédites grâce à la connaissance de la rétention de phosphore par les sédiments du lac (Rp), la température moyenne de la couche au cours de la période de stratification thermique (T) et le ratio du volume de la couche par rapport à la zone de sédiments horizontalement contique à la couche (V:SA). Une simple formule statistique élaborée à compter d'estimations de taux de consommation d'oxygène (VOD $mg/m^3/day$) publiées prevoit que

$$VOD = -6.6 + .0081T*Rp + 11.07T - 2.32T*Ln(V:SA).$$

Les previsions de cette équation coincident très bien avec les taux d'épuisement d'oxygène mensurés dans 12 lacs qui possèdent une diversité de caractéristiques physiques et chimiques. Au cours de la période de stratification, les concentrations d'oxygène hypolimnétique peuvent être évaluées par le taux prédit d'épuisement d'oxygène et une estimation de la concentration d'oxygène initiale à l'exterieur de l'hypolimnion, au début de la stratification.

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CHAPTER ONE

INTRODUCTION

INTRODUCTION

Traditionally, limnology, the study of inland waters, has been a descriptive science. Since the influential concept of a lake as a microcosm by Forbes (1887), limnologists have made a range of diverse physical, chemical, and biological observations in thousands of different lakes. Properties studied were the kinds of organisms in a lake, the abundance of organisms of each species, and the rate at which new biomass was produced. Chemical and physical variables were studied so that the environment could be described more completely than by listing only the visually apparent properties of the lake. As these descriptive studies were repeated on the same lake over a number of years, progressive changes in the biology and chemistry of many lakes were observed. Species of fish disappeared from lakes, new species of colonial algae floated upon the lake surface and replaced former species, and beaches were clogged with weeds and decaying algae (Thienemann 1925; Strom 1928; Hasler 1947; Edmondson 1962, 1966; Thomas 1969; Keleher 1972). A wealth of data documenting these changes has accumulated as recent studies repeat the observations of their predecessors in different lakes (eg. Michalski et al 1973; Nicholls 1976; Dillon et al 1978) Many of the studies which noted changes in the biota of a lake also documented changes in chemical parameters such as increases in nutrient concentrations, increases in the concentrations of total dissolved and suspended solids, and increases in the concentrations of substances which are toxic to humans and other living organisms (Hasler 1947; Edmondson 1962; Beeton 1969; Thomas 1969). As these facts were published many limnologists sounded an alarm because they perceived the changes as detrimental, and believed that the changes which they documented were caused by human activities on the lake or within the lake's catchment. However when limnologists raised their voices in concern, they were forced to focus upon questions which they had not asked previously. Interest

shifted from documenting the changes to managing the lake system. And the principal questions concerned:

1. How would the properties of the lake change in the future?
2. How could the quality of the lake be restored?
3. Will the changes in this lake also occur in other lakes?

An answer to any of these three questions listed above requires a theory which will correctly predict which event out of a wide possible array of events will occur. Early limnological studies had only accumulated facts about individual lakes and individual species (Rigler 1975). The facts had unknown generality and no predictive ability.

When I began my research I found the lack of predictive ability in limnology somewhat perplexing. I was confused because the diversity of observations collected in many areas had enormous predictive potential. Yet the data were not being exploited in many areas, and initially I could see no reason to explain the stagnation. Many limnologists appeared to be focused upon the same variables that I was interested in. Yet few predictive models had been developed.

For the past 80 years many limnologists have studied the typology or trophic status (degree of eutrophy) of lakes. In the most general sense, the typology of a lake includes the biomass and productivity of the biota in the lake, and the factors which were believed to influence these biotic variables (Naumann 1919; Thienemann 1925). Naumann and Thienemann developed a method of classifying lakes along a trophic gradient. Lakes which were very productive were called eutrophic. Less productive lakes were termed mesotrophic and the least productive systems were classified as oligotrophic. Lake typology and the classification of lakes according to their degree of eutrophy provided the focus for many limnological

investigations.

At first glance the study of lake typology by limnologists might appear to be an example of a paradigm theory (Kuhn 1962). However lake typology is not a theory. Adopting the definition of Popper (1959), a theory is a potentially fasifiable statement which makes a prediction about a set of variables. Lake typology is a concept (Peters, 1980). It is a set of ideas or beliefs that a group of parameters are important and may contain useful information. The concept of lake typology cannot make any predictions. Therefore it cannot answer any of the questions which were listed earlier. The preoccupation of limnological science with the classification of lakes prevented many studies from looking for patterns between lakes and within a single lake. Since patterns form the basis for simple predictive models, the early studies of eutrophication could not predict the properties of lakes.

During the last 10 years, the concept of the typology of the surface waters of lakes has been replaced by a series of simple theories (Rigler 1975). Now a limnologist can use existing statistical and mass balance models to predict how the concentration of phosphorus in a lake will change as the input of nutrients from natural and human sources is altered (Dillon and Rigler 1974; Reckhow 1979). The amount of a nutrient that is stored in the sediments can also be estimated (Kirchner and Dillon 1974; Ostrofsky 1979), as can the amount of chlorophyll which will be present in the epilimnion during the summer (Dillon and Rigler 1974), and the transparency of the surface water of the lake (Dillon and Rigler 1975). It is also possible to predict the sustainable harvest of fish from a lake (Rawson 1955; Ryder 1965; Matuszek 1978; Hanson and Leggett 1981).

Methods of trophic classification have used parameters measured in the surface waters such as the nutrient concentrationin the trophogenic zone, the biomass of algae, or the transparency of the water column. Other variables measured in the hypolimnion also were used to classify lakes. The hypolimnetic variables most frequently used as trophic indicators were the rate at which dissolved oxygen was depleted within the hypolimnetic water column during the period of thermal stratification (Hutchinson 1938; Mortimer 1942), and the shape of the vertical oxygen profile measured within the hypolimnion (Thienemann 1925, 1928). As a result of these investigations, limnologists had a variety of variables which various schemes of classification dictated they should measure. Some variables were more highly recommended than others. Hutchinson (1957) stated that: "A skilled limnologist could learn more from the study of a lake's oxygen regime than any other chemical limnological parameter."

Oxygen is an important parameter in lakes. Although the surface waters of almost all lakes are well oxygenated, decomposition of organic matter in the hypolimnion of a thermally stratified lake consumes significant amounts of oxygen. Since the rate of oxygen consumption is more rapid than the inputs of oxygen to the hypolimnion, the concentrations of dissolved oxygen decrease throughout the period of thermal stratification (Birge and Juday 1911; Hutchinson 1957). The rate of hypolimnetic oxygen depletion appears to be accelerated by the eutrophication of a lake's surface waters (Edmondson 1962, 1966; Bazin and Saunders 1971; Jones and Bachman 1974; Dillon et al 1978). Unfortunately, increased rates of oxygen consumption can consume all of the oxygen in the hypolimnion. Anaerobiosis in the hypolimnion may cause the release of nutrients from the sediments (Mortimer 1942), destroy populations of cold-water fishes which inhabit the hypolimnion (German et al 1980), and sometimes result in the release of

hydrogen sulphide (Burns and Ross 1972) or other toxic substances (Alberts and Tilly 1979) from the sediments. Therefore it would be useful to be able to predict the relationship between the degree of eutrophication in a lake's surface waters and the amount of oxygen which will be present in the hypolimnion of the lake.

The objective of this research is to develop and test a group of models and generalizations which can be used to predict the concentrations of oxygen in the hypolimnion of lakes. Clearly this is a long-term project. The specific hypotheses and models that were tested in this thesis will be detailed in the next section.

APPROACH AND OBJECTIVES

Several authors have attempted to use relatively complex mathematical models to define changes in oxygen concentrations in streams and reservoirs (Varga and Falls 1972). However there have been few attempts to predict the oxygen concentrations in lakes. Bella (1970) used an input output model to simulate seasonal changes in the oxygen regime of Lake Sammamish. Similar, but more compex systems analyses have been used to study the vertical profiles of other lakes (Fleming 1974;Imboden 1974; Newbolt and Liggett 1974; Snodgrass 1974). These models required estimates of all of the processes which produce or consume oxygen in the lake. Unfortunately when they were published the importance of various sources and sinks for hypolimnetic oxygen was not known. Clearly, unknown rates can only be guessed; they cannot be accurately modelled. The poor predictive accuracy of the simulations is ample evidence that the models and/or the estimated rate constants were not correct. In addition, the published simulations were specific to the lake and year for which they are designed. They cannot be used to predict future changes in oxygen concentrations in these lakes or changes in oxygen concentrations in other lakes. Problems such as these severely limit the practical utility of these models, and the simulation approach.

The holistic, empirical approach which forms the foundation for this study is the antithesis of complicated systems modelling (Rigler 1975; Peters 1980). The comparative approach was chosen for a number of reasons. First, there was too little quantitative information about the individual processes that consume or add oxygen to the hypolimnion for them to be accurately modelled. Secondly, simple models are also much easier to test rigorously than systems models because fewer variables must be measured in the test lake. Tests of the equations developed during my work are an

integral part of this thesis. Simple models are also more easily applied by nonexperts in real-life situations. Finally, a simple model can also be very general. It can apply to a diversity of different lakes. Since it is physically impossible to investigate all lakes, a useful model should be general enough to make predictions about a specific lake without first studying it for years.

I propose to predict hypolimnetic oxygen concentrations (O_t), on any day after the onset of thermal stratification by

$$O_t = O_{to} - Ks*t \qquad (1)$$

where O_{to} is the oxygen concentration at the onset of stratification and O_t is the predicted oxygen concentration t days after the initial oxygen concentration was determined. Ks is the rate of oxygen consumption during the period of t days. To predict O_t without visiting the lake, it will be necessary to predict the date that stratification commences, the duration of thermal stratification, the oxygen concentration in the hypolimnion at the onset of thermal stratification, and the rate that oxygen is depleted from the hypolimnetic water column (Ks). This thesis has focused upon one parameter in the equation.

The objective of this thesis is to develop and test a method of predicting Ks. Such a development will provide a method of predicting seasonal changes in oxygen concentrations in each stratum of the hypolimnion of a lake. During the development of the method of predicting Ks, the question "What processes influence the rate of oxygen depletion?" was also addressed. A partial answer to this question was an integral part of the development of the empirical model because it challenged the conceptual model of oxygen depletion that I developed. Since it is the mental model or concept that a scientist uses to select potential predictive variables,

it is important that the mental model is re-examined continually (Peters 1980). Additional work beyond this thesis will be required to estimate other parameters necessary to predict actual concentrations of oxygen in the hypolimnion.

The conceptual model of lake typology suggested that rates of production of organic matter in the epilimnion influence rates of decomposition of organic matter in the hypolimnion (Birge 1907; Thienemann 1928; Hutchinson 1938; Ohle 1956). Since oxygen is consumed or respired during aerobic decomposition, the rate of hypolimnetic oxygen consumption was predicted to increase as the surface water productivity of a lake increased. Several studies support this hypothesis. Edmondson (1962, 1966, pers. comm.) documented changes in the rate of oxygen depletion in Lake Washington over a period of many years as sewage added to the lake, increased the productivity of the lake's surface waters. Similarly, as nutrients polluted Lake Gjersjoen, oxygen depletion in the hypolimnion increased each year from 1960 to 1970 (Holtan 1972). Coincident with increases in surface water productivity during recent years, rates of oxygen depletion have increased in Lake Okoboji (Jones and Bachman 1974), and in Douglas Lake (Bazin and Saunders 1971). Lower hypolimnetic oxygen concentrations have also been measured at the end of the summer in Lake Maggiore (Vollenweider 1964), Lake Hayes (Mitchell and Burns 1978), and Zurichsee (von Zimmerman 1977) as the surface waters of each lake became more eutrophic. Dillon et al (1978) documented a close correlation between the decrease in sewage inputs to Gravenhurst Bay and changes in the rate of oxygen depletion in the hypolimnion between 1969 and 1974. When the new sewage plant malfunctioned during 1975, the rate of hypolimnetic oxygen depletion in the lake also increased. Gilbertson, Dobson and Lee (1972) presented evidence that the rate of hypolimnetic oxygen depletion increased in the central basin of

Lake Erie by 100% from 1929 to 1970. Phosphorus loading to the lake was estimated to have increased by more than 90% during the same period. However Charlton (1980) argued that the increase in the measured depletion rate could be accounted for by climatic changes that influenced the temperature of the hypolimnion. The study by Charlton (1980) emphasizes the necessity of comparing changes in rates of oxygen depletion in lakes that are influenced by eutrophication to changes in those lakes which are not. Even the most detailed studies have not examined "control systems". Nor have the authors who documented changes in oxygen concentrations used their observations to predict future changes in the rate of oxygen depletion in the lake which they studied or in other lakes. Following in the footsteps of the founders of the concept of lake typology, most workers produced descriptive, rather than predictive studies. Subsequent chapters of this thesis each test one or two hypotheses which are important to the development of an equation which can be used to predict rates of oxygen depletion.

Even the extremely simple equation (1) which I presented makes a fundamental assumption. It assumes that the rate of oxygen consumption is constant throughout the period of thermal stratification. In other words, respiration within the hypolimnion is postulated to be a zero order chemical process which does not depend upon the ambient concentration of oxygen present in the water column. Chapter 4 tests this assumption by statistically testing the measured oxygen concentrations for deviations from the linear model. The influence of changes in ambient oxygen concentration upon the two processes which consume oxygen - repiration in the water column and respiration in the sediments - are also examined in the same chapter. However before respiration in the water column could be measured, it was necessary to develop a method which could detect the

small, but potentially significant rates of respiration by organisms in the water column. This method is detailed in Chapter 3.

As stated earlier, it is my objective to predict Ks the rate of change in oxygen concentrations in the hypolimnia of lakes in mg $O2/m^3/day$. However the earlier work of Thienemann (1928), Strom (1931) and Hutchinson (1938) suggested that rates of oxygen depletion can only be compared between different lakes if the rate of oxygen depletion is expressed as the mass change of oxygen below a square meter of hypolimnetic surface area. Thienemann and Strom proposed that two lakes with equal productivities in the epilimnion, but with different hypolimnetic volumes, will have very different rate of hypolimnetic oxygen depletion per unit volume, but will have the same rate of areal hypolimnetic oxygen depletion (hereafter AHOD). In Figure 1 both lakes should have AHOD values of 6 mg $O2 /m^2 /day$. Thienemann (1928), Strom (1931) and Hutchinson (1938) proposed that the AHOD would eliminate the effects of lake morphometry upon comparisons of epilimnetic productivity and rates of hypolimnetic oxygen depletion.

Hutchinson (1938) conducted a preliminary test of Thienemann's hypothesis on four lakes and found an almost perfect correlation between the AHOD value measured in the hypolimnion and the standing crop of pelagic plankton. Riley (1939) did not find the same convincing pattern in the small Conneticut lakes that he studied. After he completed a detailed analysis of data from 21 lakes, Deevey (1940) concluded that there was no relationship between the AHOD and the standing crop of plankton in the surface waters of lakes. Similar tests by Sparrow (1966) and Lasenby (1975) also suggest that the correlation between epilimnetic or trophogenic biomass and the AHOD is not very strong. Therefore the results of these studies cannot be used to predict the AHOD with sufficient accuracy to

Fig. 1. Summary of the conceptual model of hypolimnetic oxygen depletion developed by Thienemann (1928), Strom (1931) and Hutchinson (1938). The squares symbolize 1 square meter of epilimnetic or hypolimnetic surface area. The open circles are 1 unit of production or decomposition.

	LAKE A	LAKE B
EPILIMNETIC PRODUCTION	● ● ● ● ● ●	● ● ● ● ● ●
HYPOLIMNETIC OXYGEN CONSUMPTION	● ● ● ● ● ●	● ● ● ● ● ●
HYPOLIMNETIC VOLUME	3 m^3	1 m^3
VOLUMETRIC OXYGEN DEFICIT	2 mg m^{-3}	6 mg m^{-3}
AREAL OXYGEN DEFICIT	6 mg m^{-2}	6 mg m^{-2}

predict changes in hypolimnetic oxygen concentrations.

However none of these studies tested the original hypothesis which Thienemann (1928) and Strom (1931) presented. The authors postulated that a relationship existed between the rate of hypolimnetic oxygen depletion and the rate of epilimnetic primary production. They also suggested that the relationship would be independent of the morphometry of the lake. Prior to this study, authors have only examined the relationship between various estimates of biomass, and the AHOD. Chapters 5, 6 and 7 examine in detail, the influences of primary productivity, and lake morphometry upon AHOD values. A simple statistical model which can accurately predict the AHOD value in a lake is also presented in Chapter 5. Further testing of the regression model is reported in Chapters 6 and 8. The attempts to predict the AHOD values of lakes suggested that the morphometry of the hypolimnion strongly influences the rate of oxygen consumption in the hypolimnion. Two explanations of this observation are postulated and explored in Chapters 9, 10 and 11. Results of these chapters suggested that the physical transport of oxygen into and within the hypolimnion does not significantly alter the measured oxygen profiles. These results prompted me to investigate the statistical prediction of Ks values using the same group of variables used in Chapter 5 (see Chapter 12).

Although this synopsis emphasizes that each subsequent chapter in this thesis is presented as an individual manuscript, the chapters are linked by a common goal. The objective of this thesis is to develop and test a simple empirical model which will accurately predict changes in oxygen concentrations in the hypolimnia of lakes.

CHAPTER TWO

METHODS

METHODS

Chapters 3 to 12 of this thesis are written in the form of manuscripts. Each paper contains a detailed description of the field techniques, the analytical methods, and the calculations performed during subsequent data analysis. This section does not repeat those detailed discussions. The objective of this chapter is to present background information concerning the selection and sampling of the lakes which were studied. This information would not normally be included in a publication. However the facts may be required by anyone wishing to evaluate and use these data for other projects.

During this study 12 lakes located in the eastern townships were sampled for a number of physical and chemical parameters (Fig. 1). All of the study lakes were chosen so that they were easily accessible from the Lake Memphremagog field station. Of the approximately 30 lakes in the area, the 12 hypolimnia sampled, were selected to cover the broadest possible range of values of annual phosphorus retention, hypolimnetic temperature, and mean depth. Preliminary estimates of phosphorus concentrations and hypolimmnetic temperature were based upon measurements collected during the spring and summer of 1978.

Many lakes have more than one name or regions have two lakes with the same name. The exact location of the lakes studied in this thesis is listed in Table 1. The nomenclature of the lakes used during this thesis was taken from the Government of Canada, Ministry of Energy, Mines and Resources 1:50000 scale topographic maps prepared in 1965. The bathymetry of the lakes was obtained from morphometric maps prepared by various government agencies (see Appendix 1). The drainage area of each lake was determined by delineating the topographic catchment area on the 1:50000 scale maps

(Table 2). The surface area of each lake was determined from the bathymetric maps (Table 2).

Each lake was sampled at approximately regularly spaced intervals throughout the period of investigation. Since one major objective of this study was to determine the rate of hypolimnetic oxygen depletion, lakes were sampled more intensely while the hypolimnion was oxic. Therefore Lakes Magog and Truite, and Fitch Bay of Lake Memphremagog were sampled weekly in the early summer until the bottom waters of the hypolimnion were anoxic. Then the lakes were sampled less frequently.

On each sampling date, duplicate temperature profiles were measured at a single location in the center of the lake. At the same station, samples were collected to determine the oxygen concentrations within the hypolimnion. The location of each sampling station is shown in Appendix 1. The sampling site was not permanently marked with a bouy. It was estimated on each sampling day from land marks on the shore. The sampling dates when oxygen and temperature profiles were collected are listed in Appendices 2 and 3. Surface water samples for phosphorus and chlorophyll concentrations and Secchi depth were made at two or three sampling sites in each lake. The location of these stations is also shown in Appendix 1. Since these and other samples mentioned in subsequent chapters were collected on the same dates as the oxygen profiles, the sampling periodicity will be identical.

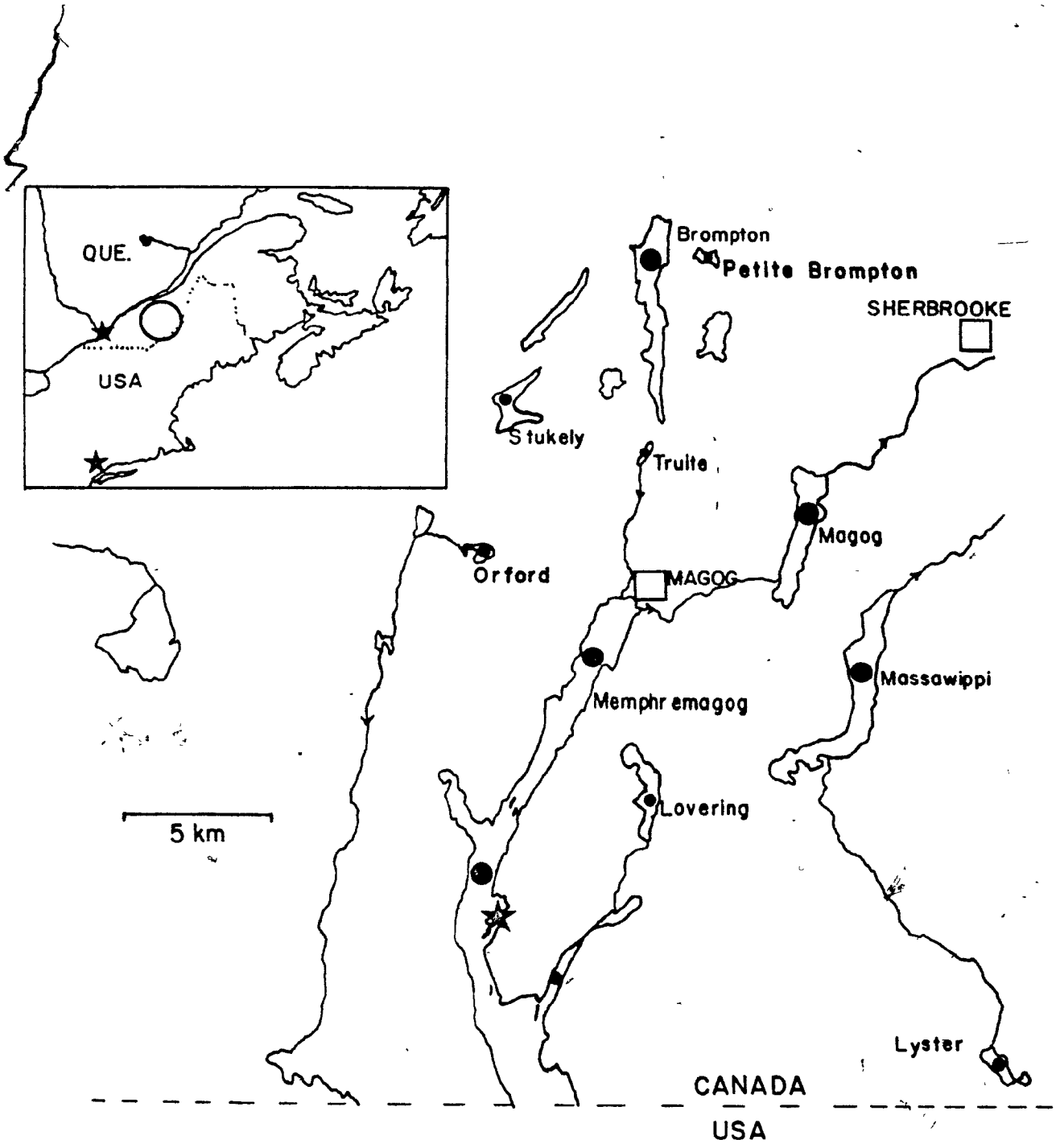
LAKE	LATITUDE	LONGITUDE
Brompton	45,13	72,09
Lovering	45,10	72,16
Lyster	45,01	71,54
Magog	45,18	72,03
Massawippi	45,13	72,00
Memphremagog	45,05	72,15
Orford	45,17	72,16
Petite Brompton	45,27	72,09
Stukely	45,22	72,15
Truite	45,20	72,10

Table 1. Location of the lakes studied during this thesis specified in degrees and minutes (degree,minutes) of latitude and longitude.

LAKE	Ao	Ad
Brompton	9.95	115.85
Lovering	5.21	43.51
Lyster	1.71	9.91
Magog	10.44	1942.76
Massawippi	21.00	480.89
Memphremagog		
central	21.64	1606.69
Fitch	2.80	116.65
north	18.81	1765.60
Orford	1.28	7.42
Petite Brompton	0.71	3.46
Stukely	3.66	14.24
Truite	0.39	3.32

Table 2. The lake area (Ao) and drainage area (Ad) of the study lakes in square kilometers. The drainage areas do not include the area of lakes located upstream from the study lake. The drainage areas of the three basins of Lake Memphremagog were calculated separately using the figures supplied by Ross (1974), assuming that the waters from the south basin of the lake do not enter Fitch Bay.

Fig. 1 The lakes investigated during this study are located approx. 100 km, south-east of Montreal, Canada, just north of the international border with the United States.


QUE.
USA
Brompton
Petite Brompton
SHERBROOKE
Stukely
Truite
Magog
Orford
MAGOG
Memphremagog
Massawippi
Lovering
Lyster
5 km
CANADA
USA

CHAPTER THREE

A SIMPLE METHOD OF MEASURING SESTON RESPIRATION IN OLIGOTROPHIC LAKES

INTRODUCTION

Many studies suggest that nutrients are rapidly recycled within the water column of lakes (Rigler 1956; Kajak et al 1972; Wetzel et al 1972; Bloesch 1974; Bloesch et al 1977). However very few hypotheses concerning the respiration of detrital substances have been tested and there are very few generalizations about planktonic respiration (DePinto 1978). Limnologists studying the rates of decomposition in the water column of lakes appear to have delayed the testing of hypotheses because the methods available to study decomposition have not adequately measured in situ rates of metabolism (Cole and Likens 1979). Field studies employing single labelled substrates (Wright and Hobbie 1966), are very difficult to compare to other metabolic rate measurements, and laboratory studies alter in situ conditions (Jewell and McCarty 1971). Even the addition of compounds which were naturally labelled under in situ conditions (Saunders 1972; Cole and Likens 1979) can alter the actual concentrations of metabolites present in the water.

In this paper we present and test a simple alternative method of measuring rates of decomposition in the water column of lakes. Although we hope that future studies will demonstrate that this method

will be applicable in a diversity of systems, we have focused our investigations upon the hypolimnion of oligotrophic lakes. The hypolimnia of lakes are the focus of a detailed study (Cornett 1982) and these systems are among the most difficult systems to study because the rates of oxygen consumption are extremely low (Cornett and Rigler 1982).

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METHODS

The method developed to measure respiration consists of 4 steps. One day before an experiment was conducted, all sampling bottles (60 mL BOD) were autoclaved at 15 psi for at least 15 minutes to sterilize the bottles. Then the bottles were frozen. The bottles were taken to the lake in a large incubator. To ensure that the bottles were as close as possible to the temperature of the water sample that they would contain, the bottles remained frozen until just before the water samples were added.

Water samples for the experiments were collected from within the hypolimnion using a VanDorn sampler or a peristaltic pump. Tschumi et al (1977) demonstrated that the order in which oxygen bottles were filled from a sampler affected the oxygen concentrations of the samples. A simple solution to this potential problem is to fill duplicate bottles simultaneously at the same flow rate by splitting the water flowing out of the sampler into two bottles using a "Y" joint. This procedure was used for all experiments. During the filling of the

samples, temperature changes were minimized by filling the bottles rapidly, out of direct sunlight, in a large bath of water collected from the same depth as the samples. As the bottles were filled, the water samples were filtered through a 250 μm screen to eliminate all larger zooplankton. Water overflowed each oxygen bottle (> 200 mL) to ensure that the samples had minimal contact with the atmosphere. Immediately after filling two pairs of bottles, these samples were returned to the cooler in a bath of water from the same depth. The entire process of filling the bottles raised the temperature of the samples by less than 4°C above the *in situ* temperature which ranged from 4°C to 13°C. An additional 2 liters of water collected from the same depth was placed in a plastic bottle rinsed twice with sample water. This sample was also placed in the incubator.

At the lake shore, 4 subsamples of 250 or 500 mL of water were filtered through a 47 mm diameter, 0.45 μm membrane filter. The filtration pressure was between 4 and 5 psi, and the filtration of each sample was stopped just seconds before the filter dried. Five to eight minutes were required to filter 500 mL of sample. 250 mL samples were filtered in 2 to 5 minutes. During the filtration, aluminum foil shielded the samples from the sun. Each of the 4 filters was rolled with forceps and dropped into one of the four sample bottles collected from the same depth. To one sample of each pair, 200 μL of 0.8 N NaN_3 was added to stop all respiration. Then the bottles were quickly returned to the incubator. Since each sample was treated identically, the sample with the azide acted both as an estimate of the initial concentration of oxygen in the water and as a control to correct for any changes in oxygen concentrations that were induced by

the experimental manipulations. Approximately 24 hours later, the samples were removed from the incubator and 200 uL of azide solution was added to the samples which had respired during the experiment. As a precaution the bottles were returned to the incubator for 1 hour, in case the azide influenced the oxygen concentration in the respiring sample. Then the samples were opened, the filters were removed with the use of forceps, and Winkler reagents were added to each bottle (Carpenter 1965). Subsamples of 25 mL were titrated using 0.15 N $Na_2S_2O_3$ standardized against 0.005 N KIO_3. The concentration of oxygen in each bottle was calculated using Carpenter's (1965) equation, modified to correct for the subsampling procedure. The volume of each oxygen bottle was measured and the oxygen concentration was corrected for the volume of the reagents added. However, no correction was made for the volume of azide added or for the volume of the sample displaced by the filter. The respiration measured during the experiment was calculated as

$$R = 1000VR(OC-OF)/((VR+VF)D) \qquad (1)$$

where VR is the volume of the bottle which respired, VF is the volume of sample which was filtered, and OC and OF are the oxygen concentrations measured in the control sample and the respiring sample in mg/L. The calculated respiration rates (R) are expressed in mg O_2/m^3/day by dividing the change in concentration by the duration of the experiment (D, in days).

RESULTS AND DISCUSSION

The utility of the method which we have just outlined depends upon evidence that the treatment did not influence the results, that the experiments are reproducible, and that the resulting respiration rates can be compared to other components of the carbon cycle. A detailed comparison of the results of this method and rates of oxygen depletion will be made in Cornett and Rigler (1983). Our purpose here is to outline a series of experiments performed to evaluate the influence of the treatments upon the rate of respiration of samples of hypolimnetic water. Most of the experiments discussed below were conducted with water collected from below the thermocline of Lake Memphremagog, a large mesotrophic lake located on the international border between Canada and the United States (Ross and Kalff 1975).

The paired design described above used one sample bottle both to estimate the initial concentration of oxygen and to correct for any experimentally induced changes in concentration. Although this design will minimize the influence of sampling artifacts, it assumes that the azide does not influence the results. Sodium azide was chosen as an inhibitor of respiration because it is known to be efficient at stopping cellular metabolism, and because it is chemically compatible with the Winkler technique of oxygen analysis (APHA, 1965). In a series of preliminary experiments, $HgCl_2$, formalin, and potassium cyanide all exhibited some influence upon the oxygen concentration or upon the Winkler chemistry. Three sets of experiments suggest that the addition of azide stopped respiration and did not influence the method in any other way. In one series of experiments, paired samples were

filled simultaneously, and then 200 µL of azide solution was added to one sample and no azide was added to the second. The samples did not have significantly different oxygen concentrations (Table 1). This suggests that the procedure of incubating the control bottle with azide for 25 hours and the respiring bottle with azide for 1 hour did not significantly alter the results of the experiments. To ensure that azide does stop oxygen consumption, 12 sets of duplicate sample bottles were filled with hypolimnetic water. Then 250 mL samples of the same water were filtered through 24 filters and one filter was added to each bottle. Six pairs of bottles (set A) were treated using the method outlined earlier. The remaining samples did not receive any azide (set B). Winkler chemicals were added to one sample from each pair of bottles in set B, and the other bottle was returned to the incubator to respire. After 24 hours respiration was stopped by adding the Winkler reagents to the respiring bottles in sets A and B. Azide was also added to the respiring samples in set A. The calculated rates of respiration for samples in the two sets were compared in a paired T test. There is no significant difference in respiration in the samples incubated with and without azide (Table 1). Further evidence that the concentration of 150 mg azide per liter of sample, is sufficient to stop respiration comes from another experiment similar to the experiment just described. Instead of adding no azide to the bottles in set B, the experiment was repeated and 400 µL of azide were added to the control and respiring bottles in Group B. Again the difference in respiration rate between the two groups was used as the statistic. There is no difference in the rate of oxygen consumption between the

two treatments (Table 2). From these results we conclude that the addition of NaN_3 stopped all respiration and did not interfere with the experiments in any other way.

The use of a control sample treated in an identical manner to the respiring sample, should ensure that abiotic effects exert the same influence upon the concentrations of oxygen in both samples. However, it does not ensure that the sample containers, bottles or filters were uncontaminated before the experiment began. It is unlikely that the containers or bottles were contaminated because they were acid washed, or autoclaved and frozen prior to each experiment. However the filters were not sterilized. To test the hypothesis that samples were not contaminated with microbial activity, a series of experiments employing 3 different treatments was conducted. Control and respiring bottles were filled with autoclaved, distilled water or autoclaved, distilled water and a filter rinsed in the same water, or autoclaved hypolimnetic water into which a filter containing the particulate matter from a 250 mL filtration of the same water was added. All of the bottles were incubated at 8°C for 24 hours. Then the oxygen concentration in each sample was measured as outlined earlier. The oxygen concentrations in the control and respiring samples of each treatment were compared using paired T tests. In no experiment was the respiration rate significantly different from zero. No changes in oxygen concentration had occurred (Table 3). Further evidence that the filters did not influence the respiration rate is presented in Table 4. The respiration of samples of hypolimnetic water was compared to the respiration rate of samples to which a filter, rinsed in the same water was added. The addition of a filter did significantly lower the

initial oxygen concentration below that measured in samples to which no filter was added (Table 4). However, there was no significant difference in the respiration rate of the samples which contained a filter compared with those which did not (Table 4).

Three different types of filters were used to concentrate organic matter during these experiments. After preliminary testing, Gelman type GA-6© filters were rejected because they interfered with the Winkler chemistry. Gelman GN-6© filters and DM-450© filters both proved to be useful in these experiments. There was no significant difference between the respiration rates measured using the two types of filters (Table 5). Since DM-450 filters are composed of polyvinyl chloride which is resistant to microbial attack, these experiments also provide further evidence that the filter did not influence the respiration rate of the sample.

In most oligotrophic systems we were unable to obtain respiration rates statistically different from zero unless the samples were concentrated upon a filter. However in Fitch Bay of Lake Memphremagog and Lake Magog, we compared the rates of respiration measured using the filtration technique to those measured by incubating unfiltered samples for 1 day (Fig. 1). In 19 replicated comparisons conducted at in situ temperatures, the respiration rates ranged from 20 to 100 $mg/m^3/day$. The rates measured with the two techniques are not significantly different. This suggests that the filtration does not cause a loss of respiratory activity in these two systems we studied. Harris and Lott (1973) and Harris and Piccinin (1977) also concluded that the concentration of algal samples by centrifugation or low pressure filtration did not alter the metabolism or microscopic structure of

the cells. In our experiments no attempt was made to determine what fraction of the metabolic activity remained on the filter after the filter was resuspended in the sample bottle. However Griffiths et al (1973) found that more than 70% of the metabolic activity of microbial samples concentrated by reverse filtration (Pomeroy and Johannes 1966) remained on the filter even after the filter was backwashed. Similar results would be expected from these direct filtrations. The calibration experiments conducted during this study are much more reproducible than similar experiments done with the reverse flow technique (Turner, 1978). The recovery of metabolic activity is also much higher. The higher, more consistent recovery may reflect either the more rapid filtrations used in our experiments or the smaller volumes of water we filtered. Evidence also indicates that the recovery and rate of respiration do not change during the period of incubation. Rates of respiration measured using pond water and hypolimnetic water were constant over periods of 1 and 3 days respectively (Fig. 2).

Encouraged by these results, we have investigated respiration in the hypolimnetic water column of 12 lakes where respiration rates ranged from 2 mg/m^3/day to 80 mg/m^3/day (Cornett and Rigler, 1982). From the pooled data from more than 400 duplicate experiments the average standard error of the mean was 4.3 mg/m^3/day when 250 mL were filtered and 2.4 mg/m^3/day when 500 mL samples were concentrated. There is no relationship between the difference in respiration rates measured on duplicate samples and the difference in the filtration time required to concentrate the material onto the filter (Table 6). The range of filtration times used to concentrate the planktonic particles

did not appear to influence their metabolism. This conclusion is correct for both of the filtration volumes used in this analysis. Using more samples, this simple filtration technique can be used to detect rates of respiration as low as 2.0 $mg/m^3/day$. These statistics demonstrate that the technique is extremely sensitive.

Rates of oxygen consumption measured by the filtration technique can be compared to the rate of change in oxygen concentration in the water column of the hypolimnion. Changes in oxygen concentration in the water column will reflect both oxygen consumption by the sediments and the water. Therefore the respiration rates calculated from the bottle experiments should be less than the total rate of oxygen consumption in the hypolimnion. In the 60 sites investigated during 1979 and 1980 (12 lakes and 5 sampling depths per lake), there was a strong correlation between the two measurements of oxygen consumption. The respiration rate calculated from the filtration experiments was always less than the total change in oxygen concentration in the water column (Cornett and Rigler, 1983). Therefore this method provides a simple technique which can be used to test a wide variety of hypotheses that discuss the respiration or decomposition of organic matter in the pelagic zone of freshwater and marine systems.

COMPARISON	K	$-NaN_3$	$+NaN_3$	SE	T
Initial O2	12	4072	4074	4.6	0.4
Respiration	6	11.4	11.4	3.5	0.1

Table 1. Comparison of initial oxygen concentrations in mg/m^3 and respiration rates (mg/m^3/day) of samples which received no azide ($-NaN_3$, set B) with samples which did receive azide (set A, $+NaN_3$). K is the number of pairs in the experiment, SE is the standard error of the mean and T is the students T statistic calculated to test the hypothesis that the means of the treatments are different. The T values are not significant.

In this and subsequent experiments the large number of replicates precluded analysis of all samples as soon as the samples were collected. However all pairs of samples were analyzed at the same time so that any influence of a variable storage time was eliminated from our results

COMPARISON	K	$+NaN_3$	$++NaN_3$	SE	T
Initial 02	12	9254	9249	11.2	0.4
Respiration	14	22.6	24.8	2.8	0.8

Table 2. Comparison of concentrations of oxygen and respiration rates of samples treated with 200 ul of 0.8 N azide ($+NaN_3$) or 400 ul of azide ($++NaN_3$). Other symbols are the sames as those used in Table 1. There is no statistical difference between the oxygen concentrations or the respiration rates of samples subjected to different treatments.

TREATMENT	F	K	RATE	SE	T
Distilled	-	10	-6.8	4.1	1.7
Distilled	+	6	-2.3	2.2	1.0
Lake	+	4	-8.7	9.3	1.1

Table 3. Rates of respiration (RATE, $mg/m^3/day$) of three different types of water (treatments) which were sterilized before they were incubated. F indicates whether filters were added (+/-) to the samples of lake water or distilled water during the incubations. Other symbols are the same as those in Tables 1 and 2. There are no significant changes in oxygen concentration during any experiment.

Negative rates suggest a slight increase in oxygen concentration during the experiments.

TREATMENT	K	FILTER		SE	T
		-	+		
Initial O2	23	9223	9175	5.4	8.8*
Respiration	7	76.8	72.6	7.9	0.5

Table 4. Examination of the influence of filters (+/-) upon the rate of respiration and oxygen concentrations of hypolimnetic water samples. Units and symbols as in Table 1. The star indicates that there is a significant decrease ($p<.05$) in the oxygen concentrations of samples to which filters were added. No differences in respiration rates were measured.

TREATMENT	K	FILTER A	FILTER B	SE	T
Respiration	18	18.4	17.7	2.5	0.3

Table 5. Oxygen consumption of hypolimnetic water samples measured by concentrating the particulates on two different types of membrane filters. Type A are Gelman type GN-6 filters. Type B are Gelman type Dm-450 filters. Units and symbols as in Table 1.

TREATMENT	K	D	SE	T
Lake water	137	-0.77	1.06	-0.72
Filter 250	204	-0.52	0.44	-1.20
Filter 500	214	0.01	0.11	0.11

Table 6. Comparison of the difference in respiration rates (D) measured between duplicate samples and the time required to filter each sample. Samples were incubated without a filter (lake water), incubated after 250 ml of sample were concentrated on a filter (+250) and after 500 ml were filtered (+500). The statistic ($\bar{D}$) is the average difference in respiration rate ($mg/m^3/day$) between the samples which took the shorter amount of time for filtration, and the respiration rate of the second sample in the pair. The difference in respiration rate of samples to which no filter was added (water only) is simply the difference between the rate of the sample filled first and the pair filled second. This comparison serves as a control of non-filter influences. None of the T values is significantly different from zero. The variations in filter time did not influence the measured rates of respiration.

Fig. 1. Comparison of respiration rates measured using the filtration technique to concentrate samples of 250 ml and 500 ml, with rates measured by incubating unconcentrated water samples for 24 hours. The line is the 1:1 line. The slope of the rates measured with the filtration technique regressed against the rates measured by incubating unfiltered samples is not statistically different than 1.0.

However at higher rates the samples do deviate significantly from the expected line and this observation should be tested in future work.

(◇ 250 ml, ◆ 500 ml).

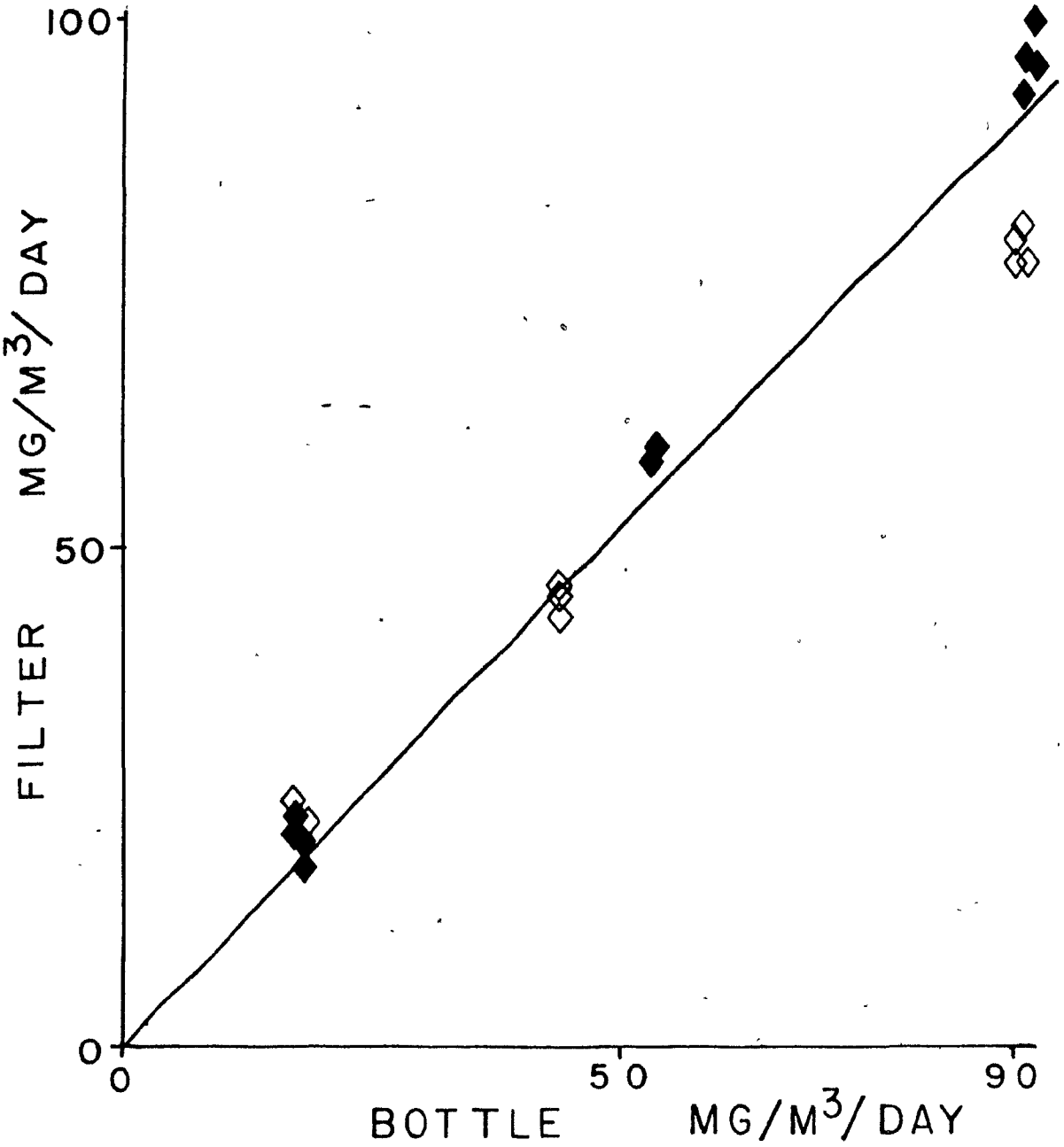
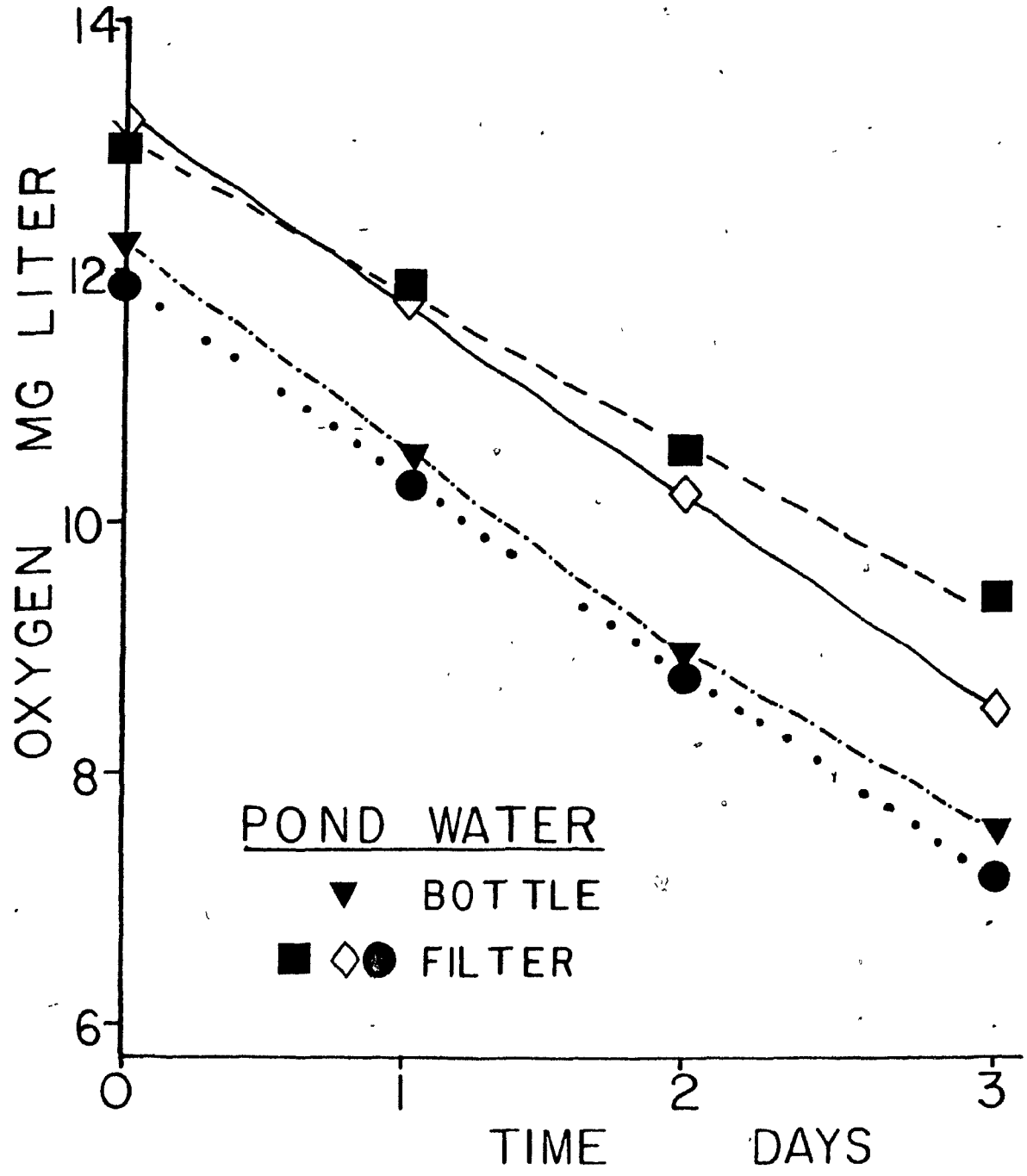
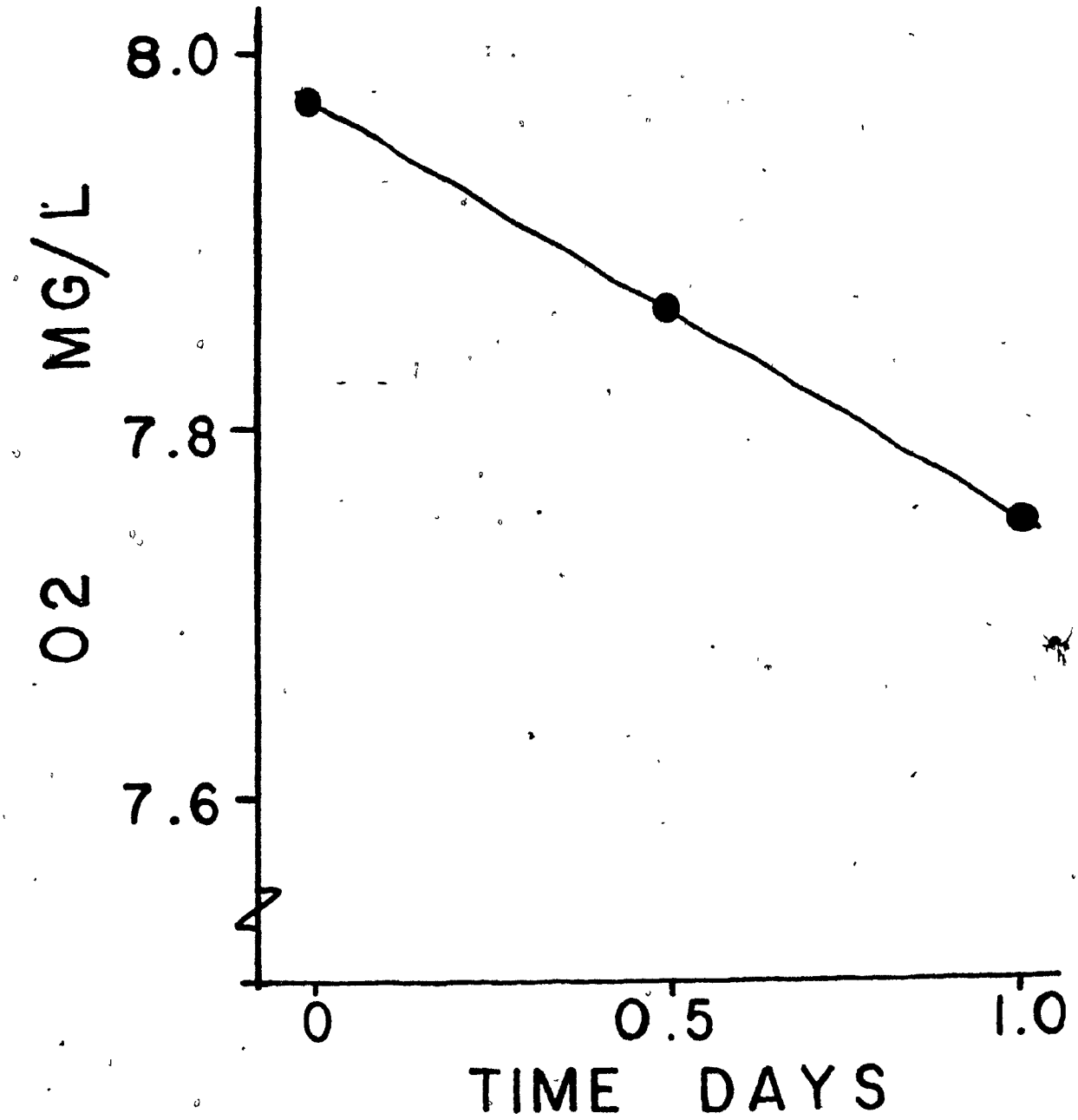

100
50
0
FILTER MG/M3/DAY
0
50
90
BOTTLE MG/M3/DAY

Fig. 2. Changes in oxygen concentration measured over periods of 1 to 3 days in samples of pond water, pond water plus a filter containing 250 ml of particulates (Fig. 2a) and hypolimnetic samples containing filters with 500 ml of filtered material (Fig. 2b). Each point is the mean of duplicate or triplicate determinations. The respiration rate did not change during the experiments.


14
12
10
8
6
OXYGEN MG LITER
0
1
2
3
TIME DAYS
POND WATER
BOTTLE
FILTER


8.0
7.8
7.6
O2 MG/L
0
0.5
1.0
TIME DAYS

CHAPTER FOUR

IS HYPOLIMNETIC OXYGEN CONSUMPTION INFLUENCED BY THE AMBIENT CONCENTRATION OF OXYGEN?

INTRODUCTION

Several studies of freshwater systems have described the impact of sewage and nutrient discharge upon the concentrations of dissolved oxygen in lakes and rivers [Varga and Fallis 1972; Dillon et al 1978; Liu 1978]. Building upon these descriptive studies, researchers have attempted to build simple models to predict quantitatively how oxygen levels will change through time as human activities alter the productivity of surface waters. In lakes, many studies have documented large seasonal changes in oxygen below the thermocline [Birge 1907; Birge and Juday 1911; Thienemann 1925; Hutchinson 1938,1957]. Therefore models of oxygen levels in lakes have focused upon the hypolimnion of lakes. Despite the numerous investigations of hypolimnetic oxygen depletion (HOD), there is very little agreement among various authors about what factors influence HOD. Nor can modellers agree upon how to predict the changes in oxygen concentration.

This paper tests the hypothesis that the rate of hypolimnetic oxygen depletion and its component processes - respiration by the sediments and respiration in the water column - are not influenced by the ambient level of oxygen in the hypolimnion. If these hypotheses are correct then HOD should be modelled as a zero order chemical process, and the seasonal change in oxygen will be linear through time.

The dependence of oxygen consumption upon ambient levels of oxygen is not a new subject for investigation. Our work was spawned by the numerous conflucting results presented by previous studies [Hutchinson 1938; Riley 1939; Edmondson 1966; Hargrave 1971; Lasenby 1975; Nicholls 1975; Burns 1976; Stewart 1975] rather than the lack of prior investigation. In addition to presenting new results which test the hypothesis, an attempt will also be made to explain why previous studies have drawn such conflicting conclusions.

METHODS

1. Hypolimnetic Oxygen Concentration

During 1979 and 1980, measurements of hypolimnetic oxygen were made on 11 lakes located in the eastern townships of Quebec Canada (Fig. 1). Before any stratum of the hypolimnion became anoxic, each lake was sampled between 6 and 10 times at approximately regularly spaced intervals during the period of thermal stratification. Samples were collected in one vertical series over the deepest location in the lake. Water samples were pulled from between 8 and 15 discrete depths using a 1 litre metallic sampling bottle or a 3 litre VanDorn. In 1980 the bottle samples for oxygen were replicated at 5 depths in each lake using a peristaltic pump. No statistically significant bias was observed between samplers. Under highly stratified conditions, replicated oxygen samples, from different VanDorn samples taken from the same depth, on the same date, could

differ by as much as 0.5 mg/L. However the variation was usually much less. From each sampler, duplicate 55 mL bottles were filled slowly and allowed to overflow at least 200 mls. Winkler reagents [Carpenter 1965] were added immediately. After the samples were agitated twice and the manganous hydroxide flock had settled, the samples were acidified with 0.5 ml of 10N H_2SO_4. Subsamples of 25 mL were titrated with a microburette using 0.15 N $Na_2S_2O_3$ standardized at regular intervals against 0.005 N KIO_3. The end point of each titration was detected using a photometric endpoint detector coupled to a microvolt meter similar to that described by Bryan et al [1976]. Oxygen values were calculated including a correction for the reagent blank [Carpenter 1965] and correcting for the volume of the subsample. Each oxygen value reported is the mean of duplicate samples from the same sampler. To reduce errors which might be caused by changes in the analytical reagents, stock solutions of all reagents were prepared at the beginning of each summer. The same batch of reagents was used for all subsequent sampling.

2. Water Column Respiration

Respiration in the hypolimnetic water column was determined using a simple method of concentrating particulate matter on a filter. On each sampling date water samples were collected from 5 depths within the hypolimnion of each lake. Since the order in

which sample bottles are filled may influence the concentration of oxygen [Tschumi et al 1977] duplicate glass-stoppered bottles were filled simultaneously by splitting the flow from the sampler using a 'Y' joint and short lengths of tubing. At each depth, this process was repeated twice. An additional 2 litres of water collected from the same depth was also placed in a separate container. All of these samples were placed in an incubator held within 3°C of the temperature from which the samples were obtained. On the shore of the lake four, 250 or 500 mL samples were filtered through 47 mm diameter, 0.45 µm filters at low pressure. Each filtration was stopped just before the filter dried. One filter was rolled with forceps and dropped into each of the 4 bottles which were filled with water from that depth. To one bottle from each pair of samples which were filled simultaneously, 200 µL of 0.8N NaN_3 were added to stop all respiratory activity. The bottles were quickly returned to the cooler and stored in the dark at the in situ temperature. This process was repeated 5 times - once for the samples collected from each depth.

Approximately 24 hours later, the samples were removed from the cooler and 200 µL of azide solution was added to the sample which had been respiring. Following one further hour of incubation, all samples were opened, the filters were removed, and Winkler reagents were added. Then the concentration of oxygen was determined using the same methods used to measure oxygen levels in the hypolimnion. The respiration rate in the water column was calculated by

subtracting the concentration of oxygen in the sample which had respired from the oxygen level of the control sample, correcting for the volume of material which was added to the sample attached to the filter. A more detailed discussion of this technique and a series of experiments that evaluate the method, is presented by Cornett and Rigler [1983a].

3. Sediment Respiration

Estimates of sediment respiration (SRR) and the influence of ambient oxygen levels were measured in situ. Since the study lakes all had a deep hypolimnion, and light penetration was very poor, this study was conducted within the metalimnion of two basins (Fitch Bay and Quinn Bay) of Lake Memphremagog [Ross and Kalff 1975; Carignan and Flett 1980]. In both study locations, the sediments were soft gyttja, visually similar to samples collected from within the hypolimnion. To measure oxygen consumption by the sediments, large 200 L barrels were modified by removing the bottom, and drilling sampling ports in the top and sides. The barrels were slowly lowered over the sediments with a hoist. A scuba diver watched each barrel to ensure that it remained vertical. The weight of the barrel caused the sides to penetrate at least 20 cm into the sediments. However to alter the volume of water within the barrel to ensure that it remained vertical. The weight of the barrel caused the sides to penetrate at least 20 cm into the sediments. However to alter the

volume of water within the barrel, wooden flanges were attached to the outside of the barrels to control the depth that the barrel sank into the sediments. The flange also ensured that the barrel did not shift during the experiments. After the barrels were in position, any resuspended material was allowed to settle for at least 1 hour. Then the holes and the sampling ports were sealed with rubber stoppers. Samples for oxygen were collected by scuba divers using 50 mL glass syringes. To sample the barrel, the diver removed the small (1.3 cm) stopper from the sampling port and dropped one end of a weighted (0.3 cm ID) piece of tubing into the barrel to a premarked depth. The other end of the tubing was attached to the glass syringe with a 3 way valve. Using the 3 way valve, 2 samples of 50 ml were drawn through the tubing into the syringe and then flushed into the water column. This procedure removed all air bubbles and any water from the syringe that did not come from the barrels. Using this technique, duplicate samples were taken from 3 depths equi-spaced between the sediments, and the top of the barrel. During the sampling, water from outside the barrel flowed into the barrel as the samples were withdrawn. The oxygen concentration outside the barrel was measured using samples collected with a syringe or a water bottle. The mass of oxygen added to the barrel during sampling was calculated and used to correct the measured oxygen values. At high oxygen levels this correction did not exceed 0.05 mg/L. However at low levels (< 1.0 mg/L), the correction was frequently greater than 0.3 mg/L. When the diver brought the samples to the boat, Winkler reagents were added and the syringe samples were treated identically

to the oxygen samples discussed earlier. The concentrations of oxygen reported are the average of the samples collected at the top, middle, and bottom of each barrel.

Control barrels were used to measure respiration in the water overlying the sediments. These barrels were treated identically to others except that the bottom of the barrel was not removed. Therefore the control barrels were not exposed to the sediments on which they were sitting.

Statistical Considerations

The lack of agreement in previous studies of the effects of oxygen concentrations upon respiration may partially reflect different and ambiguous criteria used to accept or reject the origional hypotheses. To ensure that this study does not suffer from a similar flaw, the criteria used in this study are outlined below.

The data collected from the sediment respiration studies and from the investigations of oxygen levels within the hypolimnion are time series measurements. A priori we predicted that the oxygen levels in the hypolimnion and in the barrels would decrease through time at a constant rate. However if the ambient concentration of oxygen influences the rate of oxygen consumption, this consumption

should decrease through time. Then the relationship describing the oxygen concentrations would be

$$O_2 = bo + b_1T + b_2T^2 \qquad (1)$$

where bo is a constant, b_1 and b_2 are regression coefficients, and T is the time at which the oxygen values were measured. For the hypolimnetic oxygen values time was measured in Julian days. The barrel experiments were referenced to the time, in days, elapsed since the first sample was collected. We will reject the hypothesis that ambient oxygen levels influence HOD or sediment respiration if the addition of the b_2T^2 term to the regression model does not explain significantly more variation in oxygen than the model in which that term was excluded. This test used a marginal (partial) F test in which the mean square attributable to the addition of the T^2 term after all other parameters were added, was compared to the error mean square of the complete regression model [Snedecor and Cochran 1967]. The water column respiration measurements were discrete measurements made over the period when the ambient oxygen levels decreased in the hypolimnion. If ambient oxygen concentrations exert a strong influence upon these rates, then we expect to see a statistically significant decrease in respiration throughout the season as oxygen levels drop. This hypothesis predicts that in each lake the coefficient of correlation between respiration and the Julian day on which the measurements were made should be significant.

In these experiments no attempt was made to control other factors while the influence of changing oxygen concentrations was investigated. This type of analysis was chosen because we are interested in predicting the properties of *in situ* processes and not those of manipulated laboratory systems. However, it could be argued that other factors influenced the results and our observations do not reflect the influence of oxygen concentrations. To minimize the influence of this type of argument, the parameters discussed earlier were measured in lakes in which the concentrations of oxygen decreased to levels close to zero and in "control" lakes where the ambient oxygen concentrations were greater than 8.0 mg/L. By comparing the results for the two groups of lakes the "other factors" argument can be minimized. However it can never be excluded.

RESULTS AND DISCUSSION

Hypolimnetic Oxygen Depletion

Statistically significant decreases in oxygen concentrations were observed in each of the 10 lakes sampled at every depth studied within the hypolimnion. Rates of HOD ranged from 0.01 mg/L/day to 0.23 mg/L/day. Higher rates were observed in shallow and more eutrophic lakes. In lakes Brompton, Massawippi, Orford, and Stukely, oxygen concentrations were always greater than 8 mg/L until very late in the

summer when the lowest concentrations of between 7 and 8 mg/L were measured. In these lakes all previous studies suggest that the high oxygen levels should not inhibit respiration [Hutchinson 1938; Hargrave 1971; Lasenby 1975; Nicholls 1975; Stewart 1975]. The results from these four lakes are consistent with our expectations. In no lake were significant deviations from a simple linear model statistically significant during the two years of investigation. Lake Stukely is typical of the pattern observed (Fig. 2a).

In five study lakes (Lovering, Truite, Little Magog, and Fitch Bay and the north basin of Lake Memphremagog), oxygen changed from 10 mg/L in the early summer to less than 2.0 mg/L before the lakes turned over in the fall. The hypolimnion of three of the lakes went anoxic. In four of these lakes no statistically significant changes in the rate of HOD were observed during either summer of this study. The observations for Lac Lovering are representative of the patterns measured in these four lakes (Fig. 2b). Oxygen concentrations were in excess of 10 mg/L after stratification was established, and they decreased to levels below 1 mg/L by the end of the summer. The second term of the polynomial regression was not a significant predictor of the O_2 concentrations. Only a linear model was necessary (Table 1). In the central and north basin of Lake Memphremagog, statistically significant deviations from linearity were observed (Table 2). In 1979 and 1980 oxygen concentrations dropped to values less than 3 mg/L in 6 strata studied in north basin (Fig. 3b). Because of the large volume of the central basin hypolimnion and the lower temperature, oxygen levels were always greater than 7.5 mg/L in

1979 and 1980 (Fig. 3a). The polynomial regression model improved the fit to data from almost all of the strata studied in north basin in 1979. Despite the fact that the concentrations of oxygen decreased to similar low levels in 1980, the polynomial model only improved the fit at 4 of the 7 depths investigated (Table 3). Measurements of HOD in the central basin of Lake Memphremagog show a similar nonlinear pattern, despite the fact that oxygen levels never decreased below 7 mg/L at any depth (Fig. 3b). Therefore the observed change in the oxygen deficit in the north basin does not appear to result from the decrease in ambient oxygen concentrations. If such a conclusion were justified, the polynomial model would not have improved the fit to the data from the central basin, and the model would improve the fit to all of the strata in north basin in both years of study. The polynomial term also would be significant in the regression that examined data from the deepest strata in north basin because oxygen concentrations in these strata were the lowest observed. The change in the rate of oxygen depletion in these two basins may be a result of changes in the input of organic matter, or may result from variations in the amount of oxygen transported into the hypolimnion by turbulent mixing. These two basins were the largest systems studied, and the transport of oxygen exceeded 10% of the observed change in oxygen concentration during the period of study [Cornett and Rigler 1983b].

In this study the simple linear regression of oxygen concentrations against time in Julian days, fit the observed oxygen values very well. In the 110 strata studied in 1979 the linear regression explained an average of 92.7% of the variation in oxygen concentrations, and R^2

ranged from 0.996 to 0.692. In 1980 the average R^2 was 0.954 and ranged from 0.999 to 0.867. Small deviations from the regression lines may reflect real short term changes in the rate of hypolimnetic oxygen consumption, or they may be due to errors introduced during the collection or analysis of the samples. The strata in which the linear model produced the poorest fit were characterized by one or two measured oxygen concentrations that increased above levels measured on a previous date. These anomalous values were included in this analysis. However the values are believed to reflect analytical errors rather than negative rates of oxygen consumption.

Previous investigations of seasonal changes in HOD by Hutchinson [1938], Riley [1939], Hargrave [1971] and Burns [1976] all reported significant changes in HOD which the authors attributed to the changes in ambient DO concentrations. Studies by Edmondson [1966], Lasenby [1975], Nicholls [1975], and Stewart [1975] led these authors to the opposite conclusion, and this analysis supports their findings. One explanation for the divergent results of different studies is that each lake has different properties. However this argument cannot be correct because Hutchinson [1938] and Stewart [1975] both studied Lake Mendota, and they came to opposite conclusions. Examining the published analyses, the most obvious difference between authors was the way in which they handled the data. Hutchinson [1938], Riley [1939], Edmondson [1966], Hargrave [1971], Lasenby [1975] and Burns [1976] all examined changes in the volume weighted average hypolimnetic concentration of DO. Nicholls [1975], Stewart [1975] and this study analyzed the oxygen concentrations

measured in each individual stratum. Since many authors [Birge and Juday 1911; Hutchinson 1957] have shown that the deepest strata in a lake are anoxic long before the strata located just beneath the thermocline, any analysis of the average hypolimnetic oxygen concentration may include a large volume of the hypolimnion that is anoxic and cannot respire aerobically. This logic suggests that the dependence of HOD upon the ambient oxygen concentrations may be an artifact. This explanation appears to be consistent with the observations reported by previous studies. In their analysis of average oxygen levels, Edmondson [1966], Lasenby [1975], and Stewart [1975] did not report a dependence of HOD upon oxygen levels. They examined only changes in oxygen while the hypolimnia of their study lakes were not anoxic. In the studies of Lake Mendota [Hutchinson, 1938], Linsley Pond [Riley 1939], Lake Esrom [Hargrave 1971], and Lake Erie [Burns 1976] all of the authors stated that the hypolimnion went anoxic during their studies, or oxygen profiles reported by other investigators who also studied the lake confirm that this occurred [Birge and Juday 1911; Hutchinson 1957; Jonasson 1972]. These authors also reported that the hypolimnetic oxygen deficit decreased during the summer. Since the original Lake Mendota data used by Hutchinson [1938] were published by Birge and Juday [1911], this explanation was tested more rigorously by examining the change in oxygen concentrations in separate hypolimnetic strata using the same statistical procedures outlines earlier (Table 3). Oxygen depletion in Lake Mendota follows the same pattern reported by Nicholls [1975] and Stewart [1975] and observed in the lakes investigated during this study. The measured oxygen concentrations decreased at a constant rate until the observed values were less than 0.5 mg/L (Fig. 4). Rates of change in oxygen

concentration were not dependent upon the ambient concentrations (Fig. 4). The reported dependence of the rate of oxygen depletion upon ambient oxygen concentrations was an artifact.

Respiration in the Water Column

Since the total rate of hypolimnetic oxygen depletion did not depend upon ambient levels of DO, the components of the total should show similar results. In the 10 lakes during 1980, the measured rates of water column respiration ranged from 0.003 mg/L/day to 0.10 mg/L/day. Although differences in rates were observed on different sampling dates (Fig. 5), these differences cannot be attributed to changes in the ambient concentration of DO. Water column respiration did not decrease as the concentrations of oxygen in the hypolimnion dropped (Fig. 6). There was no significant correlation between water column respiration and the oxygen concentration at which the respiration experiments were conducted (Fig. 6). In many experiments started when the ambient level of oxygen was less than 2 mg/L, the respiration rates were as high or higher than rates measured at oxygen levels greater than 8 mg/L. These results are consistent with the conclusion of Zobell and Stadler [1939] influenced by ambient concentrations of oxygen over the range of concentrations from 0.3 mg/L to 36 mg/L.

Sediment Respiration

Since the rate of respiration of the entire hypolimnion, and respiration by within the hypolimnetic water column are independent of the ambient oxygen levels, the sediments, which are the second major sink for oxygen within the hypolimnion, must also exhibit similar characteristics. This observation is not supported by many studies of sediment oxygen consumption [e.g. Baity 1938; Berg et al 1962; Edwards and Rolly 1965; Hargrave 1969; Pamatmat 1971; Edberg and Hofsten 1973; Edberg 1976; Polak and Haffner 1978]. Of the more than twenty studies which have examined this question, the vast majority of studies have reported a strong dependence of sediment respiration upon the level of oxygen in the water lying over the sediments. Clearly an explanation of the difference between our observations and these studies of sediment oxygen consumption is required. At least three explanations of this discrepancy are possible. The hypothesis that the sediment are not responsible for a signigicant fraction of the HOD is not correct. Our studies [Cornett and Rigler 1983c], suggest that the sediments consume a significant proportion of the total oxygen consumed (>40%) in all of these lakes).

The second explanation concerns techniques used to measure respiration by the sediments. In almost all of the previous investigations of the influence of changes in ambient levels of oxygen upon sediment respiration, the sediments were manipulated and subjected to oxygen levels which changed much more rapidly than those observed in the hypolimnion of lakes. Rapid changes occurred during the handling of the sediment cores and during subsequent incubations. In addition, the

sediments may have been disturbed during the handling procedure. Resuspension or the release of reduced metabolites could significantly increase initial rates of oxygen consumption [Hargrave 1975]. And the rapid decrease in oxygen could induce diffusional limitations. In the hypolimnion, changes in oxygen are rarely greater than 0.2 mg/L/day, the sediments are not resuspended, and reduced substances are buried. The slow changes in oxygen within the hypolimnion also suggest that the gradients in oxygen concentration near the sediments, the thickness of the boundary layer, and the rate of diffusion across the sediment-water interface do not change rapidly. Constant in situ conditions are rarely reproduced in short, laboratory experiments. The sediment respiration experiments discussed below were designed to eliminate any sudden changes in sediment structure before and during the experiments. They were also designed to permit the rate that the concentration of oxygen changed to be manipulated. Then the hypothesis that the influence of ambient oxygen levels upon rates of sediment oxygen consumption is dependent upon the rate that the oxygen concentration changes can be tested.

An alternative explanation of these observations - that the HOD is independent of the ambient oxygen concentration while sediment respiration is not - postulates that measurements of oxygen concentration in the hypolimnetic water column do not reflect the concentrations near the sediment water interface. If the thickness of the boundary layer, the gradient in oxygen concentration, and the rate of transport across the sediment water boundary are constant during the period of thermal stratification then respiration by sediments would exert a constant

demand upon the supply of oxygen in the hypolimnetic water column. And the change in oxygen concentration in the hypolimnetic water column would not influence events at the sediment-water interface. This hypothesis predicts that the gradient in oxygen concentration vs distance from the sediment water interface should remain constant during the experimental incubations.

In both Fitch Bay and Quinn Bay oxygen levels within the sediment chambers decreased from initial concentrations to less than 0.5 mg/L in approximately 10-14 days. During the experiments the rate of oxygen consumption within the barrel was the same at all three depths sampled. Although gradients in oxygen as large as 0.3 mg/L were observed between sampling depths, there was no consistent gradient in oxygen from the top of the barrel to the sediment interface. These observations suggest that while the barrels were not mechanically stirred, water within the barrels mixed vertically during the experiments. The prediction that the gradient in oxygen concentration measured between 0.1 and 0.8 m above the sediment-water interface was constant during the experiment was not correct in any experimental enclosure.

In all experiments, the rate of sediment respiration decreased as the concentration of oxygen decreased (Fig. 7). The change in sediment oxygen consumption was most noticable below 3 mg/L. In each experiment a curvilinear polynomial regression significantly improved the regression of oxygen concentration vs time (Table 4). However even in these

relatively long experiments, the concentrations of oxygen decreased 5 to 50 times more rapidly than oxygen concentrations changed over the sediments of the hypolimnion outside the barrels (Fig. 7). The hypothesis that the degree of dependence of SRR upon ambient oxygen depends upon the rate at which the concentration of oxygen changes can be tested by plotting the linear regression coefficient (b_1) from the regression against the polynomial regression coefficient (b_2). The hypothesis predicts that b_2 should be correlated with the absolute value of b_1. This prediction is consistent with our results (Fig. 8). Sonzogni et al [1977] used a large in situ respirometer to measure oxygen consumption of the sediments in Lake Mendota. Their results, analyzed in a similar manner (Fig. 8), are consistent with the experiments conducted in Lake Memphremagog. However these tests are not absolute because at least part of the observed relationships results from the statistical covariance between b_1 and b_2. Further tests of this hypothesis will require new methods, or systems where the oxygen consumed by the sediments can be replaced so that the oxygen concentrations approximates natural conditions. However these experiments, and the work of previous investigators who demonstrated that the rate of sediment respiration is proportional to oxygen concentration, suggest that sediment oxygen will only be strongly influenced by ambient oxygen levels when the structure of the sediments is disturbed or the oxygen levels above the sediments change more rapidly than the rate of change within the hypolimnia of lakes.

YEAR	LAKE	D	N	SSR	SSb1	SSb2
1979	LOVERING	16	7	.038	50.3***	0.022NS
		17	7	.191	53.6***	0.115NS
		18	7	.191	53.6***	0.115NS
		20	7	.737	59.6***	0.058NS
		22	7	.538	10.1***	0.077NS
1980	LOVERING	16	13	.624	107.9***	0.692NS
		17	13	.956	130.4***	0.000NS
		18	14	1.741	136.2***	0.007NS
		20	14	1.132	141.7***	0.692NS
		22	14	2.053	145.4***	0.692NS
1979	STUKELY	16	6	.006	3.4***	.006NS
		18	6	.033	2.4**	.000NS
		20	6	.020	2.6**	.001NS
		24	6	.045	2.2**	.003NS
		28	6	.036	2.3***	.006NS
1980	STUKELY	16	15	.120	12.7***	.000NS
		18	15	.076	13.9***	.004NS
		20	14	.111	14.1***	.020NS
		24	14	.034	15.9***	.006NS
		28	12	.045	15.0***	.009NS

Table 1. Abbreviated analysis of regression tables for regressions fit to oxygen concentrations measured in each stratum over the range 12.0 to 0.5 mg/L in Lakes Lovering and Stukely during 1979 and 1980. Depths are given in meters below the surface of the lake. N is the number of duplicate samples collected. SSR is the residual sum of squares which is not explained by the regression model. The other columns are the sum of squares attributable to the time squared term (SSb2) after the linear term (SSb1) was added to the regression. Significance at the 5% level is denoted by 1 star, at the 1% level (**) and at the 0.1% level (***). NS implies that the regression coefficent is not different than zero. These results are typical of the measurements made in other lakes.

YEAR	LAKE	D.	N	SSR	SSb1	SSb2
1979	NORTH	16	7	0.452	57.8***	2.13**
		18	7	0.586	57.3***	1.58*
		20	7	0.549	59.5***	1.08*
		22	7	0.504	56.0***	1.58*
		24	7	0.224	53.8***	1.91**
		26	7	0.860	60.2***	1.46NS
		28	7	0.979	61.6***	2.16*
1980	NORTH	16	11	0.209	58.1***	0.31**
		18	11	0.160	60.6***	0.26**
		20	11	0.294	58.2***	0.14NS
		22	7	0.079	44.8***	0.17*
		24	11	0.461	63.3***	0.46*
		26	7	0.048	54.8***	0.01NS
		28	11	0.233	70.7***	0.12NS
1979	CENTRAL	20	8	0.147	9.65***	0.043NS
		22	8	0.093	7.05***	0.083*
		25	8	0.036	5.70***	0.003NS
		28	8	0.028	4.34***	0.000NS
		30	8	0.017	1.59***	0.000NS
		45	8	0.035	1.38***	0.090*
		60	8	0.040	1.23***	0.027NS
1980	CENTRAL	20	8	0.042	8.82***	0.459***
		22	8	0.081	5.92***	0.249*
		25	7	0.194	4.49***	0.194*
		28	9	0.057	4.12***	0.110*
		30	6	0.025	1.45***	0.014NS
		35	6	0.017	0.99***	0.011NS
		60	7	0.016	0.98***	0.041*

Table 2. Analysis of regression table for the polynomial models fit to the oxygen concentrations measured during 1979 and 1980 in the hypolimnia of the north and central basins of Lake Memphremagog. Columns and symbols are the same as those in Table 1.

DEPTH	N	SSR	SSb1	SSb2
5	10	1.733	5.03**	0.089NS
12	7	0.284	57.7***	0.284NS
15	6	0.300	59.42***	0.245NS
18	5	0.709	50.75***	1.50NS
20	5	0.225	38.68***	2.75*
22	4	0.274	28.89*	0.000NS
H	11	2.14	59.38***	18.3***

Table 3. Analysis of the polynomial regressions fit to the oxygen concentrations measured in each stratum of the hypolimnion of Lake Mendota during 1906 (data from Birge and Juday 1911). The depth 'H' is the volume-weighted oxygen concentration below 5 m analysed by Hutchinson (1938). Oxygen concentrations measured at 20 m deviated from the linear model because of the low concentration measured in a single sample. Columns and symbols are the same as those in Table 1.

SAMPLE	N	SSR	SSb1	SSb2
F163-1	14	1.391	59.82***	3.71***
F163-2	14	0.388	85.88***	9.34***
F163-3	14	0.610	57.53***	1.25***
F163-C	12	0.008	1.06***	0.00NS
Q193-1	18	1.006	112.50***	4.92***
Q193-2	18	0.242	17.50***	6.90***
Q193-3	18	0.050	3.74***	0.76***
Q213-1	14	0.220	61.22***	5.46***
Q213-2	14	0.980	51.97***	1.08***
Q213-3	14	0.289	31.19***	0.90***
Q213-4	14	0.419	42.00***	1.00***
Q213-C	14	0.143	1.25***	0.04NS
Q224-1	8	0.203	39.06***	3.78***
Q224-2	8	0.060	51.22***	0.33***
Q224-3	8	0.175	49.02***	1.19***

Table 4. Polynomial regressions were fit to the change in the average concentration of oxygen measured within each barrel. The replicates are labelled 'F' if the experiment was conducted in Fitch Bay and 'Q' if the experiment was conducted in Quinn Bay. The number following the letter indicates the Julian day on which the experiment started. The number after the hyphen indentifies the replicate. 'C' is used to indicate that the barrel was a control which only measured respiration in the water (see text). The barrels were steel drums lined with epoxy so that no metallic surfaces were exposed. The variability in the values of b (see Fig. 8) was induced by decreasing the volume of water in the barrel. The smaller volume of water water contained a smaller reservoir of oxygen. The oxygen was depleted more more rapidly per unit volume.

Fig. 1. The lakes investigated during this study are located approx. 100 km south-east of Montreal, Canada, just north of the international border with the United States.

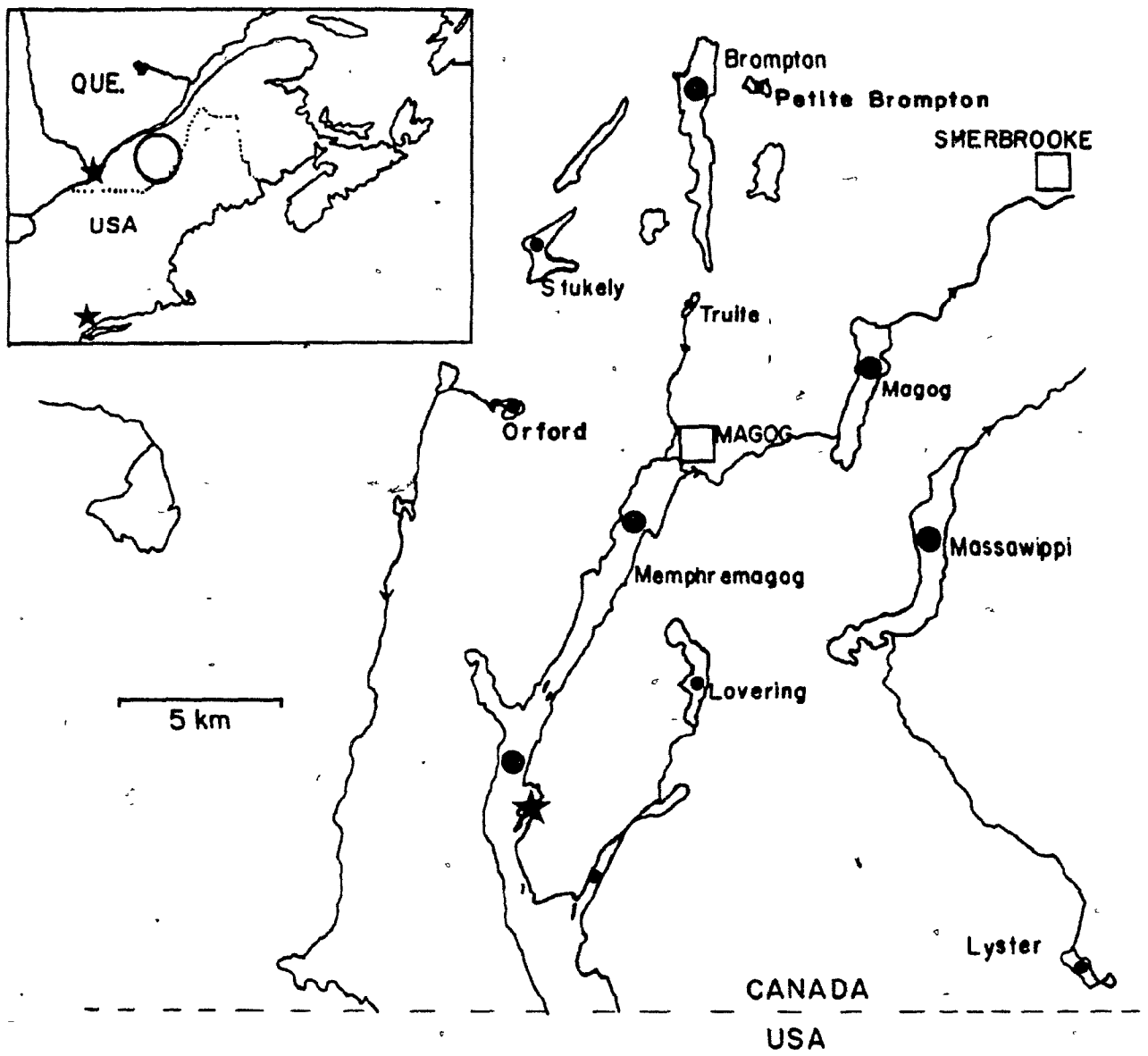

QUE.
USA
Brompton
Petite Brompton
SHERBROOKE
Stukely
Truite
Magog
Orford
MAGOG
Memphremagog
Massawippi
Lovering
5 km
Lyster
CANADA
USA

Fig. 2a. Oxygen concentrations measured in Lake Stukely at 16 m (upper panel) and 28 m (lower panel) during 1979 (solid square or circle) and 1980 (open square or circle).

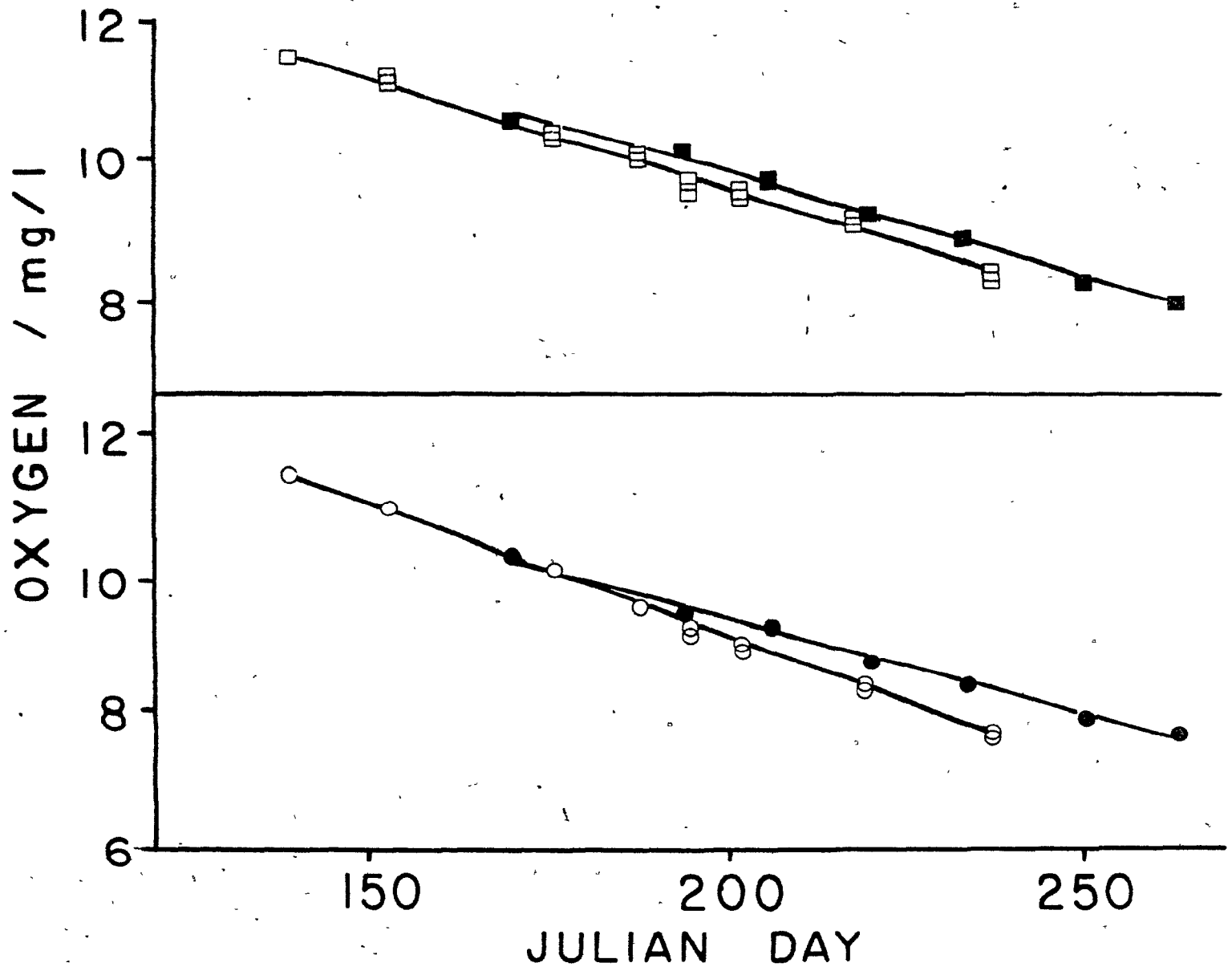

12
10
8
12
10
8
6
OXYGEN / mg/l
150
200
250
JULIAN DAY

Fig. 2b. Change in measured oxygen concentrations in Lake Lovering at 16 m (upper panel) and 20 m (lower panel) during 1979 (filled square or circle) and during 1980 (open square or circle).

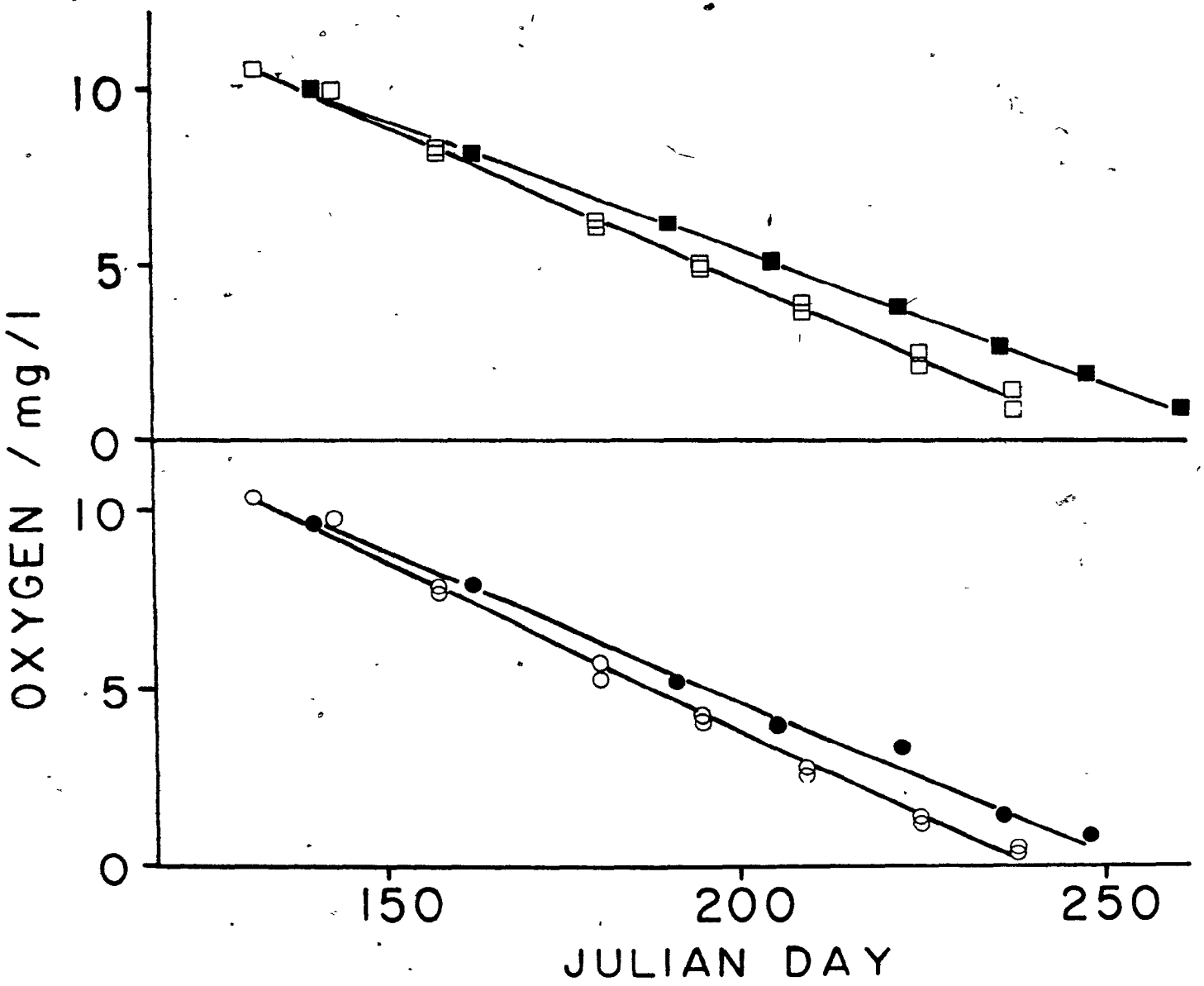

10
5
0
10
5
0
OXYGEN / mg/l
150
200
250
JULIAN DAY

Fig. 3a. Concentrations of oxygen measured at 20 m (upper panel) and 28 m (lower panel) during 1979 (solid symbol) and during 1980 (open symbol) in the hypolimnion of the central basin of Lake Memphremagog.

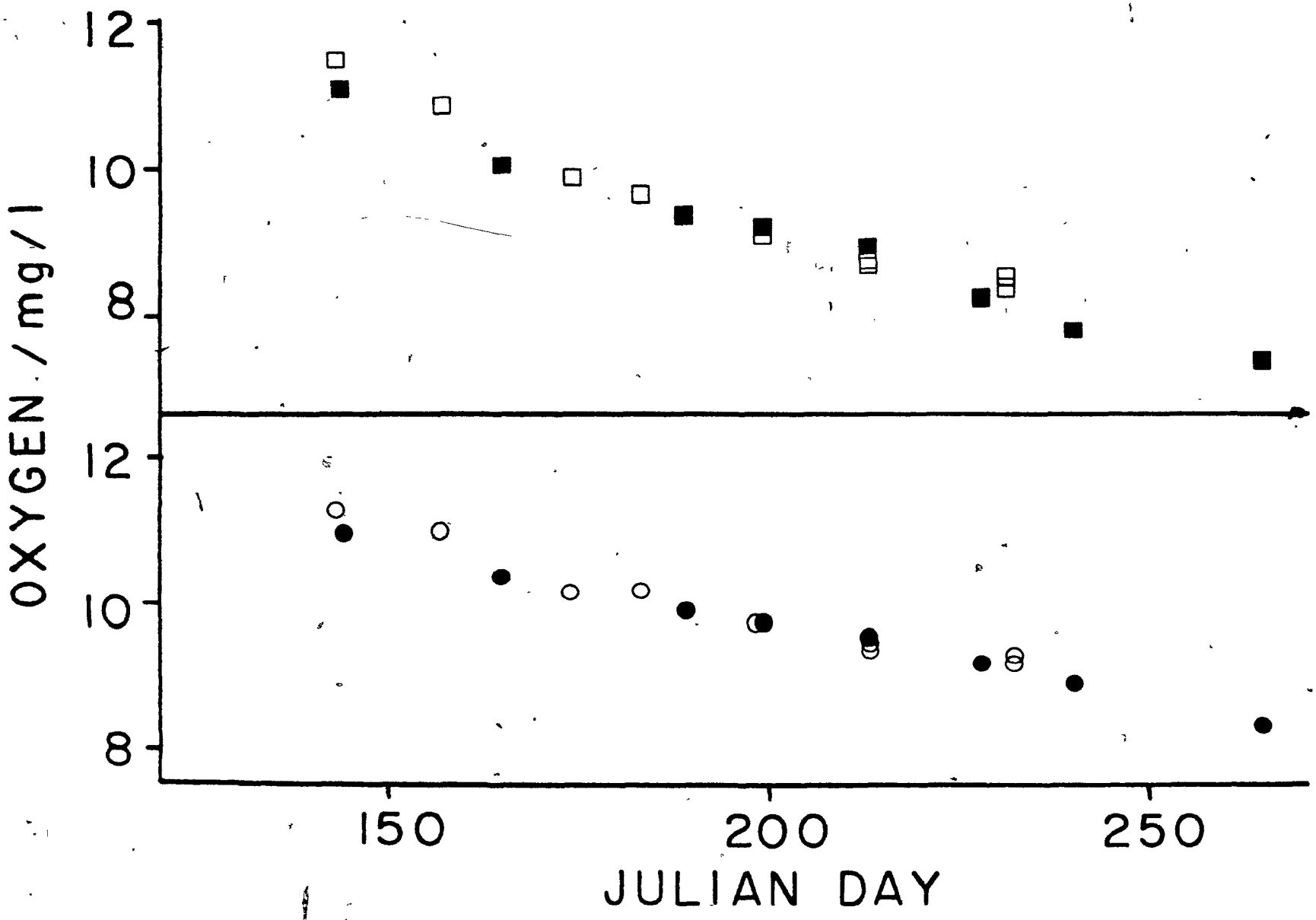

12
10
8
12
10
8
OXYGEN / mg/l
150
200
250
JULIAN DAY

Fig. 3b. Oxygen concentrations measured in the north basin of Lake Memphremagog (symbols and depths are the same as in Fig. 3a).

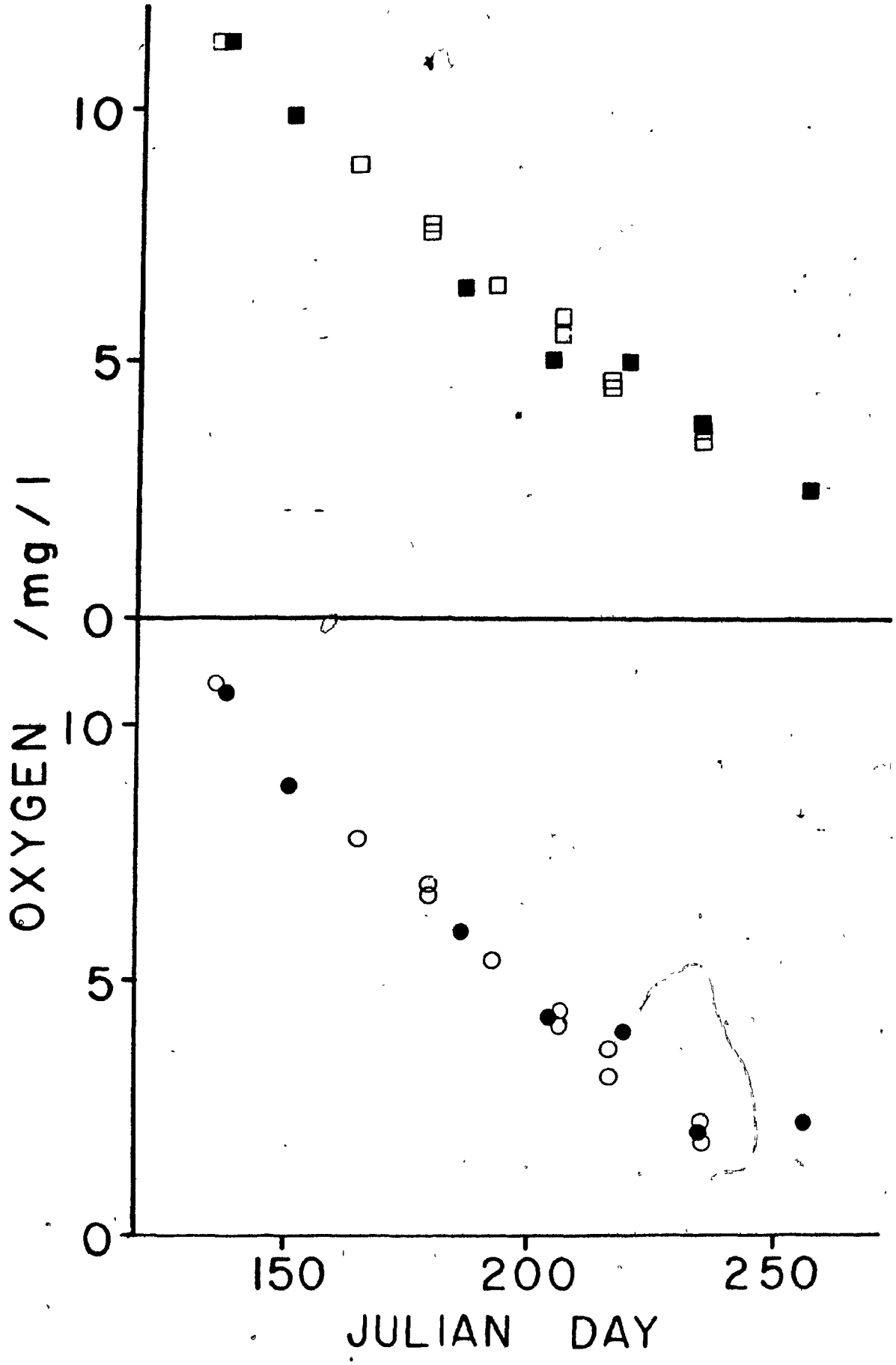

10
5
0
10
5
0
OXYGEN /mg/l
150
200
250
JULIAN DAY

Fig. 4. Oxygen concentrations in the hypolimnion of Lake Mendota during 1906 (▲ 22 m, ■ 18 m, ● 12 m, ◆ 20 m, ◇ volume-weighted average below 5 m. Data from Birge and Juday 1911).

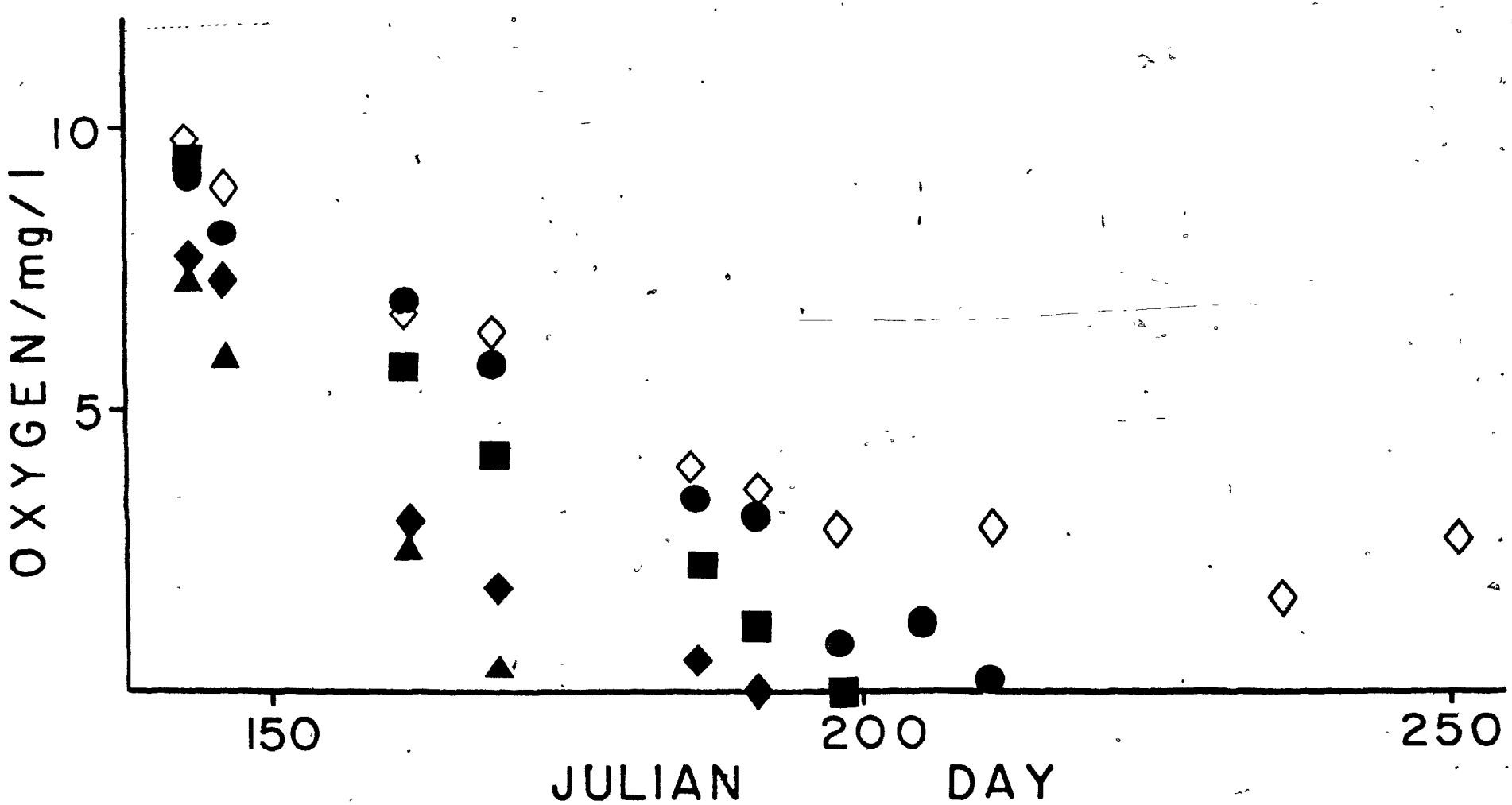

OXYGEN/mg/l
10
5
150
200
250
JULIAN DAY

Fig. 5. Average rates of water column respiration in Fitch Bay (open circles) Lake Lovering (◆), and Lake Brompton (●) plotted against the Julian day on which the experiments were conducted. The error bars are 1 standard error.

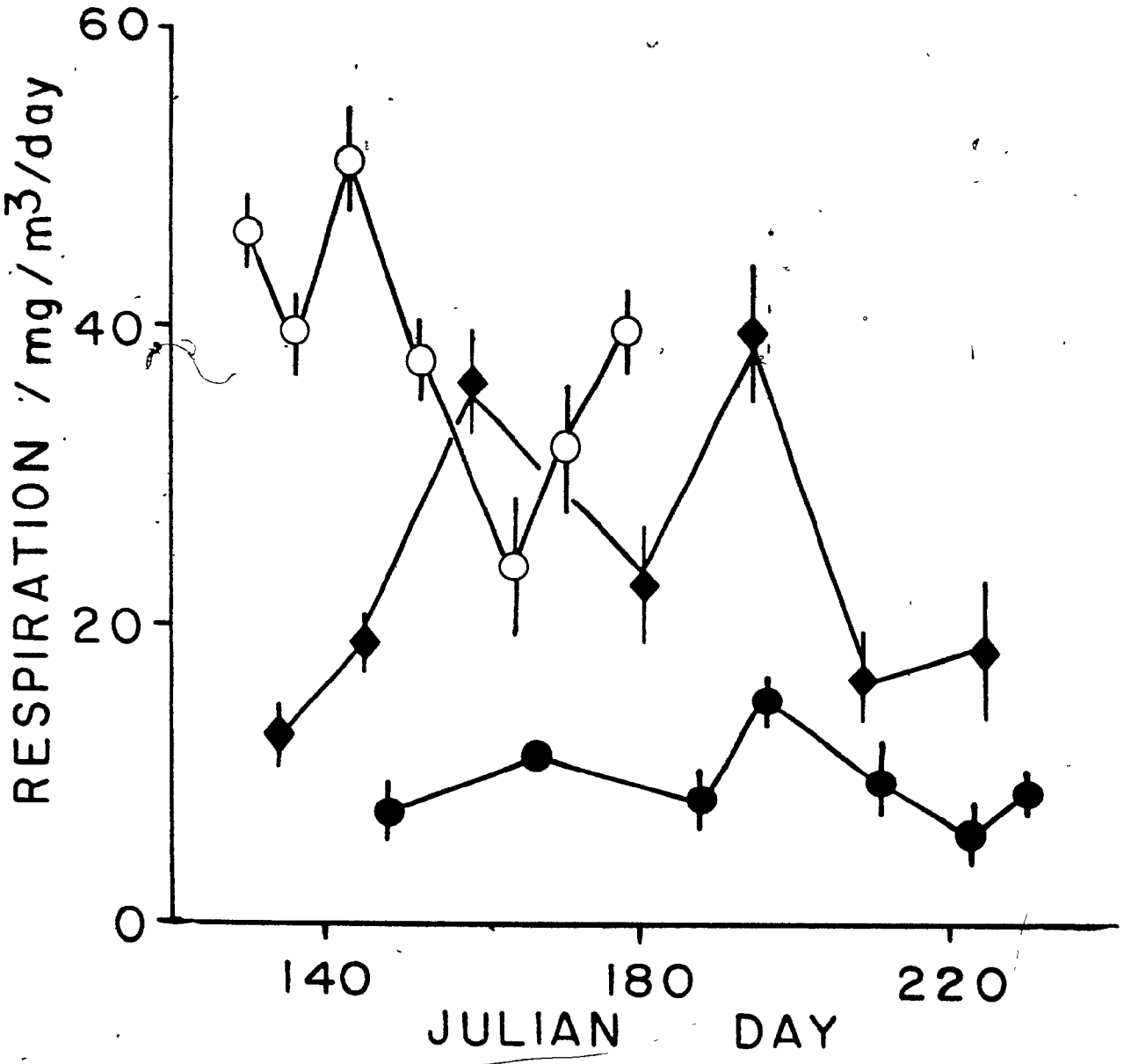

60
40
20
0
RESPIRATION / mg / m3 / day
140
180
220
JULIAN DAY

Fig. 6. Rates of respiration measured in the hypolimnetic water column of Lake Lovering and Fitch Bay during 1980 plotted against the oxygen concentration measured at the start of the experiment.

(● Lake Lovering, O Fitch Bay)

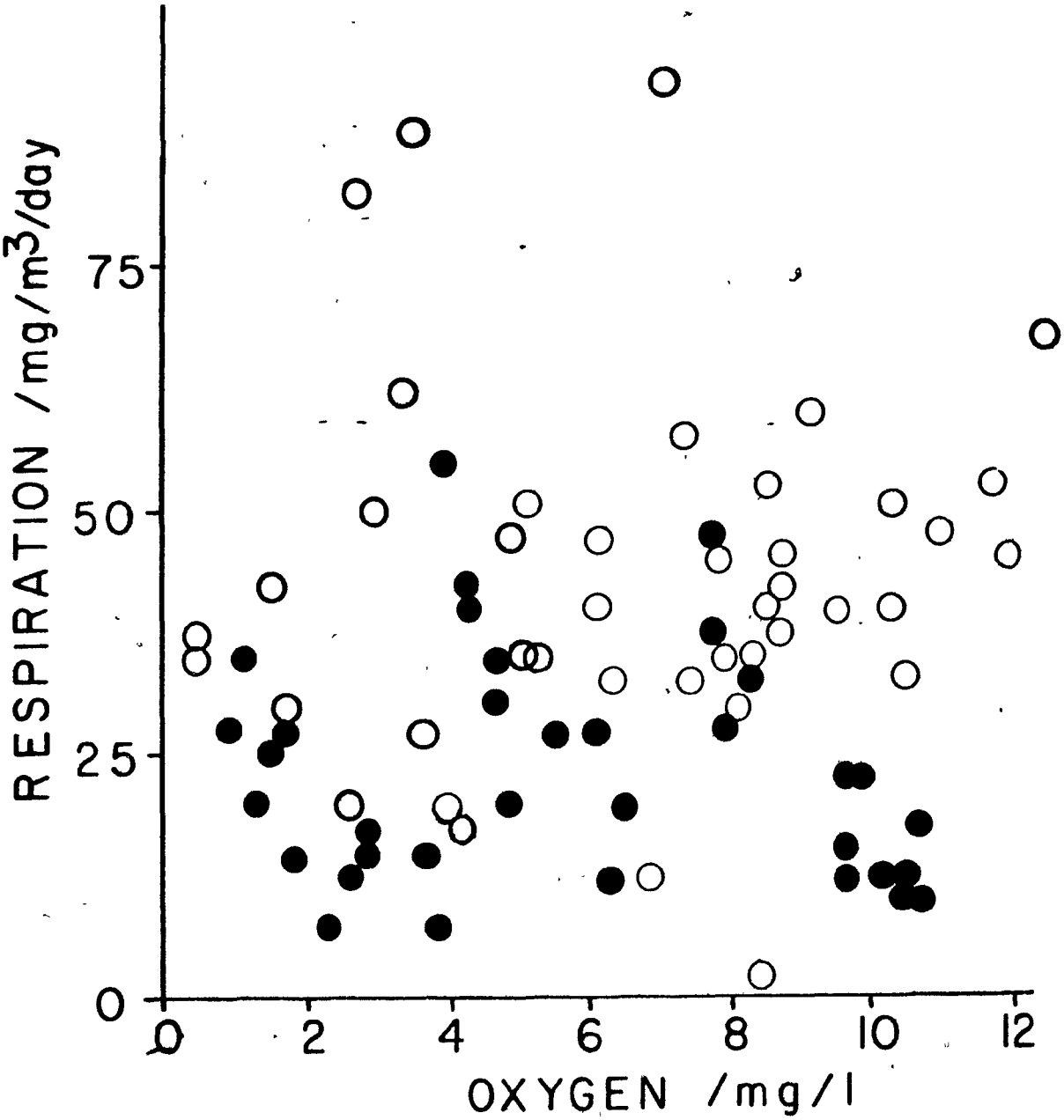

RESPIRATION /mg/m3/day
75
50
25
0
0
2
4
6
8
10
12
OXYGEN /mg/l

Fig. 7. Change in oxygen concentrations during a sediment respiration experiment (Q213 1- ● , 2- ▲ , 3- ♦ , C- ○).

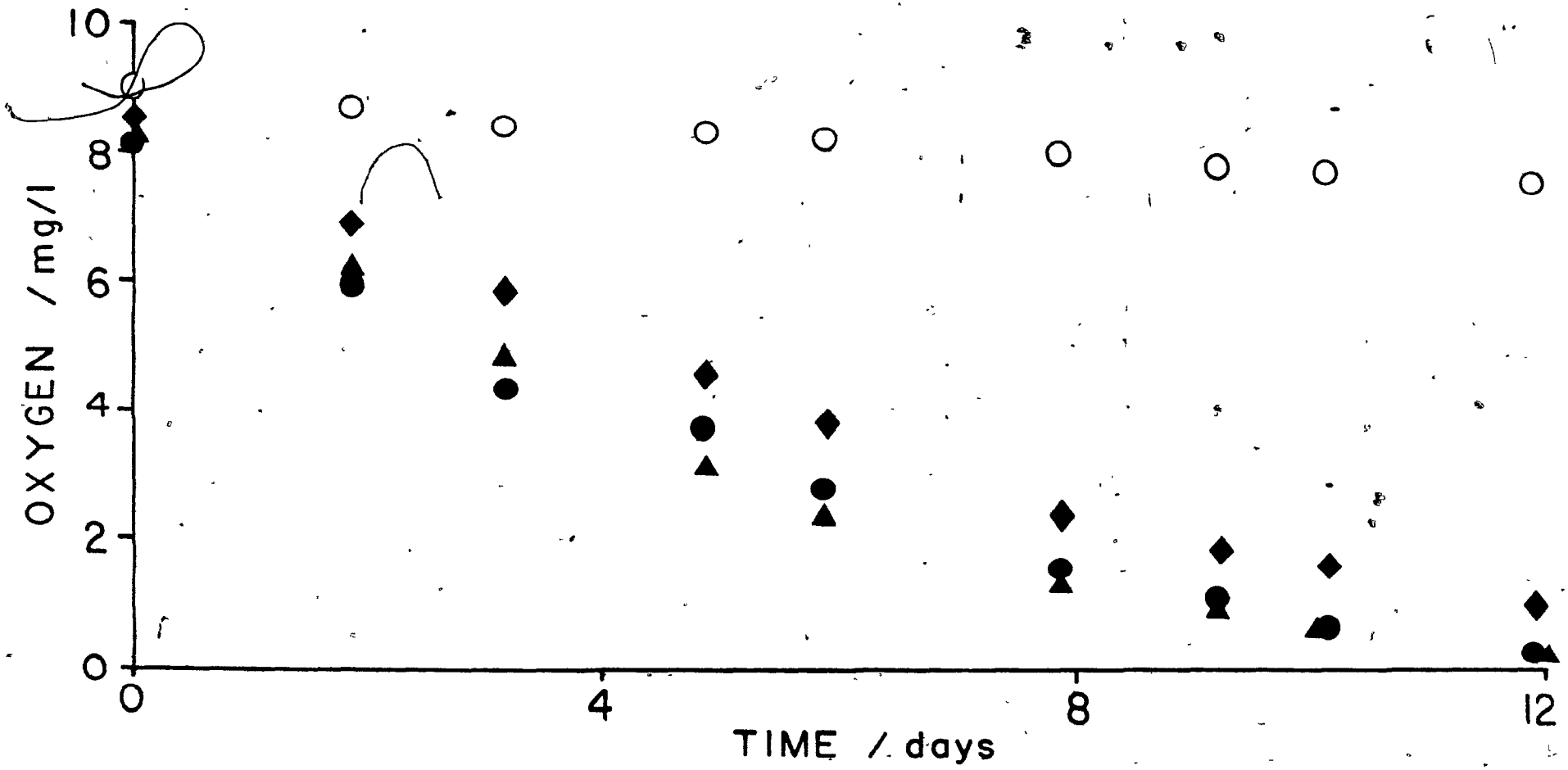
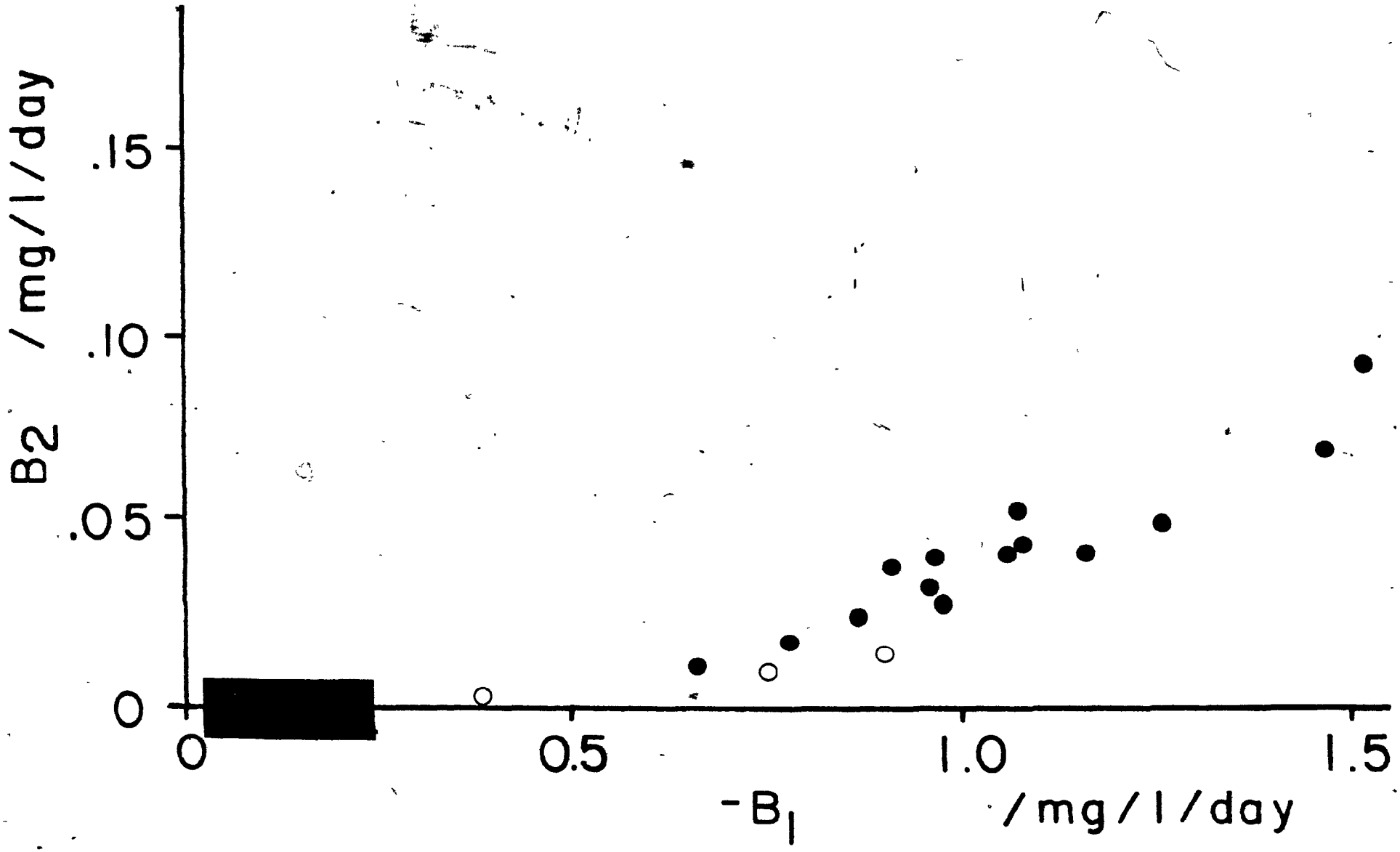

10
8
6
4
2
0
OXYGEN / mg/l
0
4
8
12
TIME / days

Fig. 8. Plot of the linear regression coefficient (B1) against the quadratic regression coefficient (B2) measured during all of the sediment respiration experiments in this study (●), and in those of Sonzogni et al (1977) (○). The broad black bar covers the range of values of rates of oxygen depletion measured in the hypolimnion of the study lakes.


B2 /mg/l/day
.15
.10
.05
0
0
0.5
1.0
1.5
-B1 /mg/l/day

CHAPTER FIVE

HYPOLIMNETIC OXYGEN DEFICITS:

THEIR PREDICTION AND INTERPRETATION

INTRODUCTION

Limnology, the study of inland waters, has traditionally been primarily a descriptive science concerned with documenting population fluctuations in time or the interactions between species. Recent lake studies have documented the overexploitation of many commercial fish stocks, reductions in water quality caused by excessive anthropogenic nutrient enrichment, and the destruction of fish populations in some soft-water lakes by acid rain (Hasler 1947; Keleher 1972; Beamish et al 1975). These discoveries stimulated the development of empirical models which predict the impact of human activity, both present and future, upon the quality of lake water. Using existing empirical models, limnologists can predict sustainable fish harvest, algal biomass and clarity of surface waters, and the occurrence of blue-green algal blooms (Barica 1975; Dillon and Rigler 1975; Matuszek 1978).

Oxygen is another important parameter in lakes. Although the surface waters of most lakes are well oxygenated, decomposition of organic matter in the deeper strata (hypolimnion) of a thermally stratified lake consumes significant amounts of oxygen. Hypolimnetic oxygen depletion appears to be accelerated by nutrient enrichment (Edmondson 1966; Holtan 1972; Dillon et al 1978). Because anaerobiosis in the hypolimnion can release nutrients from the sediments, eliminate salmonid fisheries, and sometimes result in the production of hydrogen sulfide (Mortimer 1942; Burns and Ross 1972), it would be desirable to be able to predict the relationship between nutrient loading to lakes and the minimum concentration of dissolved oxygen in the hypolimnion. We describe here a simple empirical method of accurately predicting the areal hypolimnetic oxygen deficit (AHOD), the first step toward the prediction of hypolimnetic oxygen concentrations.

Earlier in this century, limnologists concluded that, all other factors being equal, the morphometry of a lake would affect the decrease in dissolved oxygen in the hypolimnion. A lake with a thicker hypolimnion would suffer less from oxygen depletion than a lake with a thin hypolimnion. In an attempt to correct for differing morphometry of lakes, Hutchinson (1938), Strom (1931), and Thienenmann (1928) proposed that the oxygen deficit be expressed in areal terms. They reasoned that, if two lakes were equally productive but differed in hypolimnetic thickness, their oxygen deficits would be the same if expressed as the rate of oxygen depletion per square meter of surface area of the plane delimiting the upper boundary of the hypolimnion. From a study of only four lakes, Hutchinson (1938) seemed to demonstrate the promise of the AHOD in comparing the surface-water productivity and trophic status of lakes. However, subsequent studies (Deevey 1940; Sparrow 1966; Lasenby 1975; Rast and Lee 1978) failed to confirm his results. A simple proportionality between biomass in the epilimnion and AHOD does not appear to exist.

We have developed an alternative empirical model to predict AHOD as a function of phosphorus retention, the mean summer hypolimnetic temperature, and the mean thickness of the hypolimnion.

METHODS

Data for 12 lakes were gathered from the literature. We calculated the AHOD's using the method developed by Lasenby (1975). On each sampling date, we calculated the mass of oxygen in the hypolimnion by summing the product of the average measured oxygen concentration in each stratum, Gi, (in milligrams per cubic meter), multiplied by the volume of that stratum, Vi (in cubic meters). Dividing the total mass of oxygen by the surface area of the plane delimiting the upper boundary of the hypolimnion, H (in square meters), produced the mass of oxygen per square meter of hypolimnetic surface area, M (in milligrams per square meter).

$$M = (\quad ViGi)/H \qquad (1)$$

These values were regressed against the sampling dates (in Julian days), during the period when hypolimnetic metabolism was not limited by low oxygen concentrations, to determine the average areal rate of oxygen depletion (AHOD). We included only those data sets where the AHOD was measured by type 1 least-squares linear regression analysis with sufficient accuracy to define greater than 65 percent of the variation in the mass of hypolimnetic oxygen during the period of calculation.

Hutchinson's (1938) conceptual model of the AHOD implies that the fraction of surface-water productivity sedimented into the hypolimnion is constant in all lakes. Data presented by Rich and Wetzel (1972) and Lastein (1976) for Lawrence Lake and Lake Esrom suggest that this assumption is false. The sediment trap catch in Lake Esrom was approximately 47 percent of the annual areal pelagic productivity; a similar comparison in Lawrence Lake yielded only 20 percent. To eliminate this erroneous assumption from the AHOD model, we must compare the AHOD to the rate of sedimentation. Because

sedimentation is difficult to measure, it has been estimated in phosphorus models by retention. Areal phosphorus retention, Rp (in milligrams per square meter per year), can be calculated for any lake, from the mass balance model tested by Dillon and Rigler (1974) in which

$$Rp = P*Q*R/\ A(1 - R) \qquad (2)$$

where A is the lake surface area (in square meters), Q is the water discharge through the outflow (in cubic meters per year), and P is the phosphorus concentration in the lake (in milligrams per cubic meter). The fraction of the input mass of phosphorus retained by the lake (R) was defined by an empirical relation to the lake's areal water load (Ostrofsky 1978), which, if not measured, was calculated from meteorological data and the lake's catchment defined by topographic maps.

RESULTS AND DISCUSSION

Figure 1 shows that Rp is highly correlated with AHOD and accounts for 55 percent of the variation in AHOD. Of other variables tested, we found that the mean volume-weighted temperature of the hypolimnion, Th (in degrees Celsius), and the mean thickness of the hypolimnion, Zh (in meters), were most effective in reducing the residual variation. A least-squares multiple regression analysis (Table 1) showed that AHOD can be predicted from

$$AHOD = -277 + 0.5Rp + 5.0Th^{1.74} + 150\ln(Zh) \qquad (3)$$

To test the ability of this model to predict AHOD's, we applied the model to a second set of lakes for which the necessary data were acquired after the model was constructed. The measured and predicted AHOD's are highly correlated (Fig. 2).

Of the three variables found to be useful in predicting AHOD's, the only surprising parameter was Zh. Because temperature affects all biological processes, we would expect higher temperatures to increase system respiration in the range of hypolimnetic tempertures included in this analysis (4.5 to 12 C). It is more surprising that Stewart (1975) is the only limnologist that we know of who investigated Thienenmann's postulated relationship between AHOD and temperature, which was proposed more than half a century ago. We did not observe a stronger temperature effect because hypolimnetic temperature and thickness were very strongly correlated in this small sample of lakes (Table 1).

This AHOD model and our preliminary testing emphasize the influence of a lake's hydrology upon its AHOD. Since most phosphorus in lake water is

associated with plankton and is carried to the sediments in fecal pellets or dead organisms, there must be a strong correlation between the amount of decomposable organic matter and the phosphorus sedimented into the hypolimnion. However, lakes with high areal water loads retain very little of their phosphorus load or organic production (Kirchner and Dillon 1975; Richey et al 1978).

We did not expect to observe that, all other factors being equal, a lake with a thick hypolimnion would have a higher AHOD than a lake with a thin hypolimnion. In fact, this is inconsistent with the original objective and assumptions that Hutchinson used to justify the use of the AHOD. The objective of expressing the rate of hypolimnetic oxygen depletion on an areal basis was to eliminate the effects of hypolimnetic morphometry. Hutchinson thought he eliminated morphometric influences by assuming that the same percentage of the organic matter loaded into the hypolimnion was respired in hypolimnia of differing thickness. We cannot persist in assuming that a constant fraction of sedimenting organic matter is respired in the hypolimnion. One obvious way of interpreting the effects of Zh is to postulate that respiration by the sediments is limited, perhaps by diffusion of oxygen, and that deep lakes respire more efficiently than shallow lakes because more of their hypolimnetic respiration is associated with decomposition of organic matter in the thicker water column. More attention must be directed toward this phenomenon and to the question of whether the hypolimnetic oxygen deficit is, in fact, determined solely by respiration.

In addition, this model demonstrates that Hutchinson's (1957) and Mortimer's (1942) method of classifying lakes into trophic categories according to AHOD's cannot be used unless a factor is included to

compensate for the thickness of the hypolimnion. If AHOD's are used as the criteria, lakes with thick hypolimnia may be classified as eutrophic solely because of their morphometry and not because of their productivity. Current indices of trophic status as indicated by AHOD are biased and cannot be used to compare lakes of differing morphometry.

Now that it is possible to predict the rate of oxygen consumption in a restricted range of lakes, this model should be tested under conditions not found in the original data set. Measurements of AHOD in highly eutropic lakes and in lakes with changing tropic status will be particularly useful and will strengthen our confidence in this predictive equation.

PROBLEMS OF INTERPRETATION: A REPLY

Stimulated by studies that have documented the impact of human activity on the rate of oxygen depletion in the hypolimnion of freshwater lakes, we developed a simple empirical model (Cornett and Rigler 1979) to predict areal hypolimnetic oxygen deficits (AHOD). The method that we used to generate the model, the interpretation of the model, and its predictive ability are all criticized by Chang and Moll (1980). Although we will reply to Chang and Moll's first two points, we believe that the empirical testing of hypotheses is the most important step in advancing a predictive science and consequently we present a detailed analysis of their criticism of the model's predictive ability.

Chang and Moll first suggested that the model is logically invalid because it equates the areal retention of phosphorus (Rp) with sedimentation. This is not correct. We hypothesized that the input of organic matter into the hypolimnion is responsible for oxygen depletion in lakes. However, we chose Rp because it is easily estimated from existing models and because we expect it to be statistically correlated with the input of organic matter.

Chang and Moll also criticized our use of temperature raised to the power 1.74. Over the range of hypolimnetic temperatures found in our study lakes (4 to 13.5 C) many investigators (Kleiber 1961) have demonstrated that biological respiration rates increase nonlinearly with temperature. Our analysis was influenced by this work. We chose 1.74 because this exponent was used by Hargrave (1969) in his empirical equation to predict sediment respiration from ambient temperature. We retained this exponent in the final model because the use of other powers did not improve the predictive ability of our model.

The mean thickness of the hypolimnion (Zh) was transformed to a logarithmic scale, not because we originally expected a logarithmic relation but because more data of sufficient quality were available from shallow lakes than from deep lakes. Consequently, our original data set was strongly skewed toward shallow lakes, and the residuals were not randomly distributed. We transformed the data to normalize our distribution of residuals for the statistical analysis. However, more recent studies suggest that the effect of Zh does seem to decrease with increasing Zh (Chapra and Dobson 1979; Walker 1979; Charlton 1980; Cornett and Rigler 1980).

Chang and Moll also critized our model because two of the independent variables, Zh and Th, were negatively correlated in the original data set. They suggested that this correlation could have caused the apparent effect of Zh on AHOD. If this suggestion were correct, our interpretation of the multiple regression analysis would certainly be suspect, although the predictive value of the equation for AHOD would be unaffected.

The important question is whether the apparent effect of Zh on AHOD is real. Evidence that Zh is essential to any intrepretation of the model is provided by removing Zh from the regression. Using exactly the same data set that we applied to develop our predictive model (Cornett and Rigler 1979), we ignored Zh and calculated the statistical model to be

$$AHOD = 230 + 0.8\ Rp - 2.2Th^{1.74}. \qquad (4)$$

We reject this model because it implies that lakes are different from all other biological systems in that their respiration rate decreases as ambient temperature increases. This observation, although not stated

explicitly in the original paper, can be deduced from the correlation analysis we presented; Rp is not highly correlated with Zh or Th, whereas these two variables are themselves strongly negatively correlated. We also showed that ln(Zh) is positively, and Th is negatively correlated with the dependent variable AHOD (Table 1 of Cornett and Rigler 1979). Therefore, removing Zh will cause a negative partial regression coefficient for Th as (4) illustrates. This is consistent with the original multiple regression analysis. In that analysis, the partial regression coefficient for ln(Zh) was highly significant after the effects of Th and Rp were considered. Only the R^2 values were given in a stepwise progression. The conclusion that Zh exerts a strong influence upon AHOD values is not negated, as Chang and Moll (1980) have suggested. Several other more recent analyses also support the hypothesis that deeper lakes with a thicker hypolimnion have higher AHOD values (Chapra and Dobson 1979; Walker 1979; Charlton 1980).

Although we tested the predictive ability of our model with the observed AHOD values in an independent data set consisting of small oligotrophic lakes (N = 22), we also requested additional testing. Chang and Moll's (1980) most potentially serious objection is that they have completed the testing that we requested and found the model to be inappropriate in the Great Lakes. However, they presented no measured AHOD values. We have now conducted this test for most of the Great Lakes, using data collected from the literature (Chapra and Dobson 1979; Snodgrass 1974; Burns 1976). The results (Table 2) show the expectation and conclusion of Chang and Moll to be erroneous. Lake Superior's measured AHOD is higher, not lower, than that predicted by the regression model. We could find no adequate data for Lake Michigan with which to test Chang and Moll's expectation for that lake. However, for the other deep basins of the Great Lakes the model makes good predictions or underestimates measured AHOD values (Table 2).

Perhaps our model underestimates (rather than overestimates) the influence of depth upon AHOD values? However, the high AHOD values predicted by the model are certainly justified when the predictions are compared with the observed values.

Although we believe that we have countered Chang and Moll's objections, we shall be delighted if our model is found to be invalid as a result of further measurements. However, empirical theories can only be tested with good data. Beliefs and preconceptions about the way nature should work provide no scientific basis for rejecting predictive empirical models.

Parameter	AHOD	Rp	In(Zh)	$Th^{1.74}$
AHOD	1.00	0.74	0.62	-0.10
Rp		1.00	0.34	-0.07
Ln(Zh)			1.00	-0.69
$Th^{1.74}$				1.00
prc		0.50	150.0	5.03
T		3.14	3.38	1.83
P		.01	.01	0.08
R^2		0.54	0.69	0.75

Table 1. Results of the multiple regression analysis including a simple correlation matrix (top half of table), partial regression coefficient (prc). Student t value of the partial regression coefficient (T) and probability (P), and total amount of variation explained by stepwise addition of variables to regression by order in which they are listed (R^2). Other variables and units are as in the text.

Lake	Zh	Predicted AHOD	Observed AHOD
Superior	134	521	615
Mitchigan	70	504	?
Huron	50	391	394
Ontario	71	630	768
Erie (central)	3.9	431	409
Erie (eastern)	14.7	529	833

Table 2. Comparison of predicted and observed AHOD in the Great Lakes. Lake Erie temperatures were taken from Burns (1976). We assumed a mean temperature of 4 C for Lake Superior, Lake Michigan, and Lake Ontario and because it is shallower, a temperature of 4.5 C for Lake Huron.

Fig. 1. Relationship between the areal hypolimnetic oxygen deficit (AHOD) and phosphorus retention (Rp) in the study lakes.

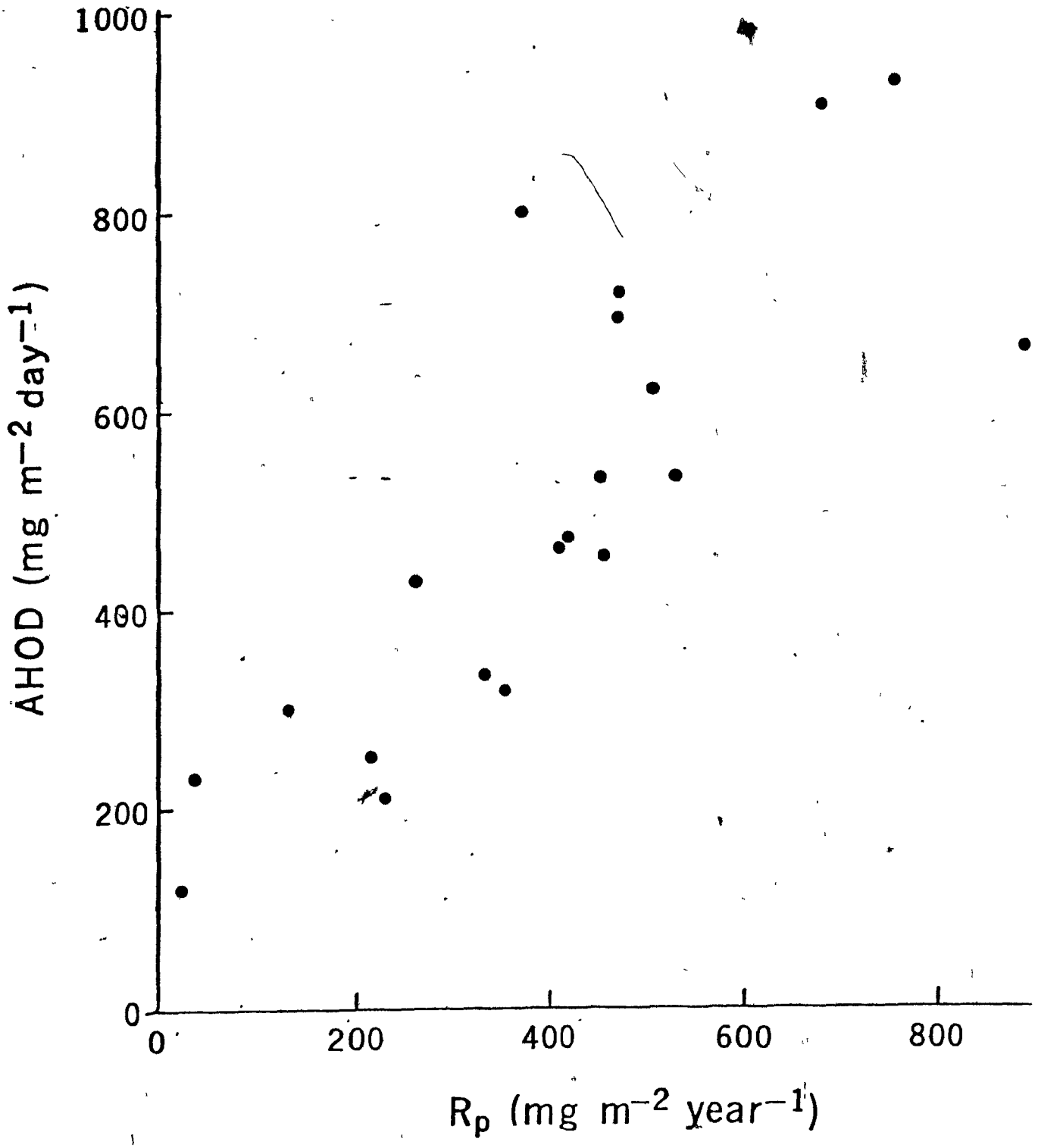
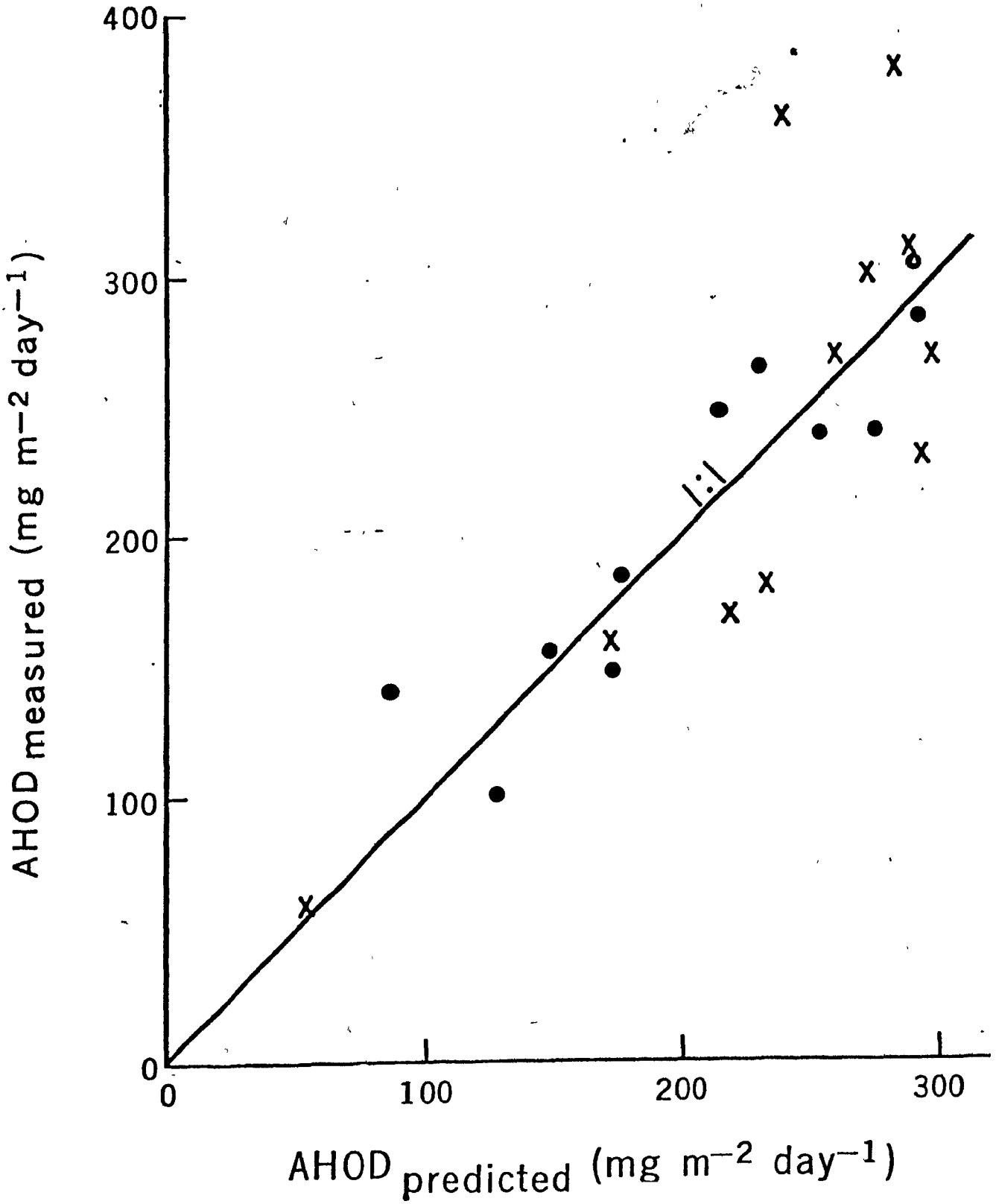

1000
800
600
400
200
0
0
200
400
600
800
ΔHOD (mg m⁻² day⁻¹)
Rp (mg m⁻² year⁻¹)

Fig. 2. Comparison of predicted and observed AHOD's in 20 oligotrophic lakes not included in the data set used to generate the prediction equation; X, AHOD measured by Lasenby (10); O, present study.


400
300
200
100
0
0
100
200
300
1:1
AHOD measured (mg m−2 day−1)
AHOD predicted (mg m−2 day−1)

CHAPTER SIX

THE AREAL HYPOLIMNETIC OXYGEN DEFICIT: AN EMPIRICAL TEST OF THE MODEL

ABSTRACT

The areal hypolimnetic oxygen deficit (AHOD) model was tested by examining the relationship between rates of hypolimnetic oxygen depletion and three measures of lake trophic status. Measurements of AHOD were positively corrlelated with the measured total phosphorus concentration and with annual pelagic primary production and inversely correlated with mean summer Secchi depth. Because each of the correlations between AHOD and trophic status explained less than 45% of the observed variation in AHOD values, other factors must also influence the AHOD of a lake. Significant amounts of the residual variation were explained by including the mean depth of the lake and mean hypolimnetic temperature as additional independent variables in a mutiple regression analysis. A lake with a thicker or warmer hypolimnion had a higher AHOD than a lake with a shallow or colder hypolimnion. The AHOD model was developed to eliminate the influence of lake morphometry on interlake comparisons of hypolimnetic oxygen depletion, but it does not do this and a new model must be developed.

INTRODUCTION

Decomposition of organic matter causes the average concentration of dissolved oxygen in the hypolimnion of a lake to decrease during thermal stratification. In some lakes this decrease is negligible; in others it quickly leads to complete anaerobiosis. In an attempt to build a conceptual model of oxygen depletion in the hypolimnion, Thienemann (1926, 1928) postulated that the productivity (trophic state) of a lake's surface waters and the morphometry of the lake's hypolimnion both influence the magnitude of the change in hypolimnetic oxygen concentration. Thienemann argued that organic matter falling into the large volume of a thick hypolimnion would be diluted. Therefore the lower concentration of decomposing organic matter in a thick hypolimnion would have a lower volumetric rate of oxygen depletion (mg Oxygen /m^3/day) than a lake with a thin hypolimnion. Since it was obvious that this morphometric influence would interfere with any attempt to investigate the relationship between phytoplankton production and rates of hypolimnetic oxygen consumption, Strom (1931) and Hutchinson (1938) proposed that the morphometric influence be eliminated by expressing the rate of hypolimnetic oxygen depletion as an areal hypolimnetic oxyen deficit (hereafter AHOD), (mg Oxygen/m^2/day). The areal dimension was chosen as the area of the plane delimiting the upper boundary of the hypolimnion.

The belief that AHOD would be independent of morphometry and proportional to lake trophic status was based on four unstated assumptions (Hutchinson 1938, 1957). First, Hutchinson assumed that input of decomposable allochthonous matter into the hypolimnion is insignificant relative to autochthonous inputs. Second, he assumed that a constant fraction of the autochthonous organic matter from the trophogenic zone sinks into the hypolimnion. The sum of the organic matter decomposed in the water column

and in the sediments was assumed to be proportional to the input of organic matter into the hypolimnion. Finally, Hutchinson assumed that respiration is the only process influencing the rate of oxygen depletion in the hypolimnion. Although none of these assumptions has been adequately tested, the use of AHOD to measure trophic status has been generally accepted because Hutchinson (1938) demonstrated that in four lakes the AHOD was highly correlated with the mass of ash-free seston in the trophogenic zone. This correlation appeared to validate the assumptions and it permitted the development of trophic indices based upon AHOD (Hutchinson 1938, 1957; Mortimer 1942). However subsequent studies have not always supported Hutchinson's results (Deevey 1940; Ohle 1956; Lansenby 1975; Rast and Lee 1978). Cornett and Rigler (1979) have argued that areal rates of oxygen depletion are not independent of lake morphometry. This suggests that the indices of trophic state as indicated by AHOD are biased. The purpose of this paper is to test the hypothesis that AHOD is simply a function of trophic status. The most obvious approach would be to test the four assumptions underlying its use. However such tests are currently plagued by uncertainties introduced by methodological problems. It is less direct, but more feasible to pool data gathered in the previous studies that yielded conflicting results as well as any other available data sets. If the AHOD method is correct, AHOD should be correlated with other indices of lake productivity and the residual variation in these regression models should not be correlated with variables which are unrelated to trophic status. Because Cornett and Rigler (1979) have developed a multiple regression model in which AHOD is predicted from phosphorus retention, mean thickness of the hypolimnion, and mean hypolimnetic temperature, we specifically chose to examine the effects of the last two variables on AHOD.

DATA AND ANALYSIS

Measurements of AHOD, total phosphorus concentration in the trophogenic zone, annual 14C pelagic primary productivity, mean summer Secchi depth, and lake morphometry were collected from a large number of studies of temperate lakes reported in the literature. Where the investigator did not report the rate of oxygen depletion, we defined the average depth of the upper boundary of the hypolimnion from the average summer isotherms. The depth of the thermocline (Zt) was defined by the maximum temperature gradient. A linear regression equation was calculated using the temperatures at depths of Zt-1, Zt, and Zt+1. The intersection of this line with the best-fitting linear equation fitted through the temperatures measured in the deepest strata in the lake defined the depth of the plane delimiting the top of the hypolimnion. The AHOD was then calculated with the linear regression technique developed by Lasenby (1975) from the oxygen isopleths reported by each worker. The mean thickness of the hypolimnion (Zh) was calculated as

$$Zh = Vh/Ah$$

where Vh is the volume of the hypolimnion and Ah is the surface area of the plane delimiting the upper boundary of the hypolimnion. The mean hypolimnetic temperatures reported are also volume-weighted summer averaged calculated from isotherms reported by the investigator. All regression analyses (Figs. 1-3 and Tables 1-4) were performed on measurements transformed to a log10 scale to normalize the residuals. Investigation and interpretation of residuals followed the outline given by Draper and Smith (1966).

Data sets included in this analysis were presented by or summarized by

Burns (1976), Deevey (1940), Dillon and Rigler (1975), Dillon et al. (1978), Fish (1970), Lasenby (1975), Rast and Lee (1978), Schindler (1971), Snodgrass (1974), Stockner and Northcote (1974), Vollenweider (1968), and Vollenweider et al. (1974). The data are summarized in the appendix of this thesis.

RESULTS

Correlations between AHOD, trophic indices, and lake morphometry. We tested for relationships between AHOD and three traditional indices of trophic status: phosphorus concentration in the trophogenic zone, mean summer Secchi depth, and annual areal pelagic ^{14}C primary productivity. Despite the considerable scatter discussed below, lakes with higher measured phosphorus concentrations generally also display higher AHOD values (Fig 1). Similarly, the AHOD decreases with increasing Secchi depth (Fig 2) and is positively correlated with the annual pelagic primary productivity (Fig 3). These observations are consistent with the plots presented by Rast and Lee (1978) and Lasenby (1975). However, there is considerable residual scatter in all three relationships. At any given phosphorus concentration, Secchi depth, or rate of primary production the range in reported AHOD is greater than half an order of magnitude. Some of the scatter in these relationships may result from analytical problems or from the different methods of calculating the oxygen deficit used by different workers. The neglect of these questions here does not affect our analysis. In each of the three cases investigated, correlations between the two variables demonstrate that these relationships explain less than 45% of the observed variation in AHOD. This suggests that other factors influence the AHOD of a lake.

The residuals in these relationships are not randomly distributed. A significant fraction of the residual variation in the relationships of AHOD vs. phosphorus concentration and AHOD vs. Secchi depth was removed by including the mean depth of the lake as an additional independent variable in the regression analysis (Tables 1 and 2). This analysis implies that over a wide range of trophic states, deep lakes tend to have higher AHOD

values than shallow lakes. There were not enough data for us to determine the additional efects of different hypolimnetic temperature regimes upon a lake's AHOD. However, the importance of mean depth does not result from an invisible positive correlation between lake depth and hypolimnetic temperature, since deeper lakes usually have a colder hypolimnion than shallow lakes (Cornett and Rigler 1979).

For the lakes where primary production and AHOD were both measured, sufficient data exist to demonstrate that hypolimnetic temperature and mean depth both influence AHOD. Multiple regression analysis showed that AHOD is positively correlated with annual pelagic 14C promary productivity, mean hypolimnetic thickness, and mean summer hypolimnetic temperature (Table 3). Because the mean thickness of the hypolimnion and the mean depth of lakes are very strongly correlated in any group of lakes, the results of these three regression analyses produce similar predictions consistent with the analyses of Cornett and Rigler (1979). At similar levels of annual pelagic primary productivity, deeper lakes with thicker hypolimnia exhibit higher oxygen deficits than do shallow lakes.

Additional test of the morphometric influence.

Although more data should be gathered specifically to test the effect of thickness of the hypolimnion on the areal oxygen deficit, other data sets in the literature can be used to test this hypothesis. One type of test is generated by lakes with two more basins with similar productivity in the trophogenic zone and similar hypolimnetic temperature, but differing hypolimnetic thickness. In these lakes the regression models developed earlier predict that the AHOD should be higher in the basin with the thicker hypolimnion. For the three lakes where such measurements are available, Erie, Nelson, and Dickey (Table 4), data are consistent with

this prediction. The deeper basin consistently had the higher AHOD. The AHOD measured in the deep eastern basin of Lake Erie was higher than that reported from the central basin despite the fact that both the phosphorus concentration (Dobson et al. 1974). and the phytoplankton productivity (Vollenweider et al. 1974) were higher in the shallower central basin.

Other data sets suitable for testing the effect of hypolimnetic thickness on AHOD are provided by measurements in groups of lakes with similar surface water chemistry (and therefore presumably similar primary productivity) and similar hypolimnetic temperatures. Birge and Juday (1911) tabulated hypolimnetic oxygen concentrations and temperatures for several Wisconsin lakes: 10 with mean hypolimnetic depth ranging from 2.5 to 30 m have similar hypolimnetic temperatures (5.0 - 8.5 C). From the data of Birge and Juday we calculated the AHOD of these lakes and found it to be strongly correlated with the mean thickness of the hypolimnion (Fig. 4).

Primary production and lake depth.

Welch et al. (1976) reported a strong correlation between the areal rate of oxygen depletion under the winter ice and lake depth in 16 oligotrophic Ontario lakes and postulated that the correlation arose because the deeper lakes had higher areal rates of phytoplankton production that stimulated increased respiration. This hypothesis could be generalized to explain the relationship between AHOD and mean depth that we observed and, if correct, would explain our observations within the context of Hutchinson's AHOD method. We here test the hypothesis of Welch et al. (1976) and will describe three observations that are inconsistent with their hypothesis. In our analysis we consider only pelagic primary productivity. However, the inclusion of littoral or benthic productivity in our analysis would

not alter our results because the extent and productivity of littoral areas is greater in shallow lakes than in deep lakes (Schindler et al. 1973).

The first test of the hypothesis of Welch et al. (1976) makes use of the same data from which we constructed Fig. 3. A significant fraction of the residual variation in the regression of AHOD on areal pelagic primary production (Fig. 3) was explained by adding the mean depth of the hypolimnion as a new variable into the regression analysis (Table 3). This suggests that phytoplankton production and mean depth of the hypolimnion act as two independent variables influencing the magnitude of the AHOD. If production and hypolimnetic thickness were correlated in these data, the addition of hypolimnetic depth into the regression analysis would not have reduced the residual variation. Since the thickness of the hypolimnion is generally correlated with lake depth, this result is inconsistent with the suggestion that the deeper lakes had higher areal rates of primary production.

A second test of the hypothesis is facilitated by the work of Schindler (1978) who showed that areal pelagic productivity is positively correlated with the total phosphorus concentration in the lakes. If, independent of phosphorus concentration, deeper lakes have higher productivity, then the residual variation in the relationship of productivity vs. phosphorus concentration should be correlated with lake depth. We collected estimates of pelagic ^{14}C primary productivity (P.P., mg $C/m^2/yr$), measured trophogenic phosphorus concentration (P, ug/L), and mean lake depth from the available published sources used by Schindler (1978). The relationship that we have used differs from that published by Schindler in two ways. First the independent variable used is the phosphorus

concentration measured in the lake water. Second, many of the data which Schindler used in his analysis were unpublished: we included only the previously published data used by Schindler. The relationship between phosphorus concentration and areal productivity that we calculated was

$$\log P.P. = 0.65 \log P + 1.37 \quad (N = 32;\ r2 = 0.59).$$

An examination of the residual variation between the observed and predicted rates of pelagic productivity calculated from our equation demonstrates that the residual variation does not correlate with mean depth (Fig. 5).

Finally, studies of pelagic primary productivity in lakes with distinct basins of different depths also demonstrate that primary production is not higher in the deeper lakes basins than in the shallow basins (Vollenweider et al. 1974; Ross and Kalff 1975).

DISCUSSION

Hutchinson (1938,1957) suggested that lakes with a maximum depth [20 m had lower areal rates of hypolimnetic oxygen depletion and lakes with a maximum depth |75 m, had higher AHOD values than were to be expected from trophic considerations alone: our results support this hypothesis. In addition Hutchinson argued that the AHOD of a lake was directly related to its trophic status in those lakes with maximum depths between 20 and 75m; he believed that he had justified this assumption when he tabulated data from a diverse group of lakes and showed that lakes 50-70 m deep sometimes had oxygen deficits of similar magnitude to lakes 20-50 m deep (Hutchinson 1957). This test was not sufficiently rigorous and our results do not support his argument. Although shallow lakes may have an AHOD equal to that of deep lakes, a comparison of lakes with similar surface water productivity (Table 5) shows that those lakes with a maximum depth of 75m have an AHOD from 75-300% higher than those 20m deep. This difference is sufficient to change the trophic classification of a lake from oligotrophic to eutrophic or mesotrophic with either the trophic status index based on rates of hypolimnetic oxygen depletion developed by Hutchinson (1957) or that developed by Mortimer (1942). Both of these indices are biased because they will consistently classify lakes with thicker or warmer hyplimnia as eutrophic and therefore cannot be used to compare the typologies of lakes with different hypolimnetic morphometries or temperatures.

Although the results of our study seem to contradict Theinemann's (1928) observation that shallow hypolimnia have higher volumetric rates of oxygen consumption, this contradiction is illusory. Volumetric rates of oxygen depletion calculated from the measurements collected by Birge and Juday (1911) are inversely correlated with the mean thickness of the hypolimnion

(Fig. 6). The same measurements were used to illustrate that AHOD is positively correlated with the mean thickness of the hypolimnion (Fig. 4). Both conclusions are correct. Lakes with thinner hypolimnia do have higher rates of hypolimnetic oxygen depletion per cubic meter and lower rates of oxygen depletion per square meter.

Since the conclusions that the thickness of the hypolimnion and mean hypolimnetic temperature influence the AHOD are not consistent with the AHOD method (Strom 1931; Hutchinson 1938), we need a new model. We conclude that one or more of the assumptions that Hutchinson (1938) made while developing his AHOD method are incorrect. That method assumes that the observed net change in hypolimnetic oxygen concentration is produced solely by respiration in the water column and at the sediment surface. In addition, both types of respiration are assumed to be proportional to the influx of organic matter into the hypolimnion. Either or both of these assumptions may be incorrect.

Perhaps vertical turbulence transports more oxygen downward across the upper boundary of the hypolimnion in lakes with shallow hypolimnia. Since Birge (1907) drew the analogy between human respiration and the decrease in hypolimnetic oxygen concentration, limnologists have assumed that there is no transport of oxygen into the hypolimnion. This assumption is not consistent with the very few measurements of oxygen transport. Although Li (1973) concluded that the AHOD of Lake Zurich was not affected by transport of oxygen into the hypolimnion, both Hutchinson (1957) and Rich and Devol (1978) corrected their reported AHOD values by adding the amount of oxygen transported into the hypolimnion to the observed rate of oxygen depletion. A more detailed study of the transport of oxygen into and within the hypolimnion is needed to test this hypothesis rigorously.

Oxygen may also be added to the hyplimnion by photosynthesis. Perhaps higher rates of benthic or pelagic photosynthesis produce greater quantities of oxygen in the hypolimnia of shallow lakes than in deep lakes. This phenomenon could also produce lower AHOD values in shallow hypolimnia.

Alternatively the morphometry of the hypolimnion may influence the AHOD by controlling the rate of decomposition of organic matter in the hypolimnion. Consumption of oxygen in the hypolimnion occurs at the sediment surface and in the water column. If respiration in the water column is more efficient per gram of organic matter than respiration at the sediment surface, deeper lakes could have higher areal rates of water column respiration, provided that the time for the particle to fall through the hypolimnetic water column is proportional to the thickness of the hypolimnetic water column. There are too few measurements of sediment and water column respiration to test this hypothesis. However, we hope that our work will stimulate re-evaluation of the mechanisms regulating hypolimnetic oxygen depletion.

	Parameter		
	log P	log Z	intercept
Estimate	0.48	0.38	1.52
F	70.3*	30.3*	1.66*

Table 1. Regression analysis of relationship between log AHOD ($mg/m^2/day$) and independent variables phosphorus concentration (P, ug/L) and mean lake depth (Z, m). Sequential F-values are reported showing additional contribution of variables as they are added to analysis from left to right ($N = 65$; $R^2 = 0.62$). * denotes significance at 1% level.

	Parameter		
	log Secchi	log Z	Intercept
Estimate	0.67	0.47	2.45
F	38.3*	48.6*	612.*

Table 2. Regression analyses of log(AHOD) on independent variables mean summer Secchi depth (m) and mean lake depth (Z, m). Symbols and units as in Table 1 (N = 91; R^2 = 0.50).

	Parameter			
	log P.P.	log Zh	Th 1.74	Intercept
Estimate	0.33	0.54	0.009	1.06
F	15.5*	19.0*	12.5*	16.4*

Table 3. Analyses of regression equations predicting log(AHOD) annual pelagic primary productivity (P.P., g $C/m^2/yr$), mean thickness of the hypolimnion (Zh, m), and average hypolimnetic temperature (Th) arbitrarily raised to exponent 1.74 (Hargrave 1969). Symbols and units as in Table 1 ($N = 20$; $R^2 = 0.75$).

	Z	AHOD	Source
Erie			
Central	18.3	380*	Burns 1976
Eastern	24.4	613*	
Dickey			
North	6.3	190	Lasenby 1975
South	19.7	410	
Nelson			
Northwest	9.8	150+	Yan et al. 1977
Main	11.6	180+	

Table 4. AHOD values ($mg/m^2/day$) in shallow and deep basins (Z m) of three lakes (* Mean values for survey intervals 4-6; + 1976 values).

Zmax	Zh	AHOD1	AHOD2	AHOD3
20	4.6	233	275	209
50	19.2	330	417	450
75	31.2	385	513	585
100	43.3	430	589	690

Table 5. Predicted AHOD values ($mg/m^2/day$), calculated with equations reported in Tables 1-3, in four lakes of differing depth. For these comparisons phosphorus concentration (10 ug/L), hypolimnetic temperature (6.5 C), and maximum lake depth (Zmax, m) were chosen arbitrarily. Mean lake depth was predicted (Neumann 1959) as were thickness of hypolimnion (Zh, m), primary productivity (104 g $C/m^2/yr$), and Secchi depth (5m) (Dillon and Rigler 1975).

Fig. 1. Relationship between measured lake phosphorus concentration and AHOD (N=65; R^2=0.43, P<0.001).

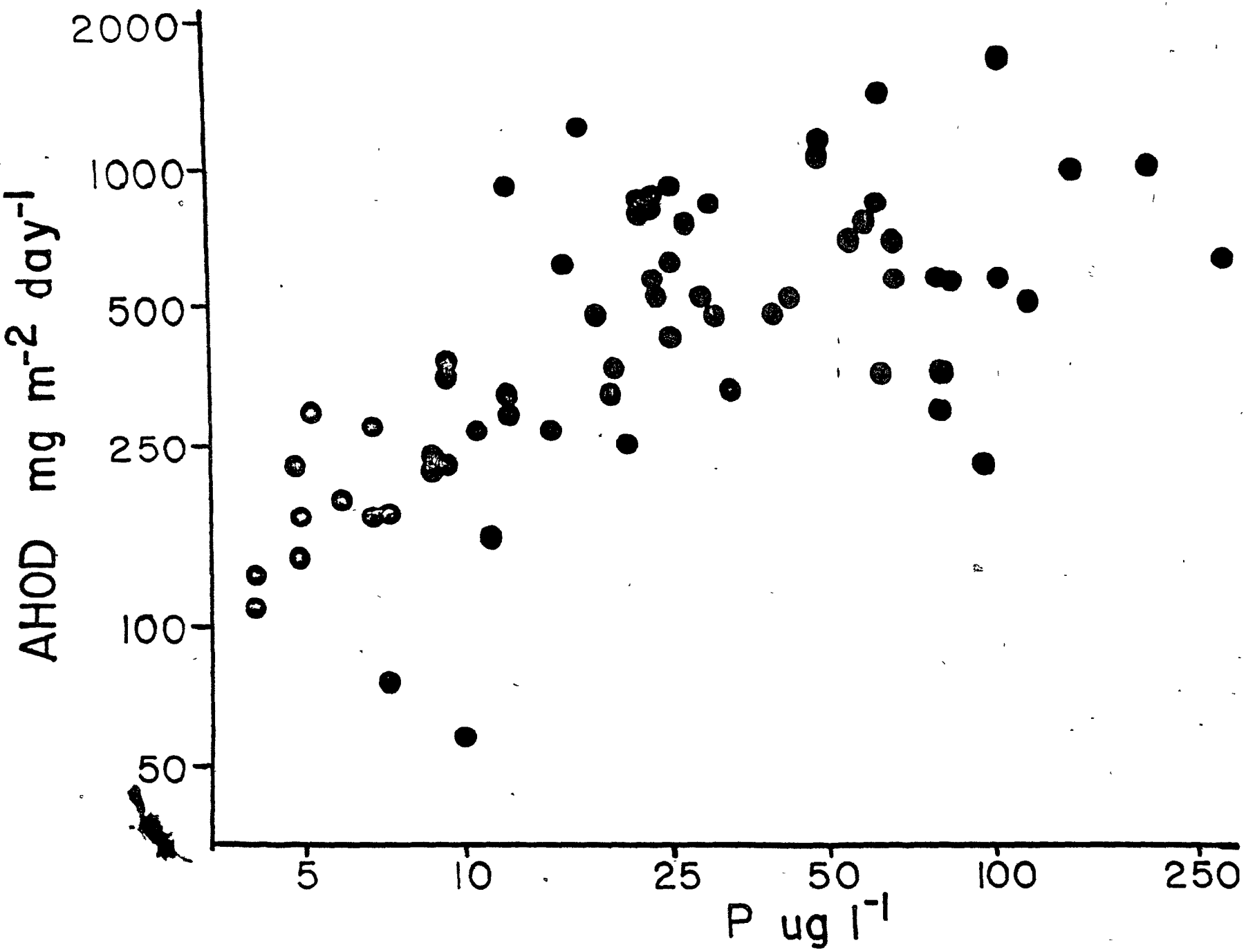

2000
1000
500
250
100
50
AHOD mg m-2 day-1
5
10
25
50
100
250
P ug l-1

Fig. 2. Relationship between mean summer Secchi depth and AHOD (N=91; R^2=0.21, P<0.0001).

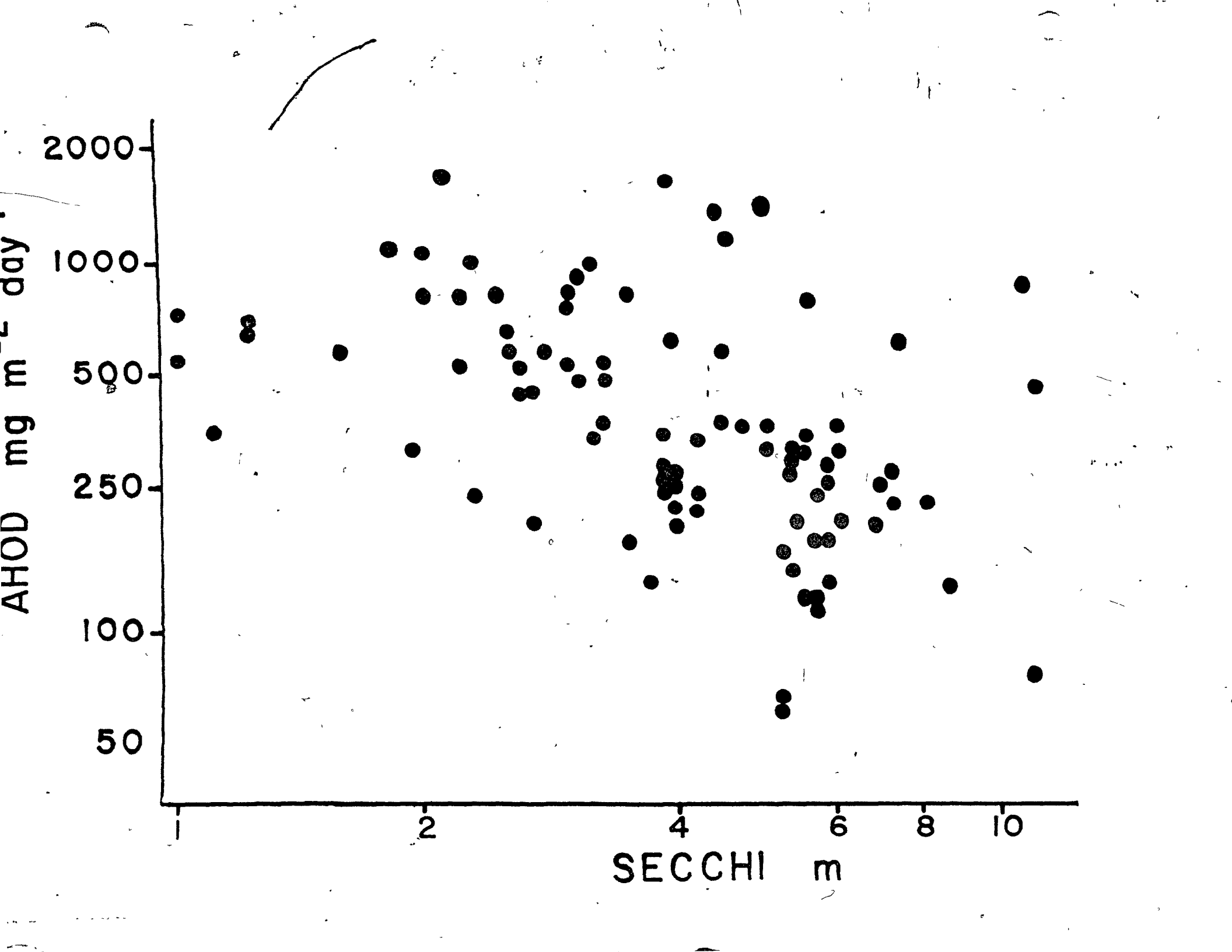

2000
1000
500
250
100
50
AHOD mg m⁻² day⁻¹
1
2
4
6
8
10
SECCHI m

Fig. 3. Relationship between annual ^{14}C pelagic primary productivity and AHOD (N=20; R^2=0.25, $p<0.05$).

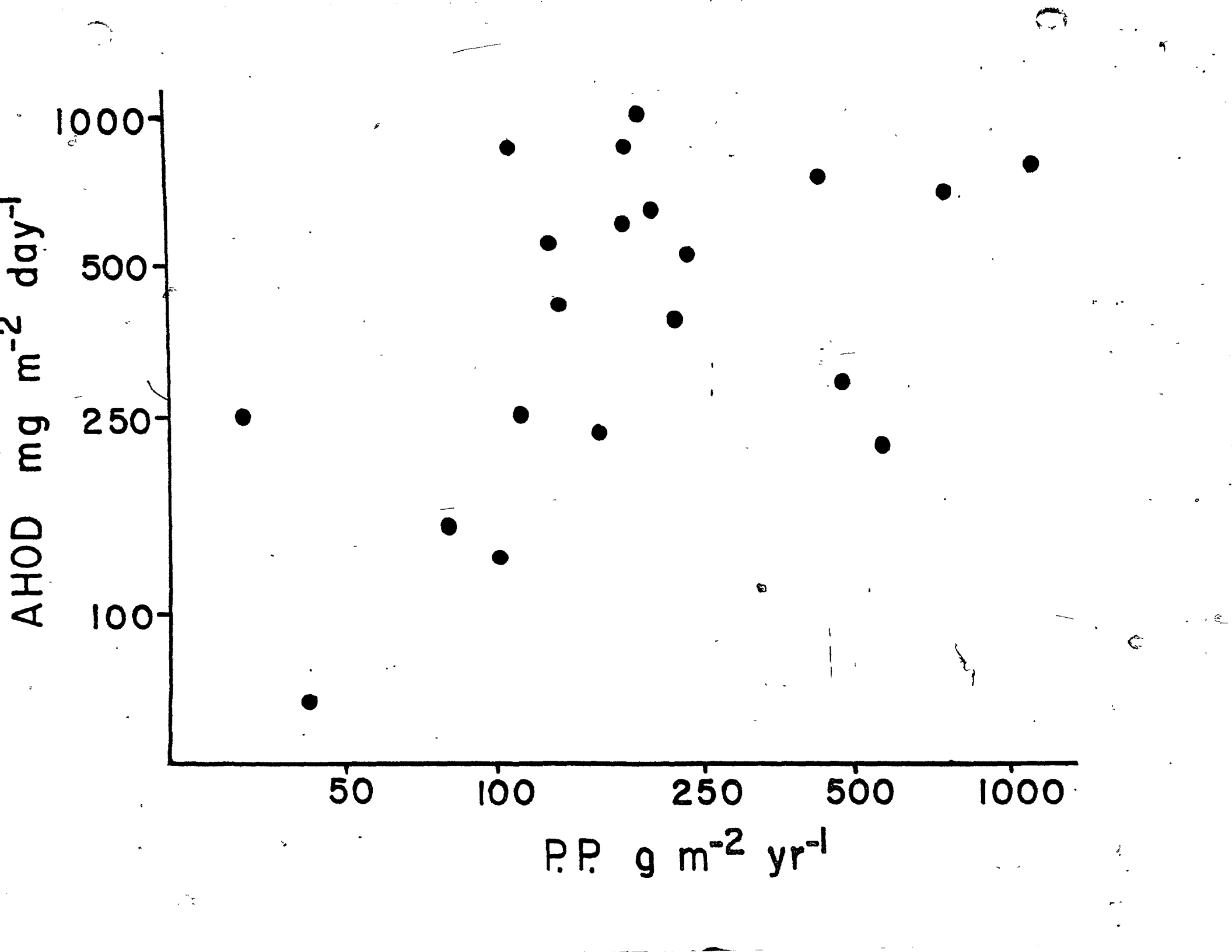

1000
500
250
100
AHOD mg m^{-2} day^{-1}
50
100
250
500
1000
P.P. g m^{-2} yr^{-1}

Fig. 4. Calculated AHOD values in 10 Wisconsin lakes plotted against mean thickness of hypolimnion.

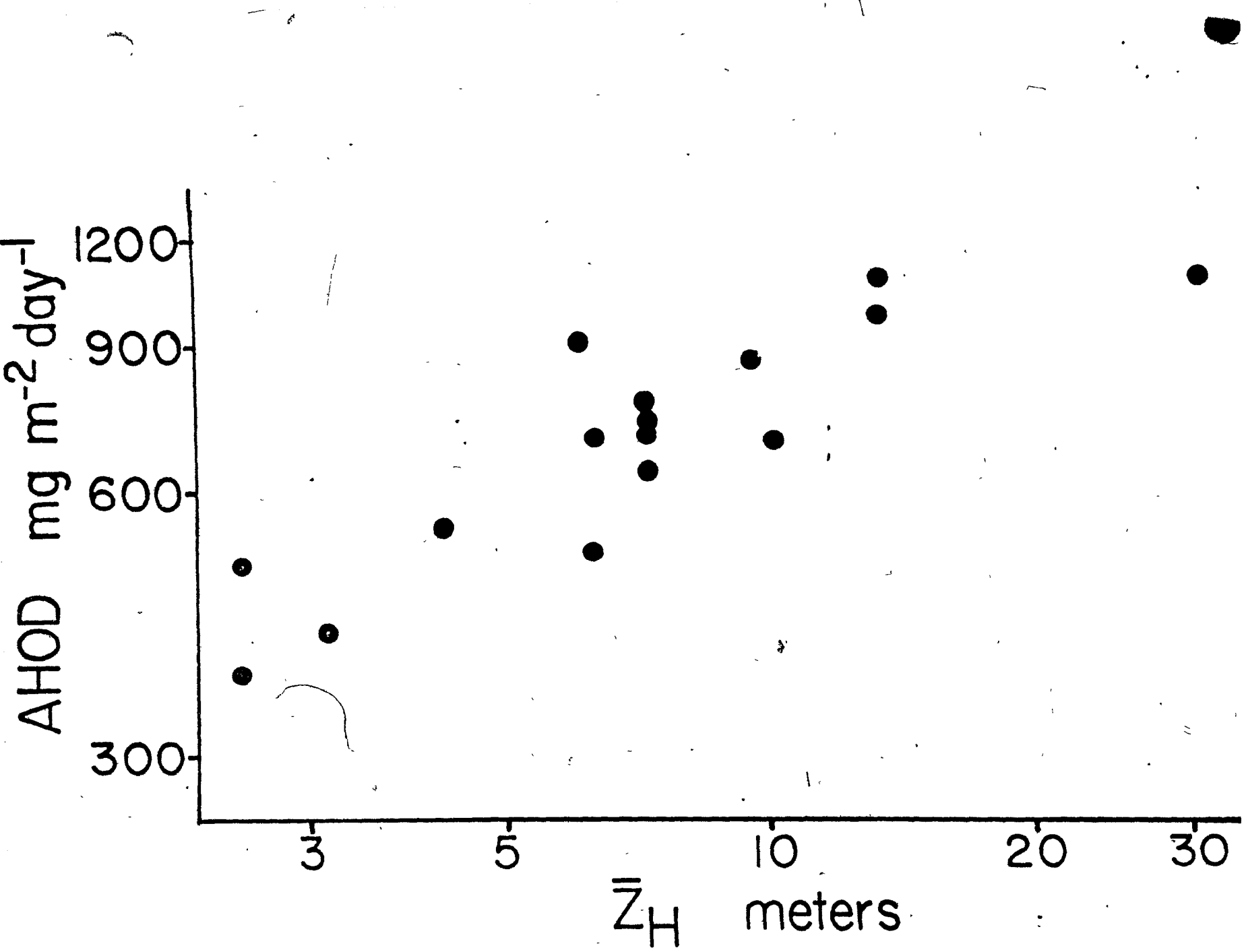

AHOD mg m-2 day-1
1200
900
600
300
3
5
10
20
30
$\bar{Z}_H$ meters

Fig. 5. Residuals (observed P.P. - predicted P.P.) from pelagic primary productivity against phosphorus regression plotted vs. mean depth of the lake.

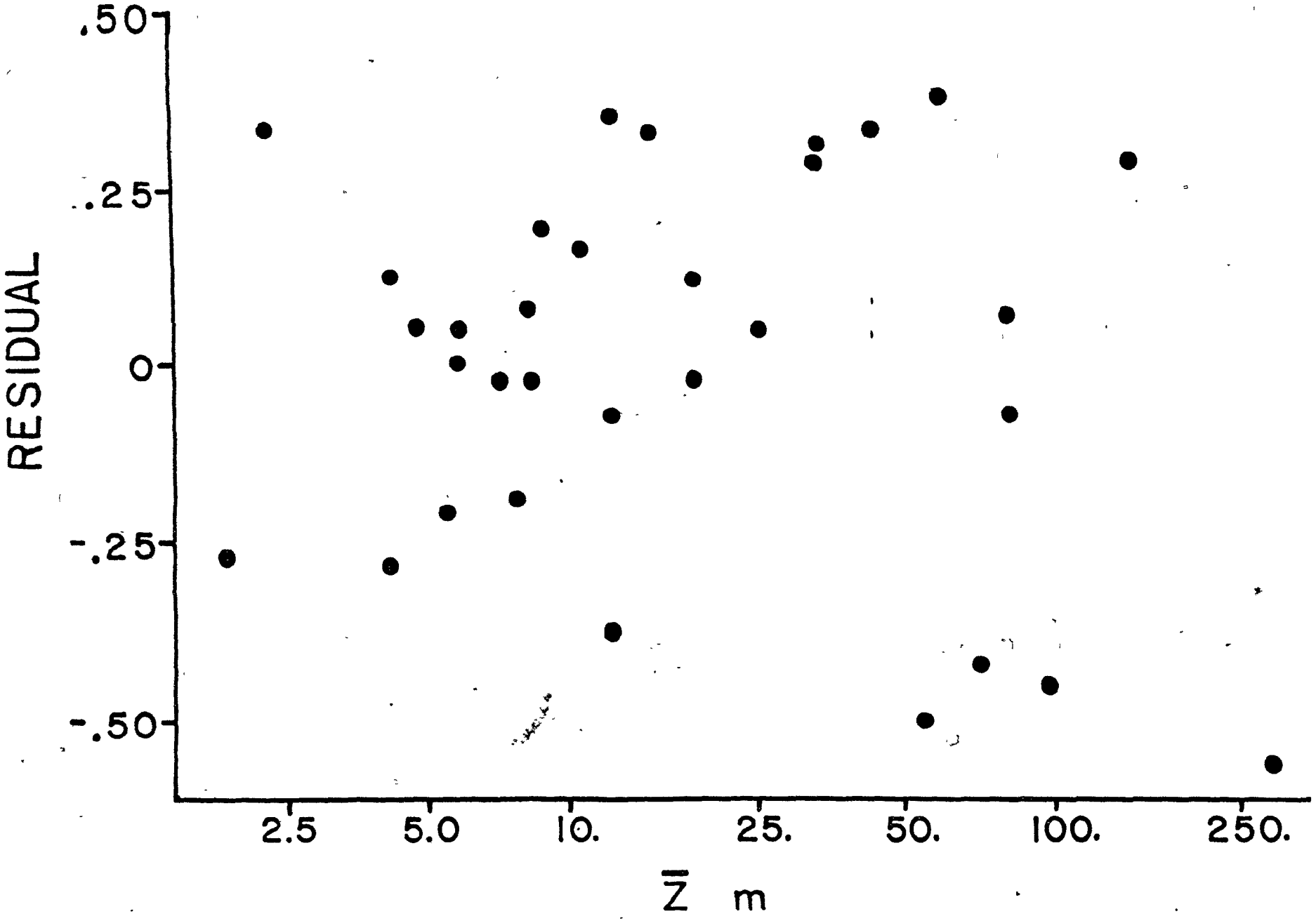
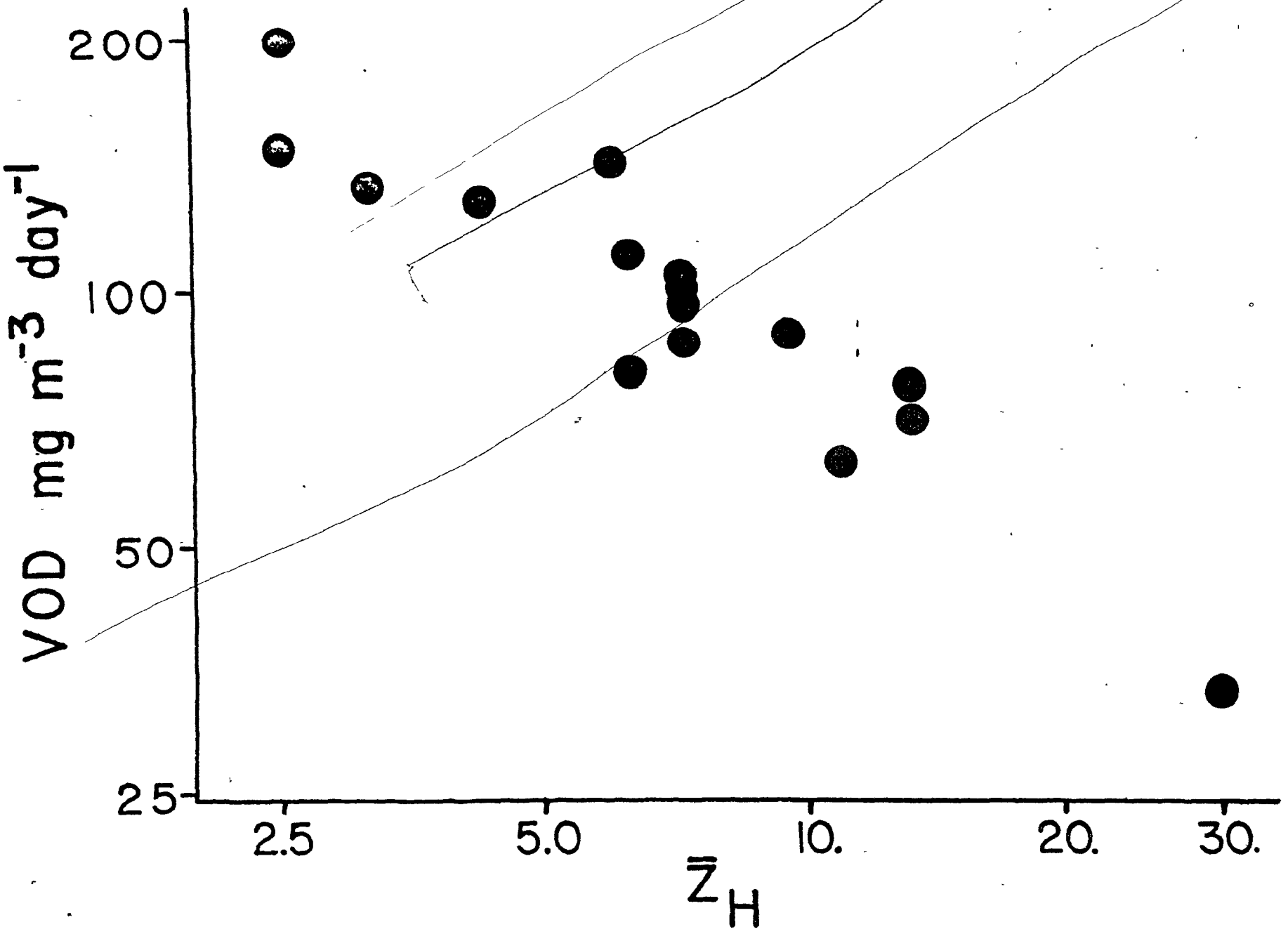

.50
.25
0
-.25
-.50
RESIDUAL
2.5
5.0
10.
25.
50.
100.
250.
$\bar{Z}$ m

Fig. 6. Average rates of oxygen depletion per cubic meter in 10 Wisconsin lakes plotted vs. mean thickness of the hypolimnion.


200
100
50
25
VOD mg m-3 day-1
2.5
5.0
10.
20.
30.
$\bar{Z}_H$

CHAPTER SEVEN

THE INFLUENCE OF LAKE MORPHOMETRY UPON LAKE TYPOLOGY: FACT OR ARTIFACT.

Introduction

As they searched for predictable patterns in lake properties, Thienemann (1928) and Naumann (1932) identified two distinct types of factors that appeared to influence the pelagic biomass and productivity of their study lakes. One group of factors, consisting of edaphic influences of the lake's catchment, formed the foundation for the present day nutrient loading models (Rigler, 1975). The second group of controlling factors that early studies identified were termed morphometric. Since Thienemann's (1928) early work, many studies have replicated the observation that shallow lakes have higher rates of productivity than deep lakes, when productivity is expressed in mg Carbon/m^3/time (Rawson 1952; Patalas and Zawisza 1966; Sakamoto 1966; Fee 1979). In fact the evidence appeared so strong that Fee (1979) classified Thienemann's observations as one of the oldest "laws" of limnology. Since rates of production and decomposition appear closely linked in many lakes (Wetzel et al 1972; Rich and Devol 1978) several recent studies also emphasize the observation that the morphometry of a lake also influences decomposition in the hypolimnion (Cornett and Rigler 1979, 1980; Walker 1979; Charlton 1980). However before the influence of morphometry upon lake typology becomes an accepted dogma, the original and more recent studies must be examined more critically.

Strong morphometric influences have been reported in three different areas of limnological investigation. Patterns have been observed between lake morphometry and the catch of fish (Rawson 1952, 1955; Ryder 1965; Matuszek 1978), lake morphometry and phytoplankton primary productivity or plankton biomass (Rawson 1952; Sakamoto 1966; Patalas and Zawiska 1966; Fee 1979) and lake morphometry and rates of hypolimnetic oxygen depletion (Thienemann 1928; Chapra and Dobson 1979; Cornett and Rigler 1979, 1980; Charlton 1980; Walker 1980). Despite the diversity of studies listed above, all of the investigators have used similar analytical techniques to arrive at the same conclusion. Limnologists intuitively expect all biotic functions to be proportional to the surface area of a lake because the energy from the sun must pass through this planar surface. Therefore all of the studies referenced above normalized measurements for each lake by expressing the variable of interest (Y) per m^2 of surface area (A) or per m^3 of volume (V). Fisheries and phytoplankton studies used the surface area of the lake as a reference. Hypolimnetic studies have employed the area at the depth of the upper boundary of the hypolinion as a reference. As a result the dependent variable that was investigated was a ratio in the form

$$G = Y/A \text{ or } G = Y/V \qquad (1)$$

with the dimensions of mass per m^2 or mass per m^3. All studies referenced above, used G in the investigation of the influence of morphometric effects. In these studies the morphometric influence was most frequently expressed as the mean depth of the lake, or epilimnion,

or hypolimnion, defined as

$$Z = V/A \tag{2}$$

The hypothesis that lake morphometry influenced lake typology was tested by determining whether the regression coefficient or partial regression coefficient (b1) was statistically different from zero when the dependent variable (G) was regressed on Z in the equation

$$G = bo + b1Z + \ldots \tag{3}$$

In order for a statistically significant relationship between Y/A and V/A to be sufficient evidence to conclude that the two variables are correlated, each author was forced to assume that the expectation of a significant regression was zero if G and Z were not related. The validity of this assumption was questionable in the original analysis and in subsequent re-evaluations of every data set. As equation 3 is written the dependent variable (G) may not be statistically independent of the regressor variable. Intuitively the lack of independence may seem unimportant because each term in the G,Z pair is divided by the same value of A. However the empirical studies of Atchley et al (1976) clearly demonstrated that our intuition is not correct. In their analysis, Atchley et al examined the influence of statistically interdependent ratios upon the inferences that can be made from simple regression analysis. They concluded that the analysis of ratios that contained the same variable could introduce spurious correlations with

coefficients of correlation (R) ranging from R=0.0 to R=0.99. The R value depended upon the distributions of the variables. In a similar analysis Kenney (1982) presented several examples of spurious correlations when data were analysed in the form

$$G = f(b_o/Y) \qquad (4)$$

The results of Atchley et al and Kenney imply that although morphometry may influence biotic processes in lakes, past studies could not have falsified the original hypothesis that lake morphometry influences lake typology. Our purpose here is to re-evaluate the hypothesis that Z is correlated with the catch of fish, the productivity and biomass of phytoplankton, and the rate of oxygen depletion in the hypolimnion.

Method of Analysis

Although many studies have discussed the influence of morphometry upon lake properties, the data sets used in different studies frequently overlap. Rather than re-evaluate every study we chose to examine two or three sets of data in each of the three areas mentioned earlier. We arbitrarily chose one of the first analyses and one more recent paper for analysis. We also attempted to choose studies that used completely independent data sets, or had a minimum of overlapping observations. The data sets used in this analysis were identical to those reported by the

original author. Two different transformations were employed to eliminate the common denominator from the dependent and regressor variables. In two cases, both sides of (1) were multiplied by the denominator (usually A) to yield

$$Y = b_1 A + b_1 AZ + \ldots \qquad (5)$$

This analysis assumes that the intercept (bo) is equal to zero. In many of the original analyses the data set was transformed to a logarithmic scale before the regression was examined. We have used the same transformation. The equation

$$\log(G) = bo + b_1 \log(Z) + \ldots \qquad (6)$$

was altered to

$$\log(Y) = bo + b_1 \log(A) + b_1 \log(Z) + \ldots \qquad (7)$$

by subtracting the logarithm of the area from both sides of (6). Similar transformations were used when volume rather than lake area appeared on both sides of the original equation. For each data set, the hypothesis that lake morphometry significantly influenced Y was tested using a marginal (partial) F test that compared the mean square (MS) attributable to the morphometric term after all other parameters were added, to the error mean square of the complete regression model (Snedecor and Cochran 1967). If the conclusion of previous studies is correct and morphometry

does influence lake metabolism, this statistic should be highly significant and the null hypothesis that the partial regression coefficient is equal to zero can be rejected.

Results

The data sets chosen for analysis, and the alternative statistical models chosen to eliminate the biases, are presented in Table 1. Analysis of variance tables for the regressions (Tables 2-4) demonstrate that each Y variable is strongly correlated with lake size. In the logarithmic analysis, partial regression coefficients for the Log(A) term ranged from 0.82 to 1.12. In no case was the coefficient for lake area significantly different from 1.0. Clearly these biotic variables increase linearly with increasing lake area.

Analysis of the relationship between net plankton standing crop and Z (Table 2) are consistent with the hypothesis that plankton biomass increases as mean depth decreased. Fee (1979) postulated that the morphometry of a lake affected a lake's typology because of the importance of internal nutrient cycling to production. He then argued that the recycling of nutrients was proportional to the ratio of epilimnetic sediment area to epilimnetic volume. Although Fee's original data analysis was biased, the correct statistical model strongly supports

his hypothesis (Table 2). Because one large lake (ELA 228) strongly influenced the regression parameters listed in Table 2, we checked the robustness of our conclusion by transforming the data to a logarithmic scale. Although the distribution of points changed, Fee's conclusion was not altered. However the ratio Ae:Ve can be rewritten as Ae:Ve·Ze and all of these terms are intercorrelated (Patalas, 1980). So although Fee's argument used different terms, the ELA primary production data (Fee, 1979) are also consistent with the hypothesis that shallow lakes are more productive than deep lakes of similar nutrient regimes.

A number of different relationships between Z and fish catch have been used to estimate sustainable fish harvest in freshwater systems (Rawson 1952; Ryder 1965; Ryder et al 1974; Matuszek 1978). Our analysis supports Rawson's (1952) conclusion that fish yields are inversely proportional to Z (Table 3). Ryder's argument that mean depth and total dissolved solids are both correlated with fish yields is also correct (Table 3). However the conclusion (Matuszek 1978) that the catch of preferred species (lake trout, walleye, sauger, and lake whitefish) could also be predicted using the same morphoedaphic variables is not correct. This result may reflect real differences in the ecology of different fishes, because some preferred species cannot survive the warmer waters of shallow lakes. However the absence of a statistically significant influence of Z upon yield may also reflect the high degree of multicollinearity between Z and A in the original data set. More data are needed to distinguish between these two alternatives.

Earlier this century Birge and Juday (1911), Thienemann (1926, 1928) and Hutchinson (1938) all concluded that rates of hypolimnetic oxygen depletion expressed in mg of oxygen per m^3 per day were greater in shallow lakes than in deep lakes. The solution adopted by limnologists was to eliminate the morphometric influence by expressing the rate of oxygen depletion in mg per m^2 of hypolimnetic sediment area per day. Recently this method was also challenged (Cornett and Rigler 1979, 1980; Charlton 1980). However both the early conclusions of Thienemann and Hutchinson, and the recent arguments are suspect because the same terms, hypolimnetic volume, or hypolimnetic area, appear in both the dependent and independent variables. The data of Birge and Juday (1911) and other data, presented by Cornett and Rigler (1979, 1980) were used to re-examine these hypotheses. Despite the fact that the original analysis could have biased their results, the conclusions of all earlier studies were upheld (Table 4). Both methods of expressing rates of hypolimnetic oxygen depletion are influenced by the morphometry of the hypolimnion, and by the productivity of the lake's surface waters.

Discussion

Analysis of the data presented in earlier studies, is consistent with the hypothesis that lake morphometry influences the typology of a lake. These relationships between mean depth, fish catch, phytoplankton biomass or production, or rates of hypolimnetic oxygen depletion and mean depth can be used to predict these variables in new sytems.

Despite the diversity of lake variables and lakes investigated in this analysis, the partial regression coefficient for log(Z) is remarkably constant. Omitting the data of Matuszek (1978), the b value for Z ranges between 0.64 and 0.46. This suggests that biotic processes are approximately proportional to the square root of the mean depth of the lake. Perhaps someone might use this observation to develop a mechanistic explanation for the empirical consistancy.

While our examination of these 8 data sets support the general conclusions of the original studies, several specific arguments were not supported. Ryer(1965) and Matuszek (1978) reported that Big Peter Pond was an obvious outlier in their regressions. This conclusion appears specific to that statistical model. This lake is not an outlier in our regression (Fig. 1). Although this lake has a larger residual than average, the residual is not larger than that of Lake Erie. Neither residual is significantly large (test of Snedecor and Cochran 1967).

In future studies, limnologists will probably continue to scale their measurements to various estimates of lake size. Therefore it is useful to ask why this scaling did not influence the important conclusions of previous workers in lake typology, when erroneous inferences have influenced the analysis of other data (Rolf and Fairbairn 1980, Kenny 1982). In one sense, the mean depth of a lake is an independent variable and is not a ratio. Z can be determined without

using the volume or area of the lake by calculating the average of the depths measured at a series of random locations around the lake. However this is almost never done. Z is calculated as the ratio of lake volume: surface area of the lake. It is more probable that the scaling of the different variables had little influence upon the results because of data distributions.

Atchley et al (1976) reported the smallest spurious correlations in their data when the numerator and denominator of the dependent and regressor terms were correlated, and the parametric coefficients of variation of the numerator and denominator were approximately equal. In all the regressions, the numerator and denominator were strongly correlated (R 0.8). The coefficients of variation of the numerator and denominator were also very similar. Therefore hindsight suggests that the influence of ratios upon the parameters that we investigated should be small. However, since there is no guarantee that truly spurious correlations of variables expressed as ratios will possess similar statistical properties, the interpretation of observations presented as ratios must be accompanied by a careful analysis of the data. We hope that this anlysis and that of Kenney (1982) will stimulate other investigators to examine other types of variables for similar effects.

AUTHOR	G	Y	MODEL
Rawson (1952)	log(NP/A)	log(NP)	bo, log(A), log(Z)
Fee(1979)	PP/Ve	PP	Ve, Ae
Rawson(1952)	log(Yc/A)	log(Yc)	bo, log(A), log(Z)
Ryder(1965)	log(Yc/A)	log(Yc)	bo, log(A), log(Z) log(TDS)
Matuszek(1978)	log(Yp/A)	log(Yp)	bo, log(A), log(Z) log(TDS)
Cornett & Rigler (1980)	log(MOD/Vh)	log(MOD)	bo, log(Vh), log(Zh)
"	log(MOD/Ah)	log(MOD)	bo, log(A), log(PP) log(Th), log(Zh)
" (1979)	MOD/Ah	MOD	ARp, ATh, Aln(Zh)

Table 1. Summary of the original and transformed models investigated in this study. A is the area of the lake, V is the volume of the lake, Z is the mean depth of the lake. The subscripts 'e' and 'h' refer to the epilimnion and hypolimnion respectively. NP is the net plankton biomass, PP annual pelagic primary production (mg C/yr), Y yield of all species of fishes (Yc) or the yield of a selected group of preferred species (Yp) in kg/yr (see Matuszek 1978). MOD is the rate of hypolimnetic oxygen consumption (mg/day). TDS is the concentration of total dissolved solids in the surface waters (mg/L). Th the mean temperature (C) in the hypolimnion. Rp is the calculated retention of phosphorus ($mg/m^2/yr$) (see Cornett and Rigler 1979). Variables transformed to a base 10 logarithm are shown as log(). Those transformed to a base e scale are shown as ln().

MODEL	SOURCE	ESTIMATE	DF	SS
Rawson (1952)	bo	-1.85	1	1.25***
	log(A)	1.04	1	24.58***
	log(Z)	-0.66	1	1.16***
	RSS	-	15	1.11
Fee (1979)	Ve	27.93	1	17.95***
	Ae	1.44	1	1.15***
	RSS	-	20	0.28

Table 2. Analysis of variance (ANOVA) table for the phytoplankton regressions. RSS is the residual sum of squares, SS is the sum of squares which can be attributed to each regression parameter (source) and DF is the number of degrees of freedom associated with the source. Statistical significance at the 5% level (*), at the 1% level (**), and at the .1% level (***) are denoted with different numbers of stars.

MODEL	SOURCE	ESTIMATE	DF	SS
Rawson (1952)	bo	4.67	1	0.44**
	log(A)	1.12	1	2.00***
	log(Z)	-0.64	1	0.54***
	RSS	-	10	0.26
Ryder (1965)	bo	4.45	1	2.54***
	log(A)	1.03	1	11.10***
	log(Z)	-0.56	1	0.54***
	log(TDS)	0.29	1	0.14*
	RSS	-	19	0.44
Matuszek (1978)	bo	-4.25	1	0.99***
	log(A)	1.03	1	4.12***
	log(Z)	-0.55	1	0.36NS
	log(TDS)	0.55	1	0.39*
	RSS	-	18	0.88

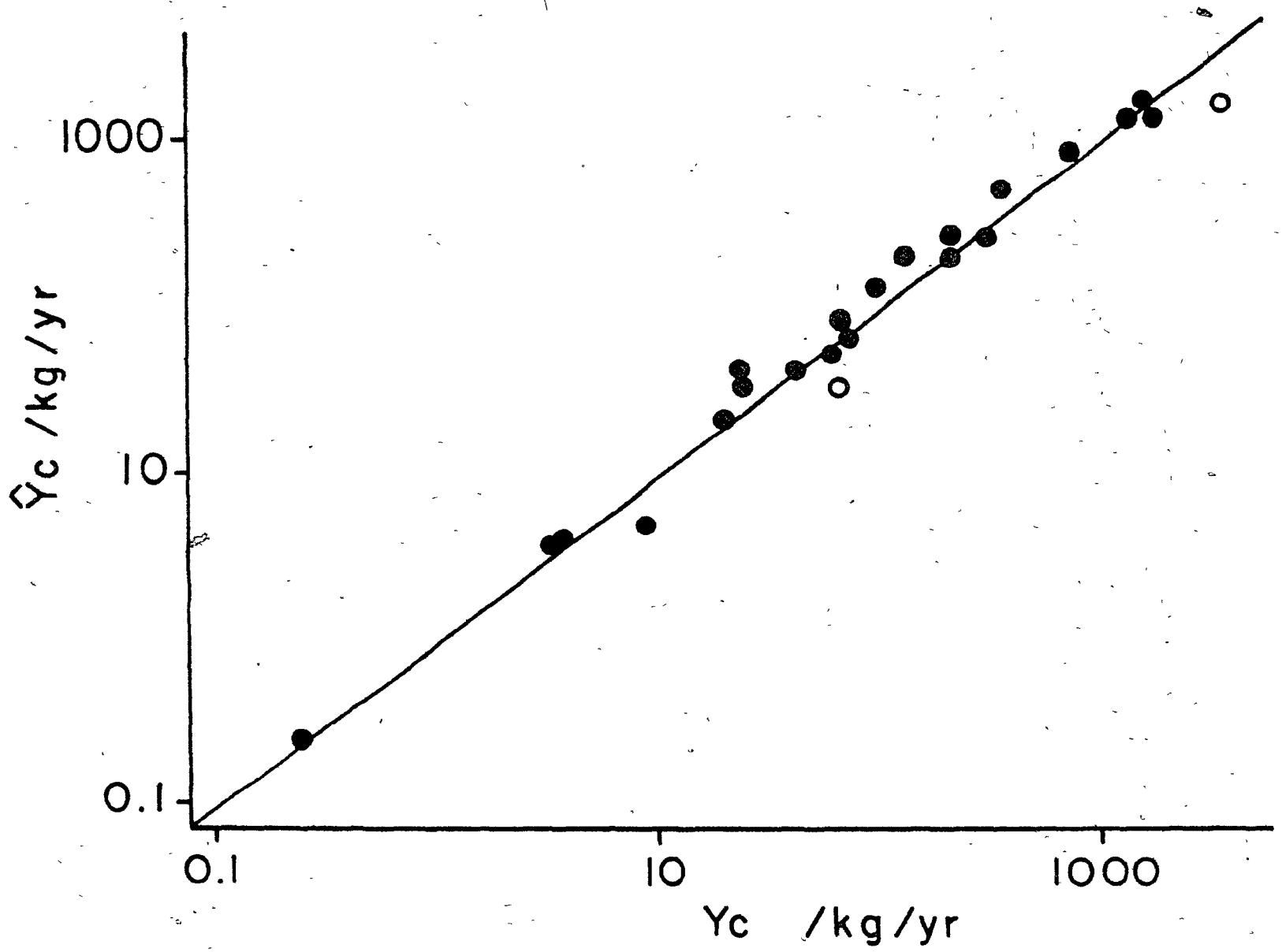
Table 3. ANOVA table for the regressions of fish yield against mean depth of the lake. NS denotes that the source variable does not explain a significant amount of variation in the dependent variable. Other symbols are the same as those listed in earlier tables.

TABLE IV

MODEL	SOURCE	ESTIMATE	DF	SS
Cornett & Rigler (1980)	bo	5.33	1	14.08***
	ln(Vh)	1.05	1	9.59***
	ln(Zh)	-0.79	1	0.32**
	RSS		13	0.33
	bo	0.93	1	0.15NS
	ln(A)	1.02	1	147.87***
	ln(PP)	0.34	1	1.49*
	ln(Th)	1.02	1	0.78NS
	ln(Zh)	0.45	1	1.85**
	RSS		15	0.29
Cornett & Rigler (1979)	Ah	954.20	1	12.12**
	Ah.Th	12.13	1	1.52*
	Ah.ln(Zh)	275.70	1	4.29**
	Ah.Rp	0.73	1	6.44***
	RSS		16	4.68

Table 4. ANOVA tables for the regression of rates of hypolimnetic oxygen depletion against the mean thickness (depth) of the hypolimnion. Symbols are the same as those used in earlier tables.

Fig. 1. Observed catches of fish plotted against the predicted catches calculated from the regression presented in Table 2 using the data collected by Ryder (1965). Big Peter Pond and Lake Erie are shown as open circles on the graph. The open circle with the higher catch is Lake Erie. Neither lake deviates significantly from the regression. The vertical axis plots the predicted catches ($\hat{Y}$).


1000
10
0.1
Ŷc /kg/yr
0.1
10
1000
Yc /kg/yr

CHAPTER EIGHT

A COMPARISON OF ALTERNATIVE METHODS OF PREDICTING AREAL HYPOLIMNETIC OXYGEN DEFICITS

Introduction

Current research in limnology emphasizes the generalities between lakes (Rigler 1975; Rast and Lee 1978). Reproducible patterns between lakes can be quantified and used to predict the properties of other lakes and to predict how one property of a lake will change as other variables are changed by external manipulations. However the empirical relationships that have been developed, can only be used with confidence if they have been rigorously tested. As a result of the intense interest in predicting several properties of lakes, different investigators conducting concurrent research develop different models that all report to predict the same variable(s) accurately. Only rarely have different empirical relationships been compared or tested using data from an independent set of lakes that were not used to develop the original equation (Ostrofsky 1978; Cornett and Rigler 1979, 1980a; Reckhow 1979; Charlton 1980).

Six studies have developed equations that can predict areal rates of oxygen depletion in the hypolimnia of lakes (AHOD), (Table 1), (Lasenby 1975; Rast and Lee 1978; Cornett and Rigler 1979, 1980a; Walker 1979; Welch and Perkins, 1979; Charlton 1980). However none of these relationships have been adequately tested. The objective of this paper is to test further the predictive ability of the relationship between AHOD measured in a lake, and the amount of phosphorus retained by the lake sediments, the

temperature of the hypolimnion, and the thickness of the hypolimnion that was published by Cornett and Rigler (1979, 1980a) and to compare the predictive ability of that relationship to the predictive ability of the relationships published by Lasenby (1975), Walker (1979) and Charlton (1980).

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Methods

Measurements of Secchi depth, trophogenic phosphorus and chlorophyll a concentrations, and hypolimnetic oxygen concentrations and temperatures were made on 12 lakes located in the eastern townships of Quebec, Canada (approx. lat. 45°16'N, long. 72°9'W). Each lake was sampled between 6 and 10 times at regularly spaced intervals during the period of thermal stratification.

The Secchi depth measurements and samples for total phosphorus and chlorophyll a analyses were collected in duplicate at 2 stations. Each Secchi depth measurement is the mean of the depths recorded as a 20 cm diameter, black and white disc disappeared from view as it was lowered into

the water column and then reappeared as it was raised towards the lake surface.

Samples for total phosphorus and chlorophyll were collected with a tube sampler (Dillon and Rigler 1974). The tube was lowered into the water column to a depth equal to twice the Secchi depth measured on the first sampling date of the season, and the water was poured into a well rinsed plastic bottle. Samples were collected from the same depth throughout the summer. Since no attempt was made to sample the larger zooplankton adequately, samples for phosphorus were poured through a 250 µm mesh to remove all of the larger particulates from the sample. Then total phosphorus concentrations were determined on duplicate or triplicate 50 ml subsamples that were digested with potassium persulphate (Menzel and Corwin 1965). The absorbance of the samples was measured at 885 nm using the same reagents and procedures discussed by Prepas and Rigler (1982).

The retention of phosphorus by the lake sediments was not measured directly. Following the criteria used by Cornett and Rigler (1979), the the retention of phosphorus in the lake sediments was estimated using the empirical relationship developed by Ostrofsky (1978). This relationship requires that the ratio of the total annual discharge of water through the lake's outflow divided by the surface area of the lake must be known. For logistic reasons discharge was not measured directly on any of these study lakes. The Water Survey of Canada accurately gauges the headwater

catchment of the Hall River approximately 40 km east of our study site. Annual areal discharge (qs) from each lake was calculated as

$$qs = Ad*QH/Ao \qquad (1)$$

where Ad is the drainage area of a lake determined by electronically planimetering the area within the topographic boundaries measured on a 1:50,000 topographic map, Ao is the lake area and QH is the annual discharge per m^2 of catchment area from the Hall River (m/yr). All of the calculations used the annual water year (Oct. 1 to Sept. 31). During 1978, 1979 and 1980 QH values were 0.80 m/yr, 0.58 m/yr and 0.54 m/yr respectively.

Two chlorophyll subsamples of 500 ml were filtered through GFC filters at 4 to 5 psi. Then the filters were frozen until the chlorophyll was extracted. The filters were extracted in 10 or 15 ml of 96% ethanol for 18 to 24 hours (Ostrofsky unpublished). The absorbance of the filtered extract was measured at 750, 650, and 649 nm. Chlorophyll a concentrations were calculated from the absorbance values using the equation developed by Wintermans and de Mots (1965). No correction was made for the presence of phaeophytins in the samples. Chlorophyll a concentrations determined using the ethanol extraction are not significantly different from values determined using the acetone extraction technique of Strickland and Parsons (1969)(Rigler unpublished).

On each sampling date, vertical profiles of electrical resistance were measured at 1 m intervals to 20 m and 2, 2.5, 5, or 10 m intervals below 20 m. Resistances were measured with a Fenwall thermistor bead attached to a

Data Precision multimeter. Temperatures were calculated from the measured resistances by calibrating the apparatus against a platinum resistance thermometer. The mean summer volume-weighted hypolimnetic temperatures (T) were calculated from the temperature profiles measured over the same period of time used in the AHOD calculations. The average summer temperature at each depth was also used to calculate the depth of the upper boundary of the hypolimnion (Zu). This definition is important. Lasenby (1975) demonstrated that the AHOD value reported for a lake could be altered by as much as 7% by changing Zu by 1 meter. Unfortunately there is no standard definition of Zu because temperature changes in lakes are continuous rather than discrete and terms used by previous investigators (eg. Hutchinson 1957) cannot be operationally defined. In this thesis the depth of the thermocline (Z_T) was defined by the average depth of the maximum temperature gradient during the three months of maximum stratification: June, July and August (Cornett and Rigler 1980a). A linear regression equation was calculated by regressing the mean temperatures at depths Z_{T-1}, and Z_{T+1} against the respective depths. A second equation was fitted through the temperatures measured at 3 depths that were equally spaced between Z_{T+1} and the maximum depth of the lake. The depth where the two lines intersected was defined as Zu (Fig. 1). This definition was used in all calculations including the calculations in which published AHOD values were re-evaluated.

Samples for oxygen concentrations were collected in a vertical profile over the deepest, most central location on the lake. Samples were collected from between 5 and 15 discrete depths within the hypolimnion

using a 1 liter metallic sampling bottle or a 3 liter VanDorn. In 1980 these samples were supplemented with samples collected from 5 depths in each lake using a peristaltic pump. No significant differences were measured between the 3 methods of sample collection. From each sampler, duplicate 55 mL bottles were slowly filled, and allowed to overflow at least 200 mL. Winkler reagents were added immediately (Carpenter 1965). Oxygen concentrations were determined by titrating 25 mL subsamples of the Winkler solution with a microburette using 0.15 N $Na_2S_2O_3$ standardized at regular intervals with 10 mL of 0.005 N KIO_3. The endpoint of the titrations was detected using a photometric endpoint detector coupled to a microvoltmeter (Bryan et al 1976).

On each sampling date the mass of oxygen in the hypolimnion was calculated by integrating the product of the lake area at each sampling depth and the oxygen concentration measured at the same depth. This calculation assumes that the concentration of oxygen is horizontally homogeneous. Horizontal homogeneity is to be expected within the hypolimnion because horizontal mixing is much more rapid than vertical mixing (Quay et al 1980). This assumption has also been tested and verified (Smith and Bella 1973; Charlton 1979). Morphometry of all of the lakes was calculated from bathymetric maps prepared by government agencies. The mass of oxygen per m^2 of hypolimnetic area was determined by dividing the total mass of oxygen by the area within the depth contour that delimited the upper boundary of the hypolimnion. These values were regressed against the Julian day the samples were collected (Lasenby 1975). The slope of the regression calculated over the period when the hypolimnion

is oxic and stratified is the estimate of the AHOD value. The precision of an AHOD value is estimated as the residual variance that is not explained by the regression.

Results

In the eastern townships study lakes, the average concentrations of phosphorus and chlorophyll a and the Secchi depth covered a broad range of values (Table 2). Total phosphorus concentrations less than 5 ug/L were measured in several extremely oligotrophic lakes. These levels were 10 times lower than those measured in lake Magog. This lake receives sewage effluent from the town of Magog. All other trophic parameters are correlated with the phosphorus concentrations. However the AHOD values measured in the study lakes (Table 3) do not correlate directly with the productivity of the surface waters of the lakes. This observation is consistent with the conclusions of Chapra and Dobson (1979), Cornett and Rigler (1979, 1980a), Walker (1979), and Charlton (1980). The results of these studies demonstrated that the temperature of the hypolimnion and the morphometry of the hypolimnion both strongly influence the areal rate of hypolimnetic oxygen depletion. As a result, a simple correlation between the surface water productivity of lakes and the AHODs measured will not be visible. The AHOD values predicted by the published models (Table 1) were calculated using the equations developed by the authors and the data measured on each lake (Table 2). In several cases the period over which the values of different parameters were averaged was not stated in the original papers. We assumed that the parameters should be averages

calculated over the same period used to calculate the AHOD value. The rates of oxygen depletion predicted for the same lake using the four different equations are frequently very different (Fig. 2). The predictions made by the regression of Secchi depth against AHOD (Lasenby 1975) do not agree with the deficits measured in any of the basins of Lake Memphremagog or other deep lakes (Fig. 2a). When AHODs greater than 450 $mg/m^2/day$ were measured, the equation developed by Lasenby (1975) predicts much lower deficits in all of the lakes except Lake Magog. The bias in Lasenby's model appears to be proportional to the mean thickness of the hypolimnetic water column.

As one of his independent variables, Walker (1979) used an index term that is partially composed of the measured Secchi depth. Walker also included the mean depth of the lake (Z) in his regression as an independent variable. Since Z and ZH are strongly correlated, this regression is qualitatively similar to the regressions developed by Cornett and Rigler (1979, 1980a) and Charlton (1980). While Walker's model predicted low AHOD values very well, it did not predict higher rates with the same accuracy (Fig. 2b). The absolute value of the residuals (observed AHOD - predicted AHOD) increased as the measured AHOD increased .

Charlton's (1980) equation predicts AHOD values using surface water chlorophyll concentrations, the mean hypolimnetic temperature and the mean thickness of the hypolimnion. This relationship predicts very well when the observed AHOD values are less than 450 $mg/m^2/day$ (Fig. 2c). The

poorer predictive accuracy displayed by the model at higher rates of oxygen depletion may reflect the limited amount of data at these high rates used to build the original model. Only 4 lakes in the original data set had AHOD values greater than 450 $mg/m^2/day$.

In nine study lakes, predictions of the AHOD model developed by Cornett and Rigler (1979, 1980a) fall within the confidence interval around the measured AHOD values. Three lakes fit this model very poorly (Fig. 2d). Predicted AHOD values were much higher than the AHODs measured in Lake Magog. The opposite is true in Lake Truite and Lake Petite Brompton. Predictions made for all of these lakes were extrapolations beyond the limits of the original relationship. The retention of phosphorus was much higher in Lake Magog than in any lake included in the original analysis (Cornett and Rigler 1979) or in subsequent discussion (Cornett and Rigler 1980b). Lakes Truite and Petite Brompton, had a lower phosphorus retention combined with a shallower hypolimnion than any of the original lakes. The poor predictive accuracy of the model in these lakes may reflect some unique properties of the lake. However it appears that the large residuals can also be attributed to the fact that it was necessary to extrapolate beyond the boundaries of the original data set to make the required predictions.

Each of the four relationships investigated makes accurate predictions in some of the lakes that we studied.

To compare the overall predictive ability of the models, the accuracy or bias and the precision of the predictions were examined. For each model the minimum and maximum residuals, the variance of the residuals (Reckhow, 1979), and the mean absolute value of the residuals were tabulated (Table 4). Bias in the model predictions was determined by examining the plots of predicted against observed AHOD values (Fig. 2). The relationship with the lowest absolute residual and the lowest residual variance was the equation developed by Cornett and Rigler (1979). The residual variance was approximately half of the variance observed in the other models. All of the AHOD values used to develop the original equation (Cornett and Rigler 1979) were recalculated from previous studies (Table 5) using the same methods applied to the field data collected in this study. This is probably one reason why the model developed earlier during this thesis produced the predictions with the lowest residuals. AHOD values have been calculated in a variety of different ways (Hutchinson 1957). By recalculating all of the rates, this study avoided two major artifacts. First the selection of the depth of the upper boundary of the hypolimnion was standardized. Secondly the AHOD values that were originally calculated over periods when the hypolimnion was anoxic and could not consume oxygen, were recalculated. Periods of anoxia or incomplete stratification were avoided. As a result several of the AHOD values listed in Table 5 differ from those published by the original investigator. However most of the differences are small.

The models of Lasenby (1975), Cornett and Rigler (1979), and Charlton (1980) all exhibit some bias. Although many of the model predictions fall

within the confidence intervals of the measured AHOD values, each model predicts a disproportionate number of AHOD values that are lower than the measured values. The bias is most obvious in the model developed by Cornett and Rigler (1979)(Fig. 2d). The simplest explanation of this bias postulates that it is induced by the statistical techniques used to analyze the data. Some statistical bias is introduced into all of the models when they attempt to predict AHOD values calculated using a type one linear regression model (Snedecor and Cochran 1967). However this bias is very small because the variance that is not explained by the regressions used to calculate the AHOD values is small (Tables 3 and 5). All of the models tested in this analysis also assumed that the variance in the AHOD values is constant. However the data show that the different variances associated with AHOD estimates are not constant (Tables 3 and 5). If the variance of a dependent variable is not constant then a weighted least squares analysis should be used (Drape and Smith 1966). If this procedure is not followed the resulting regression coefficients may be biased by data points that were not accurately estimated in the original study. A small bias in the fitted regression coefficients could produce a much larger bias when it was necessary to extrapolate outside the boundaries of the original data set to make the predictions needed to test the regression. To examine these hypotheses, the data collected in this study (Tables 2 and 3) were pooled with the data collected from the literature (Table 5), and the relationship developed by Cornett and Rigler (1979) was re-examined. The points were weighted by the reciprocal of the variance of the measured AHOD value. A weighted least squares regression was calculated. If the original analyses induced the bias predictions in the test results, then the bias should disappear in the pooled analyses and the residual variation should

decrease. The resulting equation explains 74% of the variation in the observed AHOD values (Table 6). This figure is not significantly greater than the amount of variation explained by the original relationship published by Cornett and Rigler (1979). The predictive accuracy of the variance weighted equation is not substantially improved over the original equation (Cornett and Rigler 1979, 1980b). The average variance-weighted, absolute deviation between predicted and observed AHOD values is 58 $mg/m^2/day$. On a relative scale the average ratio of residual:observed AHOD was 0.21. However the relative errors were larger than the average in lakes with a shallow hypolimnion. The measured AHOD value are plotted against the predicted AHOD values in Fig. 3. Many of the confidence intervals around the observed values (see Table 3 and 5) overlap with the predicted AHOD values. However there are an equal number of cases in which the predicted AHOD values do not fall within the confidence interval of the observed rate, and the bias reported earlier has not been removed. The poor fit is not caused by the statistical analysis of the data.

The lack of agreement between predicted and observed rates in several lakes suggests that factors that were not included in this model influenced the net rate of respiration within the hypolimnion, or that the hypolimnia of different lakes receive or respire different fractions of the organic matter produced in the trophogenic zone. One of the most obvious assumptions made during the original formulation of this model was that the annual retention of phosphorus is a good correlate of the amount of respirable organic matter sedimented into the hypolimnion. This assumption

has not been tested. Perhaps the retention of phosphorus during the summer months or measured rates of sedimentation might be a better method of estimating the amount of organic matter input into the hypolimnion. However this argument also makes several untested assumptions. It assumes that the AHOD does measure the rate of respiration (decomposition) in the hypolimnion. It also assumes that the respiration in the sediments and in the water column is proportional to the amount of organic matter that sediments into the hypolimnion. Organic matter may be buried rather than respired. And the AHOD value may measure processes other than respiration, for example, photosynthesis may add significant quantities of oxygen to the hypolimnion (Mitchell and Burns 1978). These hypotheses require further testing.

The ability to predict accurately the areal rate of oxygen depletion achieves practical significance only when the AHOD value is transformed into a volumetric rate of oxygen depletion (VOD)

$$VOD = AHOD/ZH. \qquad (2)$$

It is the magnitude of the VOD and changes in the VOD that determines whether the hypolimnion is oxic or anoxic. Since the average deviation between predicted and observed values (57 $mg/m^2/day$) is not proportional to ZH, the ability of AHOD models to predict changes in oxygen concentrations will be poorest in shallow lakes. In a lake with a phosphorus retention and hypolimnetic temperature equal to the average values measured in this data set, the error in AHOD estimates will result

in large errors in estimates of the VOD (Table 7). The estimated errors will be largest in shallow lakes. These lakes are potentially more sensitive to changes in cultural nutrient loading because they have the greatest probability of becoming anoxic. This property of all AHOD models coupled with the limited predictive success of existing models suggests that alternative methods of predicting volumetric rates of oxygen depletion may be more suitable for predicting changes in oxygen concentrations in the hypolimnion.

AUTHOR	EQUATION
Lasenby (1975)	$Log(AHOD)=-13700Log(S)-6500$
Cornett and Rigler (1979, 1980b)	$AHOD=-341+0.56Rp+5.0T^{1.74}+150Ln(ZH)$
Walker (1979)	$log(AHOD)=-3580+204I+4550log(Z)-2040Log(Z)^2$
Charlton (1980)	$AHOD=3800(1.15C^{1.33}/(9+1.15C^{1.33})$ $*ZH/ZH(ZH+50)*2^{((T-4)/10)}+120$

Table 1. Summary of published equations developed to predict AHOD values. AHOD is the areal hypolimnetic oxygen deficit ($mg/m^2/day$), S is the mean summer secchi depth (m), Rp is the annual retention of phosphorus by the lake sediments ($mg/m^2/yr$), T is the mean summer hypolimnetic temperature (^oC), ZH is the mean depth of the hypolimnetic water column, I is an index of surface water productivity defined by Walker (1979), Z is the mean depth of the lake (m), and C is the mean concentration of chlorophyll a in the trophogenic zone (ug/L). The AHOD models published by Rast and Lee (1978) and Welch and Perkins (1979) were not tested because one of the independent variables (phosphorus loading) used in the regression models was not measured during this study.

YEAR	LAKE	ZH	T	P	Rp
1978	Brompton	9.4	7.6	7.0	128
	Central	45.3	4.6	9.8	304
	Lovering	4.0	10.5	10.3	154
	Lyster	16.4	5.8	6.5	75
	Stukely	8.9	7.2	4.8	41
1979	Brompton	9.4	7.1	7.0	105
	Central	45.0	4.6	10.5	319
	Fitch	3.3	8.1	12.1	328
	Lovering	4.0	10.2	8.5	101
	Lyster	16.4	5.8	5.1	47
	Magog	2.5	11.2	38.0	1068
	Massawippi	35.1	4.8	10.6	231
	North	7.3	9.9	9.7	300
	Orford	20.1	5.0	4.3	40
	Stukely	8.9	6.6	3.9	25
	Truite	3.2	5.8	9.4	113
1980	Brompton	9.1	8.3	7.1	101
	Central	45.1	4.0	12.0	369
	Fitch	3.3	8.5	17.6	467
	Petite Brompton	6.3	6.3	7.9	58
	Lovering	4.0	11.0	8.7	99
	Lyster	16.4	5.9	5.0	44
	Magog	3.7	12.6	46.8	1360
	Massawippi	35.1	4.9	10.9	227
	North	7.3	9.8	10.1	311
	Orford	19.8	4.5	4.9	42
	Stukely	8.9	7.4	4.7	29
	Truite	2.8	5.1	8.5	98

Table 2. Summary of surface water trophic parameters measured in the 12 study lakes. P is the average concentration of total phosphorus (<250 µm) in the trophogenic zone during the summer (µg/L). Other symbols were defined in Table 1.

YEAR	LAKE	ZO	AHOD	SE	N
1978	Brompton	12	268	6.6	6
1978	Central	18	776	149	7
1978	Lovering	10	290	12.3	8
1978	Lyster	12	283	36.9	8
1978	Stukely	11	232	16.0	5
1979	Brompton	12	326	16.7	6
1979	Central	20	586	27.2	8
1979	Fitch	12	354	33.6	6
1979	Lovering	10	293	12.3	7
1979	Lyster	12	288	11.5	12
1979	Magog	12	523	18.9	6
1979	Massawippi	11	587	49.6	6
1979	North	12	538	60.0	7
1979	Orford	11	304	17.2	12
1979	Stukely	11	243	7.1	11
1979	Truite	7	207	41.1	7
1980	Brompton	13	389	7.6	14
1980	Central	19	715	55.7	9
1980	Fitch	12	519	26.1	15
1980	Petite Brompton	9	414	28.8	12
1980	Lovering	10	367	4.9	15
1980	Lyster	12	348	13.0	6
1980	Magog	10	649	22.9	9
1980	Massawippi	11	710	22.5	12
1980	North	13	584	14.3	11
1980	Orford	12	408	44.7	12
1980	Stukely	11	309	6.9	15
1980	Truite	8	208	15.0	12

Table 3. Summary of the measured AHOD values ($mg/m^2/day$). SE is the is the standard error of estimate, and N is the number of oxygen profiles which were measured.

MODEL	MIN	MAX	S	ABS
Lasenby	-194	481	33197	141
Cornett and Rigler	-424	267	18679	102
Walker	-572	576	71173	202
Charlton	-494	215	35935	158

Table 4. Largest negative residual (observed - predicted AHOD) (MIN), largest postive residual (MAX), residual variance (S), and the mean absolute residual (ABS) for the 4 different AHOD models calculated using the test data.

LAKE	YR	AHOD	SE	N	ZO	ZH	T	P	Rp	Source
Michin	69	284	17.6	6	7	4.4	7.9	9.6	240	1
Bluehill	69	134	9.9	7	13	3.9	9.6	3.9	22	1
Harp	73	314	46.0	9	9	11.6	4.7	12.5	131	2
Jerry	73	371	45.0	9	8	9.9	4.7	19.	334	2
Stoney	71	580	2.0	89	14	9.4	8.7	24.	473	3
Esrom	69	653	31.7	7	14	5.1	10.6	206.	926	4
Sammamish	65	760	39.2	8	10	9.5	10.6	28.	280	5
Kamloops	74	263	5.8	6	52	41.2	4.8	4.	7	6
Gravenhurst	74	371	23.1	6	9	3.6	8.6	25.	250	7
Gravenhurst	73	297	42.9	4	9	3.6	11.1	33.	330	7
Gravenhurst	70	232	24.0	6	9	3.1	8.8	39.	390	7
Gravenhurst	69	333	26.1	7	9	3.6	9.0	42.	420	7
Walensee	72	513	97.9	5	32	81.2	5.8	10.5	323	8
Walensee	73	928	128.0	5	26	83.9	5.8	13.7	421	8
Walensee	74	998	232.0	6	33	81.5	5.4	17.8	547	8
Horwr Bucht	69	649	18.9	6	20	30.5	6.7	26.5	505	9
Horwr Bucht	67	625	19.6	5	17	32.1	6.4	23.8	453	10
Horwr Bucht	66	642	50.8	6	21	30.0	6.0	21.6	411	10
Washington	57	652	101.0	4	20	22.7	7.5	24.2	475	11
Washington	58	670	119.0	7	20	22.7	7.5	24.3	477	11
Bob	76	309	20.7	9	8	16.6	6.0	6.9	108	12
Skeleton	69	266	21.2	6	11	5.8	6.8	7.0	198	13
Dudley	69	285	33.7	6	9	5.5	9.0	7.7	165	13
Clarke	68	104	6.6	5	7	1.9	7.4	10.0	298	14
Kearney	68	148	11.6	5	7	4.9	6.0	12.1	290	14
Brewer	68	142	8.5	7	7	3.3	7.1	8.6	108	14
Costello	68	157	22.3	6	8	5.3	6.2	9.6	181	14

Table 5. AHOD values recalculated from published oxygen concentrations. Symbols are the same as in Tables 2 and 3. Yr refers to the year that the study was done. The sources of oxygen data were: 1. Kerekes (1974) 2. Nicholls (1976) 3. Nicholls (1975) 4. Jonasson et al (1974) 5. Bella (1970) 6. St. John (1976) 7. Michalski et al (1973) 8. Von Zimmerman (1977) 9. Stadleman (1971) 10. Von Zimmerman (1969) 11. Shapiro (1959) 12. Rigler (unpublished) 13. Michalski et al (1973) 14. Langford (unpublished).

SOURCE	DF	ESTIMATE	SE
Model	3	5630.	
Residual	53	1946.	
bo	1	-236.8	55.95****
Rp	1	0.41	0.055****
$T^{1.74}$	1	5.40	0.818****
Ln(ZH)	1	141.33	15.590****

Table 6. Weighted least squares regression of pooled data from tables 2, 3 and 5. The model and residual estimates are estimates of the sum of squares. Estimates of the other sources refer to the slope estimates and standard error for each parameter. The asterisk indicate that each parameter explains a significant amount of variation in the AHOD values ($p<0.0001$).

Z1	VOD	SE
2	68	28.5
5	58	11.0
10	41	5.7
20	26	0.38
40	16	0.0014

Table 7. Predicted changes in hypolimnetic oxygen concentration (VOD mg/m3/day) and standard error of the prediction (SE) for hypolimnia of differing mean depth (ZH m).

Fig. 1. An operational definition of the average summer depth of the upper boundary of the hypolimnion. The point of intersection of the two regression lines is the operational definition of the upper boundary of the hypolimnion used in this thesis.

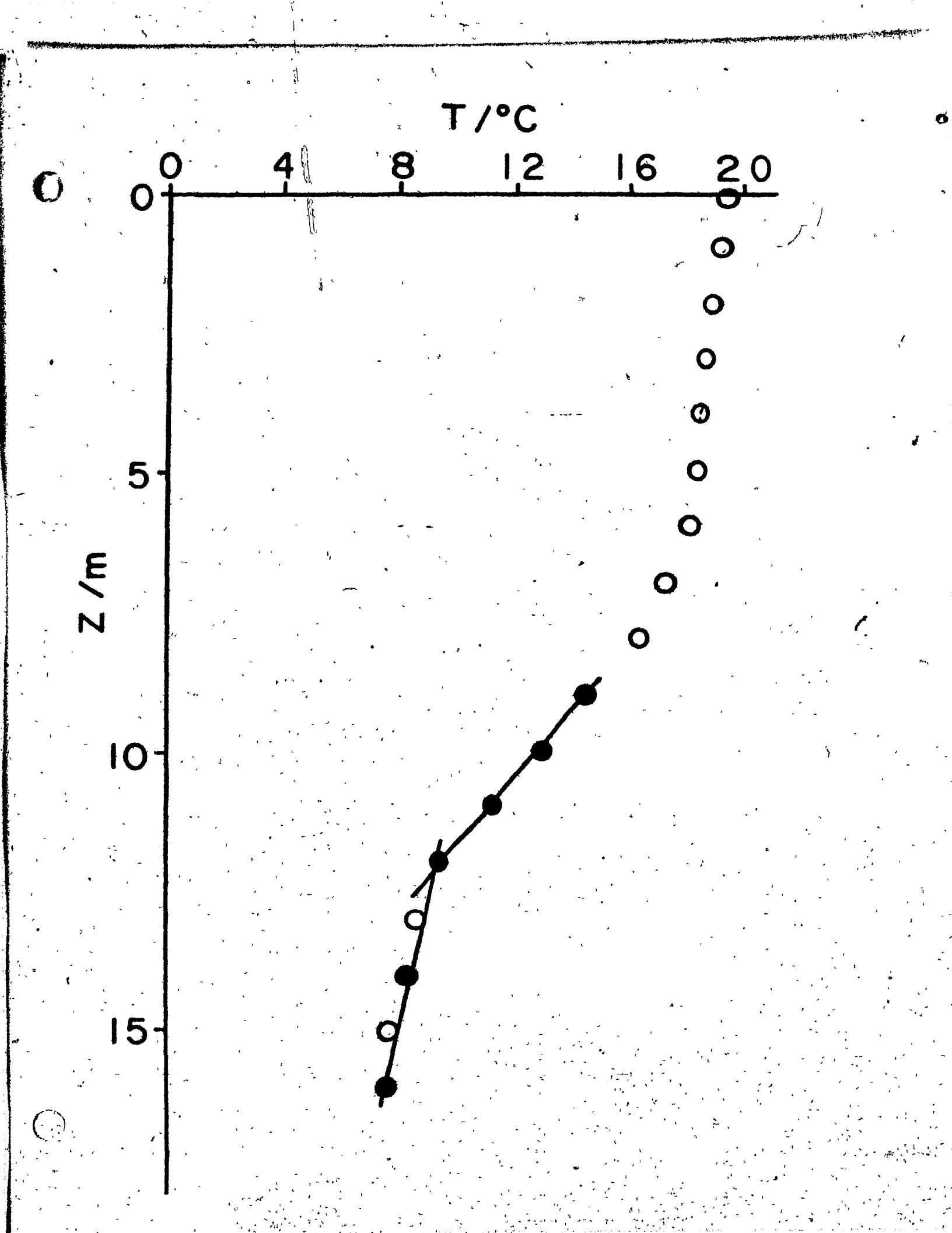

T/°C
0
4
8
12
16
20
0
5
10
15
z/m

Fig. 2a. Predicted $\widehat{AHOD}$ values calculated using the equation developed by Lasenby (1975) plotted against measured rates.

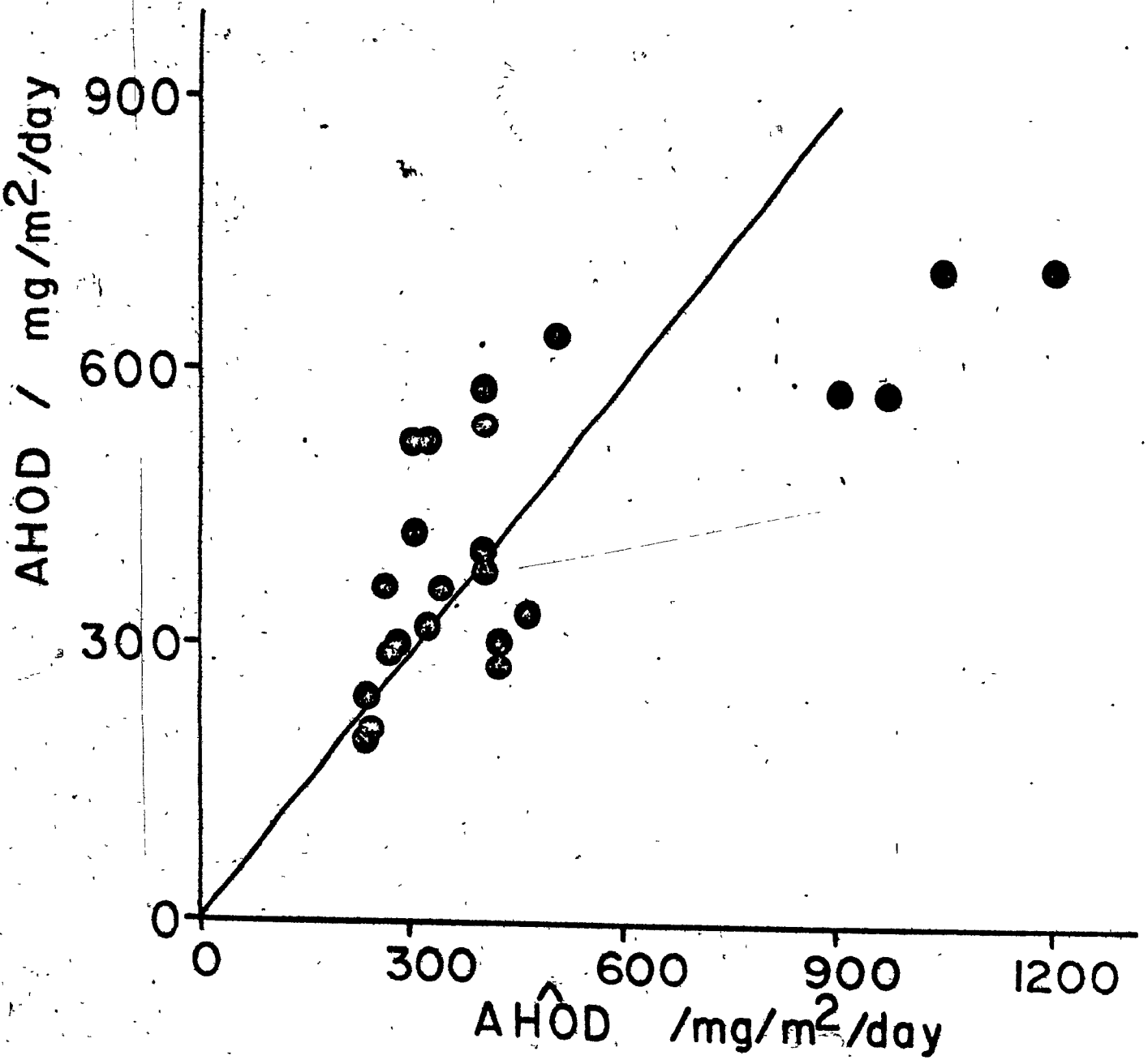

AHOD / mg/m2/day
900
600
300
0
0
300
600
900
1200
AHOD /mg/m2/day

Fig. 2b. Predicted $\widehat{AHOD}$ values calculated using the equation developed by Walker (1979) plotted against measured rates.

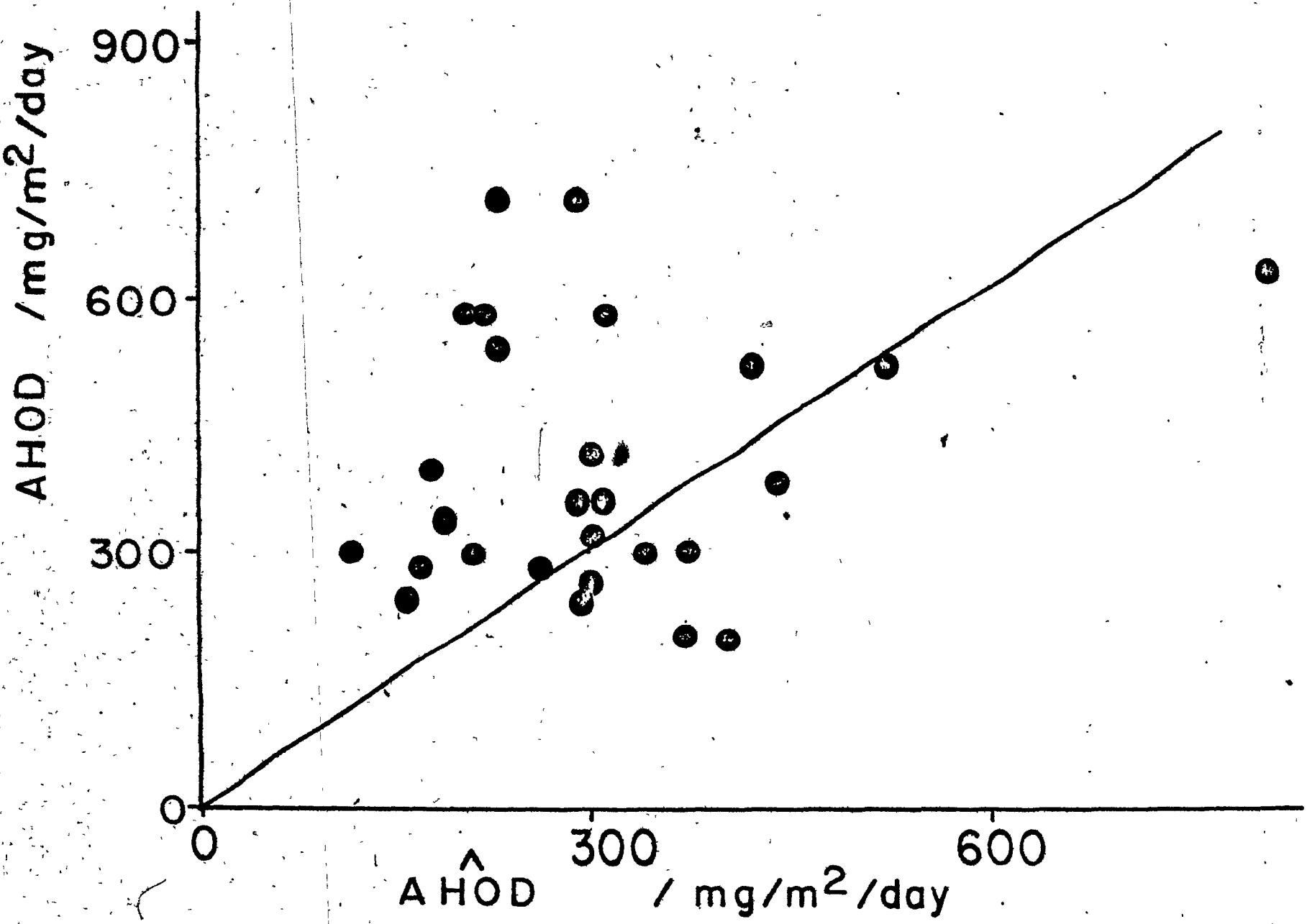

AHOD /mg/m2/day
900
600
300
0
0
300
600
AHOD / mg/m2/day

Fig. 2c. Predicted $\hat{AHOD}$ values calculated using the equation developed by Charlton (1980) plotted against values measured in the study lakes.

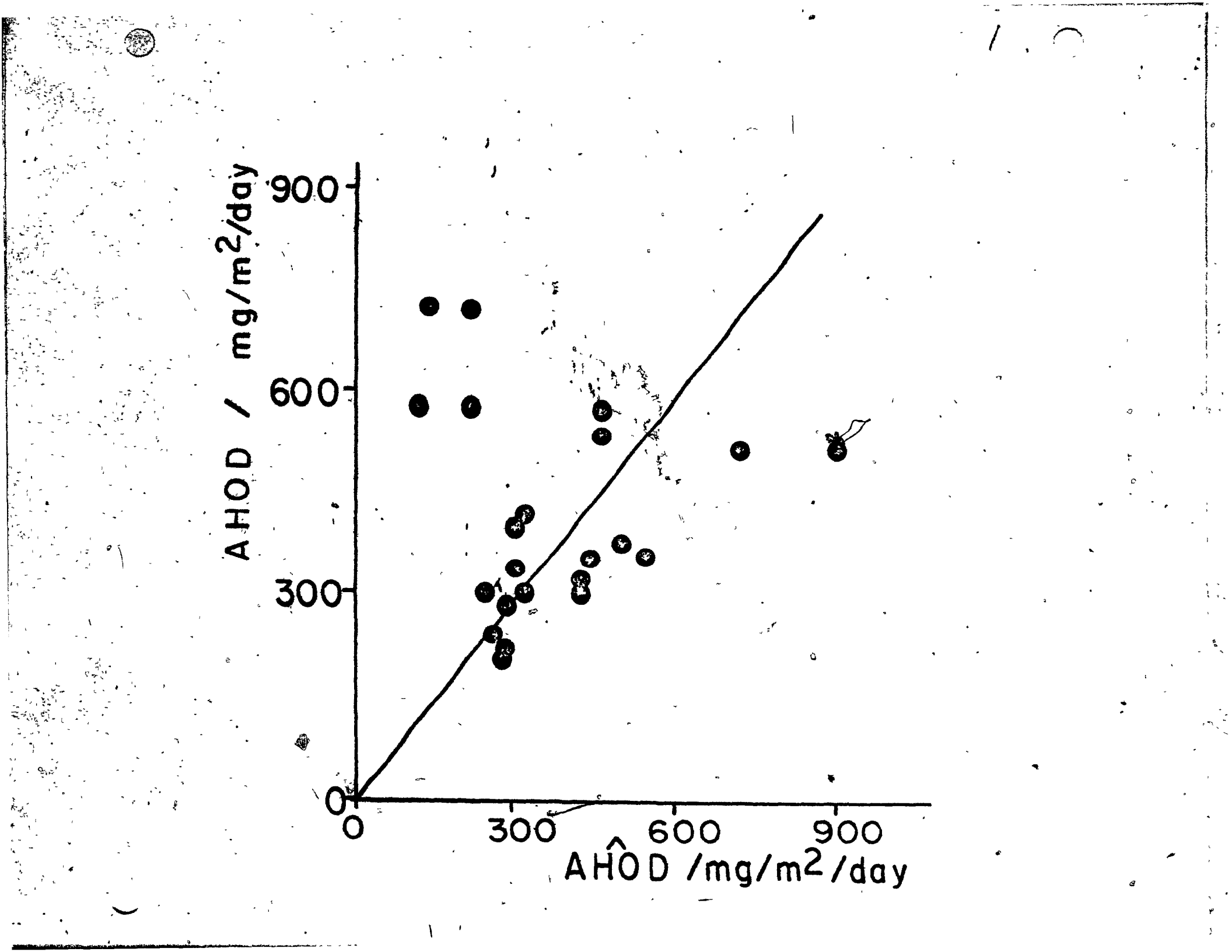

AHOD / mg/m2/day
900
600
300
0
0
300
600
900
AHOD /mg/m2/day

Fig. 2d. Predicted $\widehat{AHOD}$ values calculated using the equation developed by Cornett and Rigler (1979, 1980a) plotted against the values measured in the study lakes.

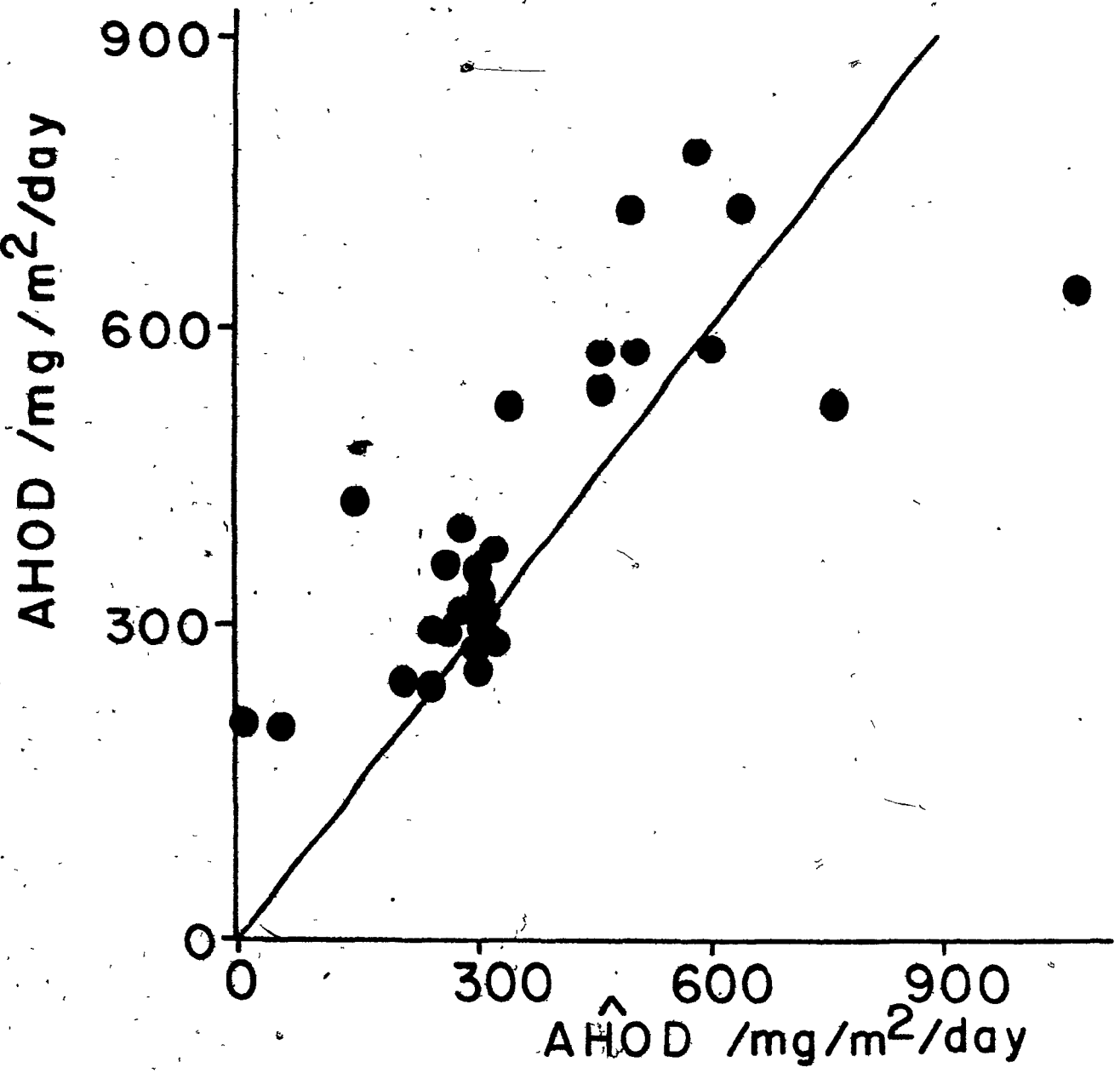
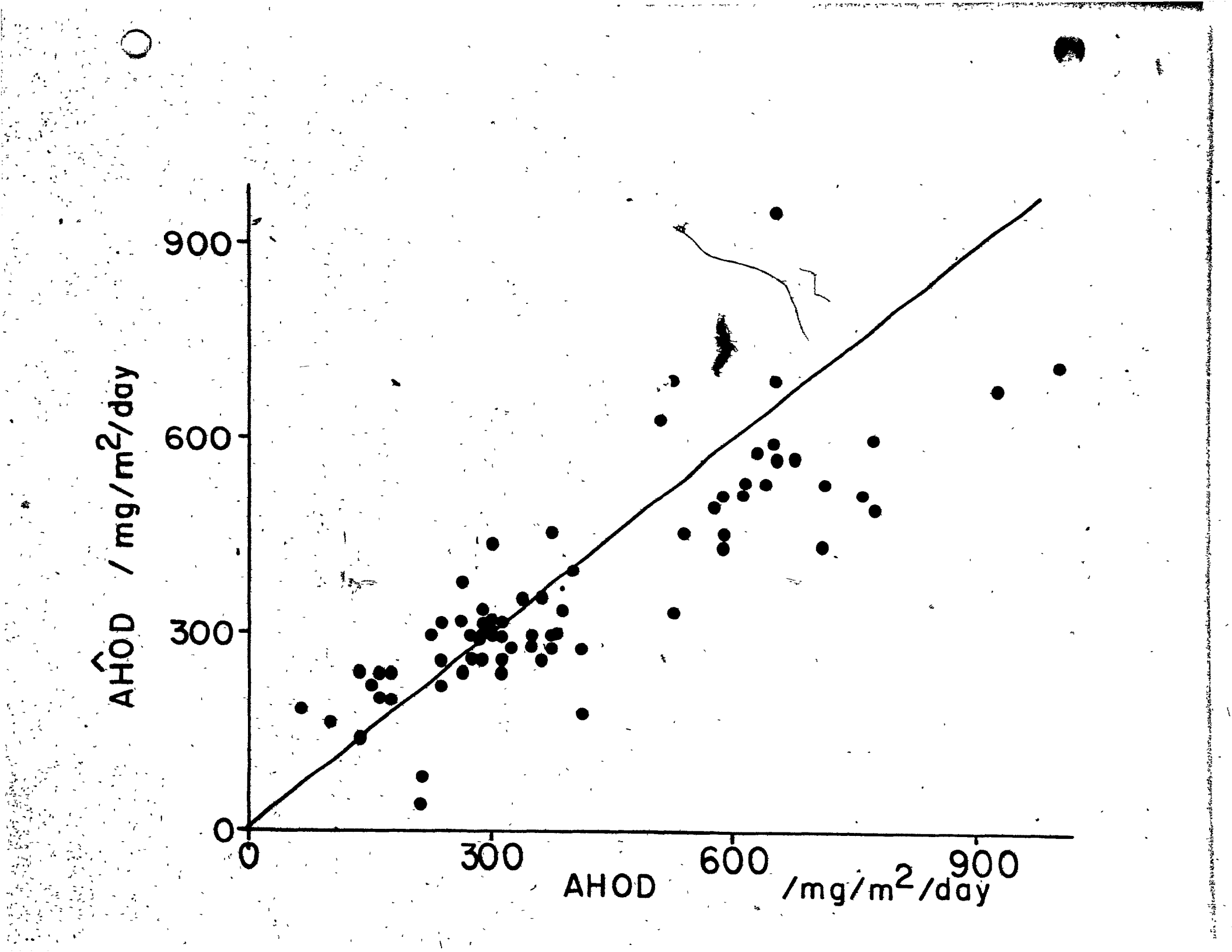

900
600
300
0
AHOD /mg/m2/day
0
300
600
900
AHOD /mg/m2/day

Fig. 3. Predicted $\widehat{AHOD}$ values calculated from the least squares regression plotted against the measured values.


900
600
300
0
0
300
600
900
AHOD /mg/m2/day
AHÔD /mg/m2/day

CHAPTER NINE

VERTICAL TRANSPORT OF OXYGEN INTO THE HYPOLIMNION OF LAKES

INTRODUCTION

During the period of thermal stratification, the average concentration of dissolved oxygen in the hypolimnion of a lake decreases. Several studies have developed correlations between the rate of oxygen depletion and the eutrophication of lake surface waters (Lasenby 1975; Cornett and Rigler 1979; Walker 1979; Charlton 1980). However these theories that predict rates of oxygen depletion are imprecise. In part the lack of precision may result from an ignorance of what hypolimnetic processes the rate of hypolimnetic oxygen depletion measures. Since Birge (1907) drew the analogy between human respiration and the decrease in hypolimnetic oxygen concentrations, most limnologists have assumed that hypolimnetic oxygen depletion is equivalent to hypolimnetic respiration. Inherent in this statement is the assumption that there is no vertical turbulent transport of oxygen between a lake's surface water and the hypolimnion. Three different groups of studies suggest that this assumption must be more rigorously tested.

One set of observations consists of various systems analyses or compartment models developed to simulate the distribution of dissolved gases in stratified lakes (Bella 1970; Fleming 1974; Imboden 1974; Newbold and Liggett 1974; Hesslein 1980). All models include terms for the transfer of dissolved gases across the hypolimnetic-metalimnetic boundary. Although all of these studies did not discuss the importance of physical transport, the simulations of Lake Sammanish (Bella 1970) and Cayuga Lake (Newbold and Liggett 1974) suggest that the simulated oxygen profiles are sensitive to changes in the transport term.

The physical transport of oxygen has also been measured in 9 lakes by several different authors (Table 1). Although Li (1973) concluded that there was no significant transport of oxygen into the hypolimnion of Lake Zurich, Hutchinson (1957), Burns (1976), Mitchell and Burns (1978), and Rich and Devol (1978) all corrected their reported rate of hypolimnetic oxygen depletion by adding the amount of oxygen transported into the hypolimnion to the observed rate of oxygen deple- tion. The importance of the transport correction ranged from 5% of the observed rate of oxygen depletion in the eastern basin of Lake Erie (Burns, 1976) to greater than 250% in Lawrence Lake (Rich et al, 1978). The large differences between lakes may be a result of methodological difference, or may result from different properties of the lakes. One property of these lakes which is highly variable, is their morphometry. Recently Chapra and Dobson (1979), Cornett and Rigler (1979, 1980), Walker (1979), and Charlton (1980) argued that rates of hypolimnetic oxygen depletion were dependent on lake morphometry. They observed that, all other factors being equal, a lake with a thicker hypolimnion had a higher rate of oxygen depletion when the rate was expressed as an areal hypolimnetic oxygen deficit (AHOD)' in mg $O_2/m^2/day$. One way to explain this observation is to postulate that vertical turbulence transports more oxygen across the upper boundary of the hypolimnion in lakes with shallow hypolimnia. This hypothesis appears to be consistent with the published estimates of oxygen transport (Table 1).

The objective of this paper is to test the hypothesis that the vertical turbulent transport of oxygen exerts an important influence upon the measured areal rate of hypolimnetic oxygen depletion.

The hypothesis that more transport occurs in shallow lakes than in deep lakes will be tested simultaneously.

H. L'Hereux, B. Isings and S. Cameron assisted with the field measurements. J. Lardner, C. Nagy, E. Ryan and L. Chant helped to prepare the manuscript.

METHODS

1. Field Techniques

Samples for oxygen concentrations were collected in a vertical profile over the deepest location on the lake. Samples were collected from between 5 and 15 discrete depths within the hypolimnion using a 1 liter metallic sampling bottle or a 3 liter VanDorn. In 1980 these samples were supplemented with samples collected from 5 depths in each lake using a peristaltic pump. No significant differences were measured between the 3 methods of sample collection. From each sampler, duplicate 55 mL bottles were slowly filled, and allowed to overflow at least 200 mL. Winkler reagents were added immediately (Carpenter 1965). Oxygen concentrations were determined by titrating 25 mL subsamples of the Winkler solution with a microburette using 0.15 N $Na_2S_2O_3$ standardized at regular intervals with 10 mL of 0.005 N KIO_3. The endpoint of the titrations was detected using a photometric endpoint detector coupled to a microvoltmeter (Bryan et al 1976).

On each sampling date duplicate temperature profiles were measured at 1 m intervals to 20 m, 2 m intervals from 20 to 30 m, 2.5 m intervals from 30 to 40 m and 10 m intervals at depths below 40 m. Temperatures were measured using a Fenwall thermistor bead attached to a Data Precision multimeter. The meter had a resolution of 0.001 ohm.

In the 4 to 6°C range this is equivalent to approximately 0.007°C. Resistances were converted to temperatures (°C) by calibrating the ohm meter against a platinum resistance thermometer and an NBS mercury thermometer. The calibration was checked by measuring the resistance at 0°C in an ice bath of distilled water. The same calibration was used for all of the temperature conversions. The thermistor was very stable. Seasonal changes in temperatures of 0.0028 + 0.0017°C/day were measured in the deepest strata of Lake Truite.

As lake levels decrease during the summer, measurements referenced to the lake surface will continually be made in deeper strata in the hypolimnion. This is a potential artifact. To eliminate the problem the lake level was measured on each sampling date. The largest change in lake level during the study (approx. 150 days) was 0.6 m. The measured lake levels were used to correct the measurements made at slightly different depths to a constant depth. The lake level corrections changed the Kz values by less than 3% in all lakes but one. It was not necessary to correct the oxygen data because the vertical concentration gradients were not as steep as the temperature gradients.

The penetration of light into the water column was measured using a GEM underwater photometer. Light profiles were measured at 1 m intervals from a depth of 2 m to 20 m, or until the measured values were below the resolution of the meter. If the irradiance at the lake surface was variable, the light intensities were referenced against a similar photometer cell stationed on the deck of the boat.

2. Calculations

AHOD values used in this analysis were calculated using the methods of Cornett (1982) and Cornett and Rigler (1980). The depth used to delineate the upper boundary of the hypolimnion was defined from the average summer temperature profile. On each sampling date the mass of oxygen in the hypolimnion was calculated by integrating the product of the lake area at each sampling depth and the oxygen concentration measured at the same depth. This calculation assumes that the concentration of oxygen is horizontally homogeneous. Horizontal homogeneity is to be expected within the hypolimnion because horizontal mixing is much more rapid than vertical mixing (Quay et al 1980). This assumption has also been tested in other lakes (Smith and Bella 1973; Charlton 1979). The mass of oxygen per m^2 of hypolimnetic area was determined by dividing the total mass of oxygen by the area within the depth contour that delimited the upper boundary of the hypolimnion. These values were regressed against the Julian day the samples were collected (Lasenby 1975). The slope of the regression calculated over the period when the hypolimnion is oxic and stratified is the best estimate of the AHOD value.

The vertical transport of oxygen across the upper boundary of the hypolimnion (VT in $mg/m^2/day$) was calculated by multiplying the vertical eddy diffusivity coefficient (Kz) by the vertical gradient in oxygen concentrations

$$VT = Kz \; dO_2/dz \qquad (1)$$

The vertical gradient in oxygen concentration (dO_2/dz) used in the calculations is the average gradient across the depth delimiting the upper boundary of the hypolimnion. The average gradient was calculated over the same period as the AHOD value, using the same oxygen profiles.

On each sampling date, the gradient was determined from the vertical oxygen profile by calculating the derivatives of cubic spline polynomials (Ahlberg et al 1967) which were fit to the oxygen concentration Vs depth data. Boundary conditions were imposed upon the cubic spline so that the gradient in concentration was equal to zero both below the mud-water interface at the maximum depth of the lake, and at the air-water interface. This was done to ensure that the calculated gradients mimic the conditions in the lake despite the fact that concentrations at these depths were not measured.

Kz values were calculated from the change in heat content of the hypolimnion corrected for the input of solar radiation. The flux-gradient method used in this study is a modified version of Fick's law (Powell and Jassby 1974). Assuming that the specific heat capacity and density of water are equal to unity, the Kz value at the upper boundary of the hypolimnion (Zu) is equivalent to

$$Kz = \frac{-1}{dT/dz} \cdot \left(\frac{1}{Au} \cdot \frac{d \int_{Zmax}^{Zu} Az\ Tz\ dz}{dt} - Ru \right) - Kmol \qquad (2)$$

The vertical gradient in heat content (dT/dz) was calculated by differentiating cubic spline polynomials fit to each temperature profile measured during the period of calculation. The mass of heat in the hypolimnion was calculated by numerically integrating the product of the temperature (Tz) measured at each depth and the area (Az) within the contour at that depth. The change in mass of heat over time (t) was calculated by linear regression of the mass of heat against the Julian day on which the temperature profiled was measured. The total heat gain in the hypolimnion was corrected for inputs of solar radiation (Ru) using the method developed by Bachman and Goldman

(1965). Estimates of daily global solar radiation, obtained from the Montreal weather office, were summed over the period used to calculate the heat gained by the hypolimnion (approximately 130 days). The error in extrapolating the solar radiation estimates to the study lakes, which are approximately 100 Km south east of Montreal, will be less than 5% (Wilson and Petzold 1972; Suckling and Hay 1976). 5.5% of the total global radiation was assumed to be reflected back into the atmosphere when the light struck the surface of the lake (Davis 1941). The spectrum of the remaining energy was split into separate wave bands (Moon 1940) assuming that the atmosphere contained an average daily air mass of 2.0 (Manabe and Moller 1961), a barometric pressure of 0.973 atmospheres (Monthly Weather Review 1979, 1980), 26.5 mls of precipitable water vapour (Byers 1959), 3.8 mm of ozone and 100 dust particles per cc (Moon 1940). In each wave band the solar energy absorbed below the upper boundary of the hypolimnion (Ri) was

$$Ri = Io \exp(-Ki*Zu) \qquad (3)$$

where Io is the light incident upon the surface of the lake in a spectral band, Ki is the extinction coefficient of the light in that band, and Zu is the depth below the surface of the lake. The extinction coefficient that was measured using the photometer is the average value for the visible region of the spectrum. The measured value was used for the spectral band from 0.3 to 0.7 m. For the remaining 5 infra-red bands, the absorption of lake water closely approximates the absorption of pure water (Collins 1925; Hutchinson 1957). Extinction coefficients used in these wavelengths were taken from the work of

Collins (1925). The infra-red spectrum was split into the same band widths described by Bachman and Goldman (1965). The sum of these Ri values is equal to Ru.

Errors were propagated using the formulae of Beverington (1969) assuming that the covariance terms in the error estimates are negligible. All of the error estimates also assume that errors in the estimates of the morphometry of the hypolimnion are not significant. Errors in AHOD and transport estimates include all other methodological errors and seasonal fluctuations in the values of the parameters which were studied.

RESULTS AND DISCUSSION

The Kz values measured in this study ranged over two orders of magnitude (Table 2). In three lakes rates of hypolimnetic heating were so low that the Kz values were lower than, but not significantly different from the molecular transport of heat. Kz values in these lakes were assumed to be equal to 0.0 m^2/day. The highest Kz values were measured in Lake Memphremagog - the largest lake studied. Lake Memphremagog is over 40 km long and has three distinct basins with separate hypolimnia. The largest and deepest basin (central basin) had higher Kz values in both years of study than the north basin or Fitch Bay (Table 1). The higher Kz values measured in 1980 than in 1979 reflect the climatic differences between the two years, the earlier start of the sampling program during 1980, and the slower establishment of strong temperature gradients during 1980. Surface water temperatures measured in all lakes during 1980 were several degrees less than those measured during 1979. Rates of hypolimnetic heating

were higher in 1980 and the vertical gradients in temperature across the upper boundary of the hypolimnion were up to 48% lower in 1980 than in 1979. These changes resulted in higher Kz values during 1980.

Both positive and negative vertical gradients in oxygen concentration were measured across the top of the hypolimnion (Table 3). The positive gradients were observed in the deeper, more oligotrophic, lakes. Much larger gradients in oxygen concentrations were measured in the shallower lakes. In these lakes the concentrations were invariably higher in the metalimnion than in the hypolimnion. The broad confidence intervals around both the Kz estimates and dO_2/dz values reflect the difficulties in estimating vertical gradients and long term changes in heat content of the hypolimnion when short term internal seiches can influence individual measurements at each depth.

Although the errors in Kz and dO_2/dz are large relative to these parameters, the amount of oxygen transport (VT) was very small (Table 4). In most lakes oxygen transport was more than one order of magnitude less than the AHOD value measured over the same period (Table 4). The largest estimates of VT, 56.8 and 69.1 $mg/m^2/day$, were calculated in the central and north basins of Lake Memphremagog. On a relative scale the highest rates of vertical transport were 14% of the measured AHOD in Lake Lovering and 12% of the measured value in the north basin of Lake Memphremagog. However the relative significance of transport was less than 10% of the AHOD values measured in these lakes during 1979. In all other lakes VT was less than 10% of the measured AHOD value during both years of study (Table 4). Pooling the data from

all lakes gave an average absolute amount of vertical transport of 11.6 $mg/m^2/day$ in 1979, and 22 $mg/m^2/day$ in 1980.

The upper boundary of the hypolimnion was defined operationally from the temperature profile (Cornett 1982, Cornett and Rigler 1980). Since that definition may not be agreed upon by all investigators, we checked the sensitivity of these conclusions to changes in the definition of the depth delimiting the upper boundary of the hypolimnion. Placing the boundary 1 m deeper in the water column increased the magnitude of the VT values by an average of 11 $mg/m^2/day$ during 1979 and 4 $mg/m^2/day$ during 1980. Raising the boundary 1 m above the stated values (Table 2) increased the magnitude of the VT values by an average of 4 $mg/m^2/day$ in 1979. In 1980, the same change would decrease the magnitude of the VT values by 4 $mg/m^2/day$. The transport estimates are not sensitive to the definition of the upper boundary of the hypolimnion in these study lakes.

Cornett and Rigler (1980) postulated that the amount of oxygen transported into the hypolimnion of shallow lakes was significantly greater than transport into or out of the hypolimnion of deep lakes. This hypothesis is supported (Fig. 1). Using Kendall's non parametric rank correlation (Sokal and Rolf 1969) there is a significant relationship between the amount of oxygen transported and the mean thickness of the hypolimnetic water column ($\tau = 0.53$, $p < .001$). There is also a significant rank correlation between the relative importance of transport and the mean depth of the hypolimnion (Fig. 2) ($\tau = 0.48$, $p < .001$). However Cornett and Rigler (1980) postulated that

the relationship between transport and the mean depth of the hypolimnion could explain changes in AHOD values of greater than 100 $mg/m^2/day$ per unit change in the logarithm of ZH. Clearly the differences in transport between the lakes in this study are not large enough to explain all of the changes in measured AHOD values.

The conclusion that average VT values are less than 10% of the measured AHOD, appears to be correct over periods much shorter than the entire summer (Table 5). In Lake Lovering and in the north basin of Lake Memphremagog, Kz values changed significantly over the summer. Large changes were also observed in the oxygen gradients (Table 5). However Kz values decreased as the metalimnetic temperature gradients increased, while the oxygen gradients increased throughout the period of thermal stratification. The opposing changes in the two parameters effectively cancelled the influence of transport. VT was less than 10% of the AHOD in both lakes in 12 of the 13 periods studied in these two lakes. Similar seasonal patterns were observed in other lakes. However the VT values were smaller and the seasonal variation in Kz and dO_2/dz was also smaller.

The generality of the results presented above can only be rigorously tested by a study of other groups of lakes. However several lines of reasoning suggest that the transport of oxygen is usually less than 10% of the observed AHOD value. First, the lakes chosen for this study cover a broad range of morphometric characteristics. Since Kz values are higher in larger lakes (Mortimer 1942; Snodgrass and O'Melia 1975; Quay et al 1980), it is significant that even in Lake Memphremagog with a wind fetch of greater than 40 km, transport was no higher than 15% of the AHOD. However it could be argued that this is a

result of the oligotrophic character of the lake. Since our results suggested that gradients in oxygen concentration could be higher in shallow, more eutrophic lakes, the choice of study lakes might have influenced our results. We estimated the average vertical gradients in oxygen concentration in 11 more eutrophic lakes for which oxygen concentrations were published. Pooling those data with the data presented in Table 2, the best fitting regression which predicted the change in oxygen gradients in lakes of different morphometry and different surface water phosphorus concentrations (P mg/m^3) was

$$dO_2/dz = -474 - 206 \log(P) + 387 \log(Zmax-Zu). \quad (4)$$
$$(N=36, R^2=0.67, s_b=145)$$

This equation predicts that the highest gradients in oxygen concentration will be seen in shallow eutrophic systems. However the relationship between the concentration of phosphorus and the oxygen gradient is not a linear relationship. It is logarithmic. Gradients in oxygen are more similar in magnitude in eutrophic and oligotrophic lakes than one might expect apriori. Kz values are also lower in shallow lakes than in deep lakes (Mortimer 1942; Snodgrass and O'Melia 1975). Therefore the higher gradients in shallow eutrophic lakes will not result in higher VT values, unless the lakes have much larger fetches than the lakes used to construct the predictive relationships.

The results of this analysis, that transport is always less than 15% of the AHOD, are also very comparable to previous estimates of transport in the central and eastern basins of Lake Erie (Burns 1976), in Lake Zurick (Li 1973) and in Lake Hayes and Johnson (Mitchell and

Burns 1978). VT values in Lake Mendota (Hutchinson 1957) and the three small lakes studied by Rich and Devol (1978) appear to be extremely high (Table 1). The high VT values calculated by Rich and Devol resulted from large Kz values (Rich pers. comm.). Kz values in these small lakes were much higher than values predicted by any of the empirical models of Mortimer (1942), Snodgrass and O'Melia (1975), or Quay (1977). These Kz values may be a result of bias introduced by the difficulty in attempting to determine how to correct the rate of hypolimnetic heating for the input of solar radiation in very shallow lakes (Rich 1979). More detailed study of these anomolous lakes is necessary. The apparent difference between Lake Mendota and the lakes investigated in this study resulted from the different method of calculating AHOD and VT values used by Hutchinson. Hutchinson (1957). calculated both values over the period when a large volume of the hypolimnion was anoxic. This resulted in a lower AHOD and a much higher VT value than would be calculated using the methods described in this paper. Using the AHOD value calculated over the period when the lake was oxic (Stewart 1975), the Kz value calculated using the flux gradient method (Powell and Jassby 1974), and the gradients in oxygen concentration calculated while the hypolimnion was oxic (data from Birge and Juday 1911), the VT value is 97 $mg/m^2/day$, and the AHOD is 783 $mg/m^2/day$. Therefore transport is 14% of the AHOD and the results for Lake Mendota are very similar to other lakes.

To date, all analyses of the vertical transport of oxygen have calculated Kz values by modelling the flux of heat into the hypolimnion using Fick's law. The use of Kz coefficients, derived from the heat budget of the hypolimnion, to calculate the vertical diffusivity

of mass (oxygen) assumes that the heat and mass are transported at the same rates within the water column. This assumption only appears to be correct in regions of low thermal stability (Turner 1968; Quay et al 1980). At the top of the hypolimnion, gradients in temperature are usually greater than 0.5 °C/m. In these highly stratified regions, the turbulent transfer of mass may be more than 1 order of magnitude less than Kz values calculated from the heat budget (Turner 1968; Hesslein and Quay 1974; Quay et al 1980). Therefore the VT values calculated in all studies must be considered to be upper limits to the correct rate of oxygen transport. In this study, the transport of oxygen into the hypolimnion averages 3.4% of the observed rate of hypolimnetic oxygen depletion. True rates of transport may be much less. Models of oxygen depletion will gain relatively little precision if they stress the vertical transport of oxygen across the upper boundary of the hypolimnion. Research must focus upon predicting the variation in AHOD values, or variations in respiration in the sediments or in the water column of lakes.

LAKE	Z	AHOD	VT	AUTHOR
Durham	2.4	180	56	Rich and Devol (1978)
Lawrence	5.9	66	150	"
Mirror	5.6	146	125	"
Mendota	12.0	570	217	Hutchinson (1957)
Johnson	17.1	546	80	Mitchell and Burns (1978)
Hayes	18.7	915	120	"
Central	18.3	380	46	Burns (1976)
Eastern	24.4	613	30	"
Zurichsee	50.0	1200	40	Li (1973)

Table 1. Summary of published estimates of vertical transport (VT) and AHOD values of 9 lakes investigated during other studies. AHOD and VT values are in units of $mg/m^2/day$. Z is the mean depth of the lake in meters. Central and Eastern refer to the two distinct hypolimnia of lake Erie.

LAKE	1979			1980		
	Zu	Kz	SE	Zu	Kz	SE
Brompton	12	.053	.017	13	.264	.034
Central	20	.212	.040	19	.866	.135
Fitch	12	.01	.002	12	.037	.007
Petite Brompton				9	.043	.008
Magog	12	.040	.014	10	.153	.033
Lovering	10	.094	.042	10	.170	.038
Lyster	12	0.0	.035	12	0.0	.118
Massawippi	11	.188	.046	11	.269	.065
North	12	.169	.073	13	.422	.0666
Orford	11	0.0	.029	12	0.0	.010
Stukely	11	.01	.003	11	.111	.027
Truite	7	0.0	.012	8	0.0	.023

Table 2. Coefficients of vertical eddy diffusivity (Kz) and their associated standard error (SE) calculated in m^2/day at the depth of the upper boundary of the hypolimnion (Zu in meters). Central, North and Fitch are 3 separate basins of Lake Memphremagog. Lake Petite Brompton was not studied during 1979.

LAKE	1979		1980	
	dO2/dz	SE	dO2/dz	SE
Brompton	44	72	-44	11
Central	121	31	66	25
Fitch	-591	132	-580	123
Petite Brompton			-252	90
Magog	-435	80	-229	44
Lovering	-204	74	-309	55
Lyster	78	28	44	12
Massawippi	79	75	14	20
North	-248	70	-164	29
Orford	-550	135	-343	181
Stukely	82	38	51	10
Truite	-795	155	-355	55

Table 3. Gradients in oxygen concentration (dO2/dz) measured at the depth of the upper boundary of the hypolimnion. Depths are the same as those given in Table 1. When higher oxygen concentrations were measured above Zu than below Zu the gradient is defined as negative.

LAKE	1979				1980			
	AHOD	SE	VT	SE	AHOD	SE	VT	SE
Brompton	326	16.0	2.4	4.0	389	7.6	-11.5	3.2
Central	586	27.2	25.6	8.2	715	55.7	56.8	23.2
Fitch	354	33.6	-5.9	1.8	519	26.	-21.3	6.0
Petite Brompton					414	28.8	-10.8	19.0
Magog	523	18.9	-17.3	6.8	649	22.9	-35.1	10.1
Lovering	293	42.3	-19.1	11.0	367	4.9	-52.6	15.1
Lyster	288	11.5	0.0	1.0	348	13.0	0.0	4.2
Massawippi	587	49.6	14.9	14.6	710	22.5	3.8	5.5
North	538	60.0	-42.0	21.7	584	14.3	-69.1	16.2
Orford	304	17.2	0.0	3.9	408	44.7	0.0	1.8
Stukely	243	7.1	-0.8	0.4	309	6.9	5.7	1.8
Truite	207	41.1	0.0	1.9	208	15.0	0.0	1.3

Table 4. Areal hypolimnetic oxygen deficits (AHOD), rates of vertical oxygen transport (VT) and error estimates for each variable (SE) All rates are in units of $mg/m^2/day$.

PERIOD	Kz	dO2/dz	VT	AHOD
133	2.11	-5.	-10.	774
136	4.90	-16.	-81.	537
150	1.13	-47.	-54.	694
164	0.13	-83.	-11.	690
179	0.09	-147.	-13.	667
192	0.05	-173.	- 9.	499
206	0.08	-201.	-16.	580
217	0.17	-257.	-44.	451

Table 5a. Seasonal variation in the vertical transport of oxygen into the hypolimnion in the north basin of Lake Memphremagog during 1980. The first day of each period of investigation is listed in Julian days. Other symbols and units were defined earlier.

PERIOD	Kz	dO2/dz	VT	AHOD
134	0.81	-31	-25	278
145	0.29	-69	-20	414
181	0.09	-152	-14	391
195	0.02	-364	-9	319
209	0.04	-551	-24	360
238	0.11	-635	-68	-

Table 5b. Seasonal variation in the transport of oxygen into the hypolimnion of Lake Lovering during 1980. Symbols and units are the same as those used in earlier tables.

Fig. 1. Vertical transport of oxygen in each lake plotted against the mean depth of the hypolimnion (Zh).

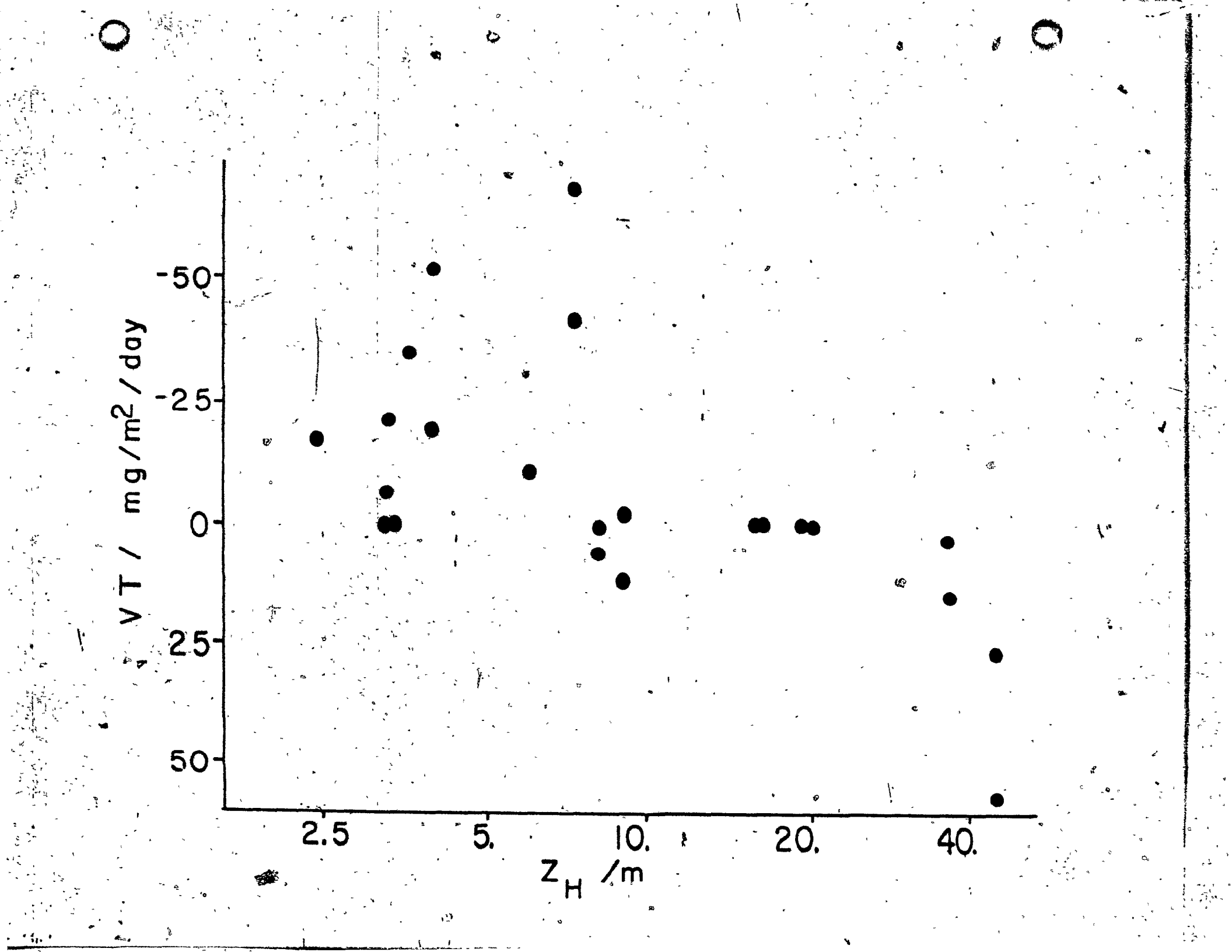
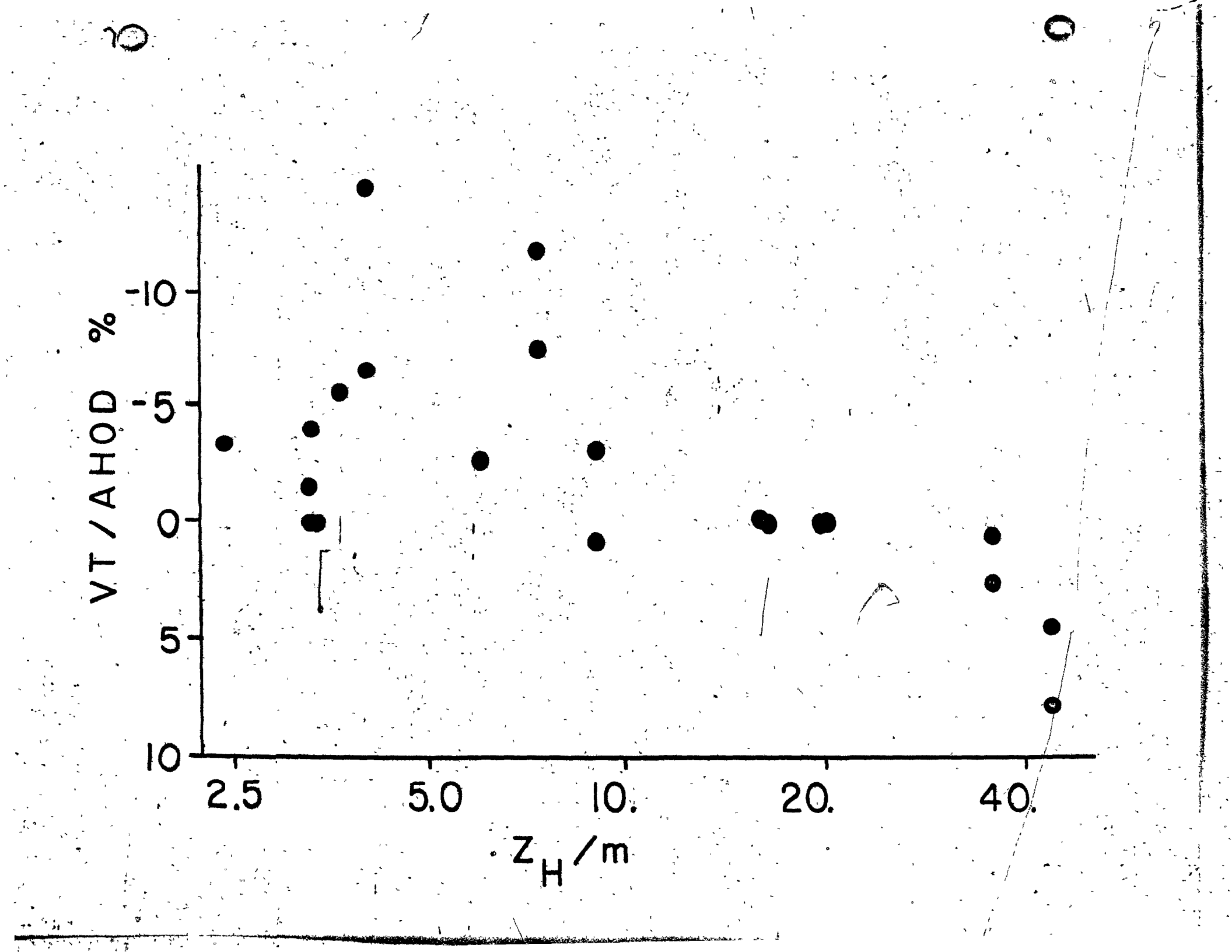

-50
-25
0
25
50
VT / mg/m²/day
2.5
5.
10.
20.
40.
Z_H /m

Fig. 2 Ratio of the vertical transport of oxygen compared to the AHOD measured in each lake and plotted against the mean depth of the hypolimnion.


VT / AHOD %
-10
-5
0
5
10
2.5
5.0
10.
20.
40.
z_H / m

CHAPTER TEN

Physical Transport of Oxygen Between Adjacent Hypolimnetic Strata

INTRODUCTION

Within the past decade, the focus of limnological research was shifted from qualitative descriptions of lake characteristics to the development of quantitative models that predict various properties of lakes. The model used most frequently is a one box continuously stirred reactor. This type of model has proved extremely useful when the lake is unstratified or when properties of the rapidly mixed epilimnion are studied (Dillon and Rigler 1974). However in the hypolimnion of lakes, there are very steep vertical gradients in the concentration of most dissolved substances, and dissolved oxygen concentrations are no exception (Birge and Juday 1911; Hutchinson 1957). In many lakes, oxygen concentrations are several ppm higher at the top of the hypolimnion than are the concentrations observed near the maximum depth of the lake. Lakes with this type of gradient are classified as clinograd (Hutchinson 1957). In other lakes, the gradients in concentration are opposite. The measured concentrations are lowest just beneath the upper boundary of the hypolimnion. Gradients of this type are called negative heterograde (Hutchinson 1957). These gradients in oxygen concentration must result from differences in the rate that oxygen is depleted in different depth strata.

The areal hypolimnetic oxygen deficit (Hutchinson 1938) measures the average rate of oxygen consumption within the hypolimnion. It does not consider, and cannot be used to predict accurately, changes in oxygen concentrations in each stratum of the hypolimnion. Before changes in oxygen concentration in each stratum of the hypolimnion can be predicted, the descriptive classification of orthograd and clinograde must be replaced by a model that predicts how the rate of

change in oxygen concentration will vary between strata within the hypolimnion. Such a model can be developed if rates of oxygen depletion display reproducible and predictable patterns both within the discrete strata of one lake and between different hypolimnetic strata of different lakes.

Lund et al (1963) reported that there was a pattern to the depletion of oxygen in the strata of the hypolimnion of Lake Windermere. They observed that rates of oxygen depletion, expressed in mg O_2 per day per m^2 of sediment area in contact with the stratum, were higher near the upper boundary of the hypolimnion than were the rates that they measured near the maximum depth of the lake. In a study of 14 oligotrophic lakes, Lasenby (1975) observed a similar pattern in 13. To explain these observations, both authors suggested that the true rate of respiration by the sediments and water were the same in each hypolimnetic stratum. However higher rates of oxygen depletion were measured near the top of the hypolimnion because oxygen was transferred by turbulent transport down a concentration gradient, either deeper into the hypolimnion or into the metalimnion of the lake. Although Cornett and Rigler (1983) concluded that the rate of transport of oxygen across the upper boundary of the hypolimnion is low, this does not preclude the possibility that significant amounts of transport occur between adjacent hypolimnetic strata. Coefficients of vertical eddy diffusivity and vertical oxygen gradients frequently increase in magnitude below the thermocline as the stability of the water column decreases (Birge and Juday 1911; Quay et al 1980).

The objective of this paper is to test the two hypotheses presented by Lund et al (1963) and Lasenby (1975). First they

postulated that significant amounts of oxygen are transported by physical mixing between adjacent strata of the hypolimnion. Secondly, Lund et al (1963) hypothesized that rates of oxygen depletion, expressed per square meter of sediment area, would be the same at all depths within the hypolimnion, once the observed changes in concentration were corrected for vertical transport into and out of each stratum. If the net transport of oxygen between strata is significant then future models should include this parameter. However if this hypothesis is incorrect and respiration varies significantly between depths, research should focus upon predicting the vertical variability in respiration rates.

We are grateful for the assistance of H. L'Hereux, B. Isings and S. Cameron in the field. J. Lardner, C. Nagy, E. Ryan and L. Chant helped to prepare the manuscript.

METHODS

The lakes investigated in this study are the same lakes studied by Cornett and Rigler (1983). The same profiles of oxygen concentrations and temperatures used to examine the transport of oxygen across the upper boundary of the hypolimnion were used in this analysis. Sampling techniques and analytical techniques are identical to those reported earlier.

To test the hypotheses listed in the introduction, the hypolimnion of each lake was divided vertically into a series of discrete strata that were assumed to be horizontally homogeneous. The vertical thickness of the strata ranged from 1 m in shallow lakes to 2.5, 5, or 10 m in lakes with a very deep hyplimnion. The choice of the

thickness of the strata was made arbitrarily. However the hypolimnion of the deeper study lakes could not be subdivided into thinner strata because the gradients in temperature and oxygen concentration were very small and could not be accurately measured over 1 m intervals. The change in oxygen concentration within each stratum (VOD in mg O_2/ m^3/day) was calculated by linear regression of the measured concentrations of oxygen against the Julian day the samples were collected. Only concentrations greater than 1.0 mg/L were used in this calculation. The rates of oxygen depletion were expressed per unit of sediment area (SOD in mg O_2/m^2/day) by multiplying the VOD value by the volume of the stratum and dividing that product by the area of the sediments contiguous with the stratum. The area of sediments was measured as the difference between the lake area at the upper boundary of the stratum (A_{Z1}) and the area within the depth contour at the lower boundary of the stratum (A_{Z2}). Transport across the upper or lower boundary of the stratum (T_Z) was calculated as

$$Tz = Kz * dO_2/dZ \qquad (1)$$

where Kz is the vertical eddy diffusivity coefficient at depth Z calculated from the average seasonal change in the heat content of the water column below depth Z, corrected for solar inputs. The vertical gradient in oxygen concentration (dO_2/dZ) is the average gradient across the plane at the same depth calculated by differentiating cubic splines that were fit to the vertical profiles of oxygen concentration measured throughout the period of stratification while the hypolimnion was oxic. The procedures used to calculate Kz and dO_2/dZ are detailed by Cornett and Rigler (1983). We will assume that the Kz

values calculated from the vertical flux of heat can be applied to calculate the flux of oxygen, and that there is no input of oxygen into the hypolimnion by ground water. Then the net respiration (NR in mg $O_2/m^3/day$) of a stratum can be calculated by

$$NR = (VOD*V + T_{Z1}*A_{Z1} - T_{Z2}*A_{Z2})/V \quad (2)$$

where V is the volume of the stratum (m^3), A_{Z1} and A_{Z2} are the lake areas (m^2) within the depth countours of the depths delimiting the upper (Z1) and lower (Z2) boundaries of the stratum respectively. The term net respiration was used to emphasize that no correction was made for photosynthetic inputs of oxygen. Nor did the original hypotheses deal with this term. The NR values are also expressed per square meter of sediment area (NSR) using the same morphometric conversion used to calculate the SOD values. Although the rates of oxygen consumption are expressed per unit volume or per unit area of sediment, this is not meant to imply that either the sediments or the water are the only sink for oxygen.

RESULTS AND DISCUSSION

The patterns in oxygen consumption in separate strata of the hypolimnion reported by Birge and Juday (1911), Hutchinson (1957), Lund *et al* (1963), and Lasenby (1975) were observed during this study. In this investigation the rates of oxygen depletion ranged from 10 to 225 $mg/m^3/day$. The calculated VOD values increased significantly with depth in 10 of the 12 lakes studies (Fig. 1a, 1c). In two deep lakes, higher VOD values were measured at the top of the hypolimnion than at any other depths within the water column (Fig. 1b). In 11 lakes the decrease in SOD values with the depth reported by Lund *et al*

(1963) and Lasenby (1975) were also observed (Fig. 1a, 1b). Only Lake Lovering deviated significantly from this pattern (Fig. 1c). The novel pattern exhibited by this lake was observed in studies conducted during 1978 as well as during this study in 1979 and 1980. The pattern may reflect the fact that the morphometry of this lake is much more complex than that of the other study lakes. There are three contiguous hypolimnetic basins in this lake that are separated by varying degrees by a series of bedrock shelves. All of the other hypolimnia investigated have only a single tub or bowl shaped hypolimnetic basin. Within a single lake differences between apparent SOD values of separate strata were extremely large. SOD values at the top of the hypolimnion were 3 to 10 times greater than the values calculated near the maximum depth (Fig. 1a, 1b, 1c). The changes in SOD between strata within a lake were often larger than the differences between lakes.

The measured vertical oxygen gradients within the hypolimnion ranged from 10 to 1000 mg O_2/m^4. Although the vertical patterns in the gradients were different in each lake, most lakes had a much higher oxygen gradient near the maximum depth of the hypolimnion (Fig. 2). Many lakes also had a higher gradient just below the thermocline than that measured in the middle of the hypolimnion (Fig. 2). Higher vertical gradients in oxygen concentration were observed in lakes with a shallow hypolimnion than in lakes with a thick hypolimnion.

Kz values calculated by modelling the amount of heat transported within the hypolimnion, increased in magnitude below the thermocline (Fig. 3). This pattern was observed in all lakes. It is consistent with the theoretical discussions of Turner (1968) and

Powell and Jassby (1974), and the in situ tritium experiments performed by Quay et al (1980). In the highly stratified region at the top of the hypolimnion, the Kz values calculated in several lakes were of the same order of magnitude as the molecular diffusivity of heat (0.14 m^2/day). The larger and deeper study lakes had higher Kz values. However in many of these lakes the confidence limits around the vertical eddy diffusivity estimates are very broad. The broad confidence limits reflect the difficulty in trying to determine the gradient in heat content accurately at a depth within the hypolimnion where the gradient is very small (0.005°C/m).

Significant quantities of oxygen were turbulently mixed through the planar surfaces that delineated the boundaries of the different hypolimnetic strata (Fig. 4a, 4b). This observation is consistent with the hypothesis of Lund et al (1963) and Lasenby (1975). However the total vertical flux of oxygen is not the important parameter because the flux is continuous. Oxygen is transported both into and out of each adjacent stratum. Within a lake, the Kz values, dO_2/dZ values, and the area through which transport occurs, vary little between the depths of the upper and lower boundaries of each stratum. Therefore the flux into a stratum, and the flux out of a stratum are strongly correlated (Fig. 5). The net amount of oxygen input or removed from a stratum is much smaller than the total amount of transport (Fig. 4a, 4b). Of the 160 strata that were examined in the two years of this study, the net amount of oxygen mixed into these strata was greater than 20% of the observed VOD value in only 26% of the strata studied. Transport had the most significant effect upon the NR values in the stratum located at the maximum depth of the

hypolimnion. The strong influence of vertical transport upon the NR values calculated in these strata reflect two factors. First the gradients in oxygen concentration and the Kz value were largest at this depth in all of the study lakes. However it is more important to note that transport into this stratum was only one way in. If the deepest stratum in the hypolimnion of each lake is omitted from the comparison, the median amount of transport was 10% of the measured VOD. In only 11 strata was transport greater than 50% of the observed VOD.

When the SOD values were corrected for the net turbulent transfer of oxygen into a stratum, the affect of the correction is small (Fig. 6a, 6b, 6c). Therefore the second hypothesis of Lund et al (1963) is false. Rates of oxygen depletion expressed per m^2 of sediment area adjacent to the stratum and corrected for the turbulent transport of oxygen are not the same in each stratum of the hypolimnion (Fig. 6a, 6b, 6c). The rates show much the same trend as the SOD values shown earlier (Fig. 1a, 1b, 1c). In all of the lakes studied the rates of oxygen depletion were higher at the top of the hypolimnion than the rates that were calculated for strata located deeper in the hypolimnion. The simplest hypothesis that is consistent with this observation is that a larger mass of oxygen is consumed in the strata near the upper boundary of the hypolimnion because respiration in the water column consumes a significant amount of oxygen and the volume of water in these strata is larger than the volume of deeper strata.

When the data from these lakes are pooled, more than 90% of the variation in NR can be accounted for by the variation in the VOD value (Fig. 7). This result appears to be applicable to a wide variety of lakes. There is no relationship between the rate of oxygen

depletion within a stratum and the net amount of oxygen transported into the stratum, or between the size of the lake and the amount of transport that occurred. Large lakes and small lakes (lake areas from 90 km^2 to 0.4 km^2), deep lakes and shallow lakes (Zmax from 106 m to 15 m), with a range of spring total phosphorus concentrations from 4.0 µg/L to 45 µg/L, all displayed similar characteristics. This generality suggests that quantitative predictions of VOD values will be possible without extensive modelling of the physical transport of oxygen between adjacent strata.

CONCLUSIONS

This study supports the hypothesis that significant amounts of oxygen are vertically transported between adjacent strata in the hypoliminion of lakes. However the net transport into a stratum is much smaller than the total amount of oxygen that enters the stratum. As a result the variation in the rate of oxygen depletion at different depths within the hypolimnion cannot be explained totally by the transport of oxygen along a vertical concentration gradient. The variation must result from differences in the total amount of respiration occurring in the water and sediments of the lake. Models that focus upon the transport of oxygen within the hypolimnion will gain relatively little in predictive ability. The thrust of investigations must be directed towards the prediction of the amount of respiration within the water column and at the sediment surface.

Fig. 1a. Rates of oxygen consumption in the hypolimnetic strata of the north basin of Lake Memphremagog expressed in $mg/m^2/day$ (VOD) (● 1979 O 1980) and expressed per square meter of sediment area contiguous with the stratum (SOD) (▲ 1979 Δ 1980).

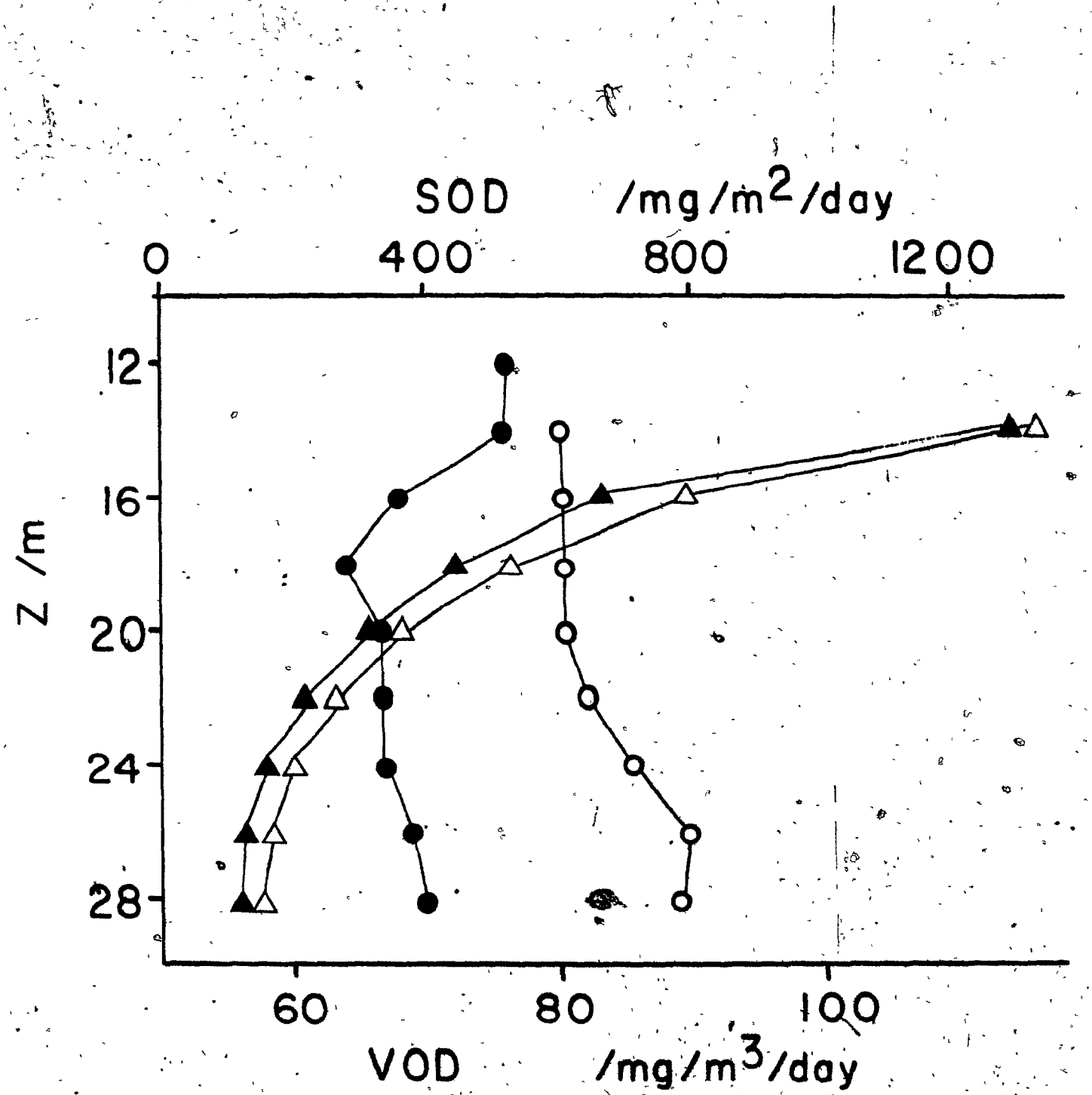

SOD /mg/m2/day
0
400
800
1200
12
16
20
24
28
Z /m
60
80
100
VOD /mg/m3/day

Fig. 1b. Rates of oxygen depletion in individual strata within the hypolimnion of the central basin of Lake Memphremagog calculated per unit volume and per unit sediment area. Symbols and units as in Fig. 1a.

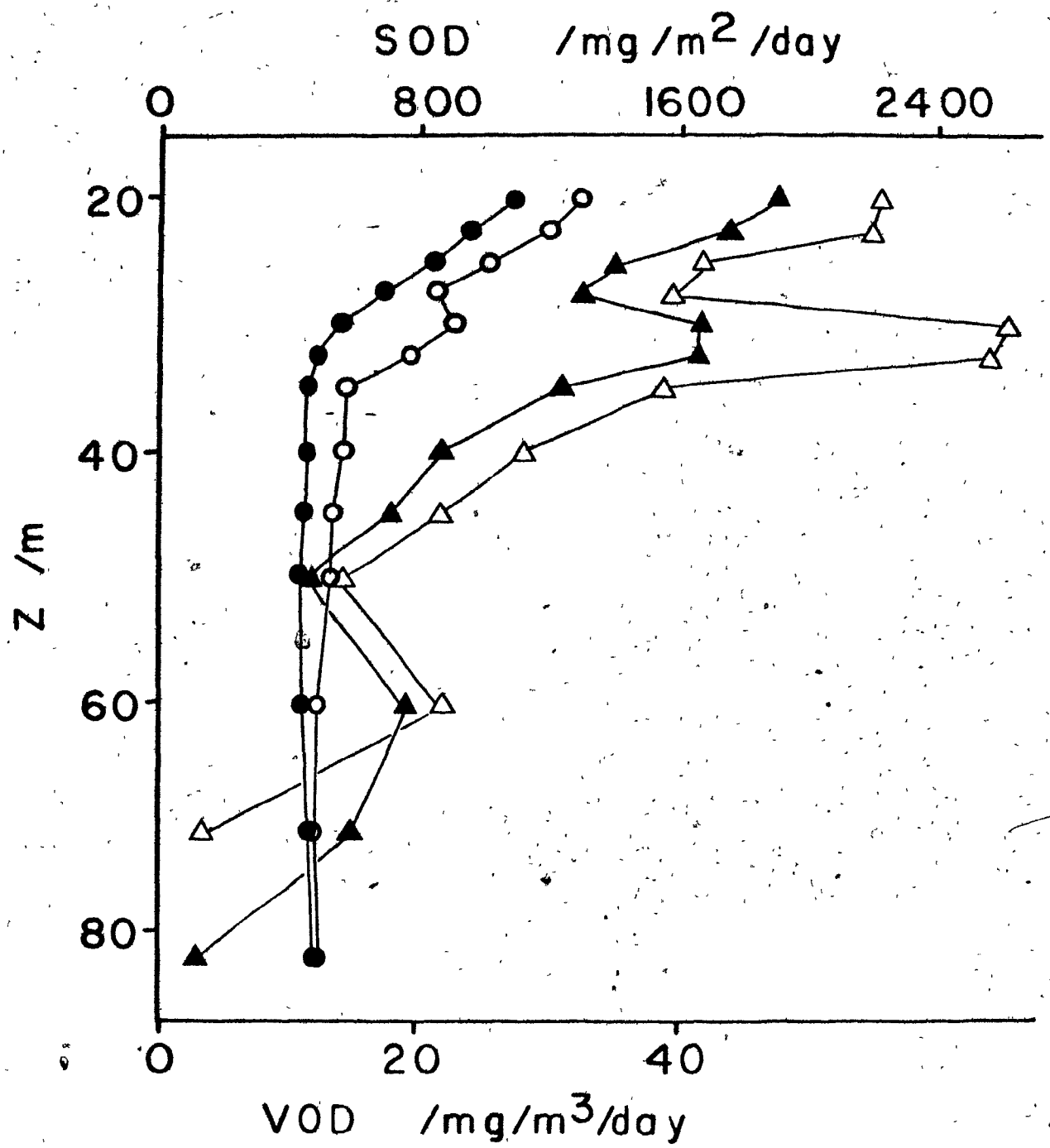

SOD /mg/m2/day
0
800
1600
2400
20
40
60
80
Z /m
0
20
40
VOD /mg/m3/day

Fig. 1c. Rates of oxygen depletion in individual hypolimnetic strata of Lake Lovering. Symbols and units as in Fig. 1a.

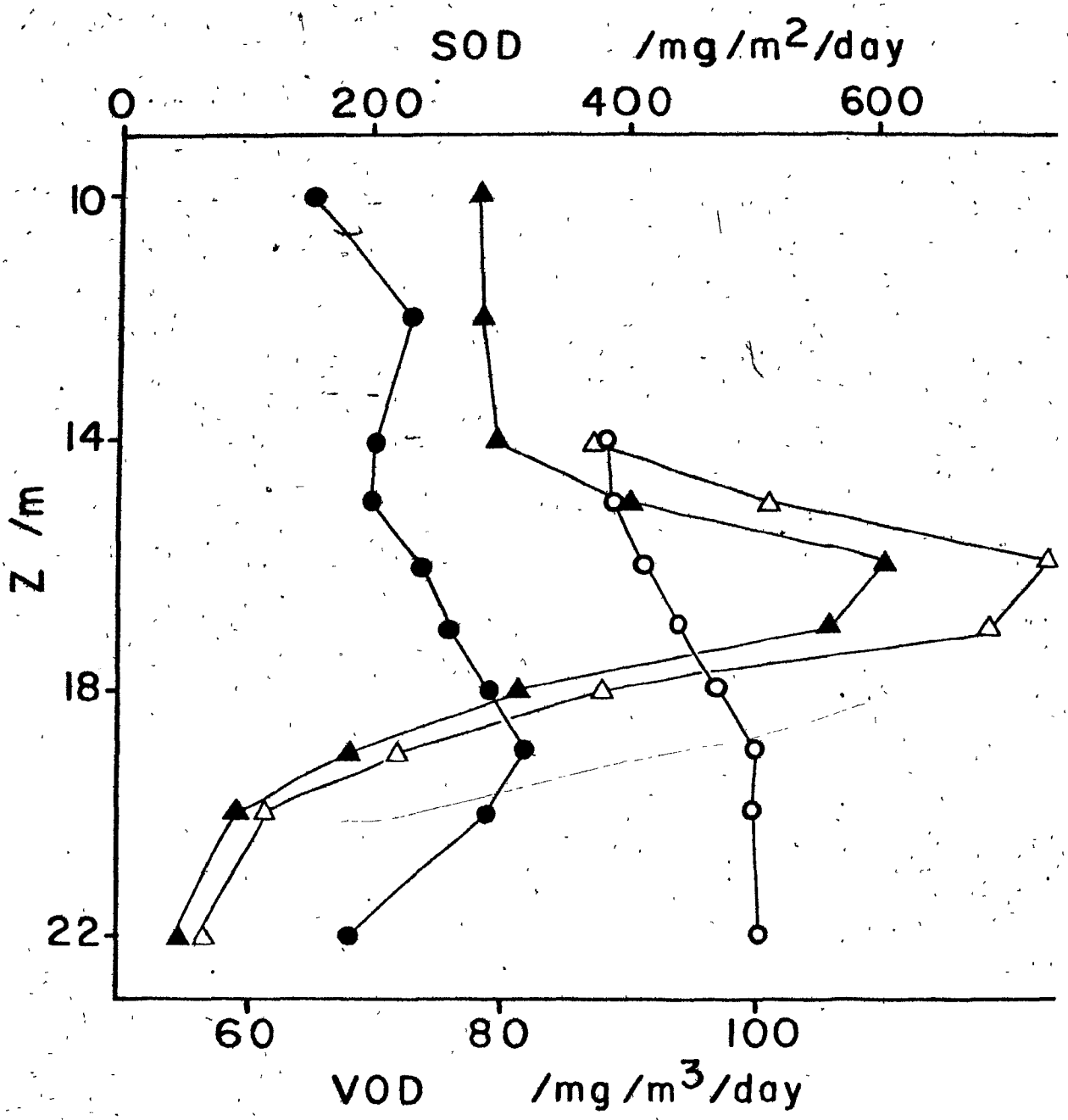

SOD /mg/m2/day
0
200
400
600
10
14
18
22
Z /m
60
80
100
VOD /mg/m3/day

Fig. 2. Coefficients of vertical eddy diffusivity measured within the hypolimnion of the north basin (▼ 1979 ▽ 1980), central basin (● 1979 ○ 1980), and Fitch Bay (◆ 1979 ◇ 1980) of Lake Memphremagog.

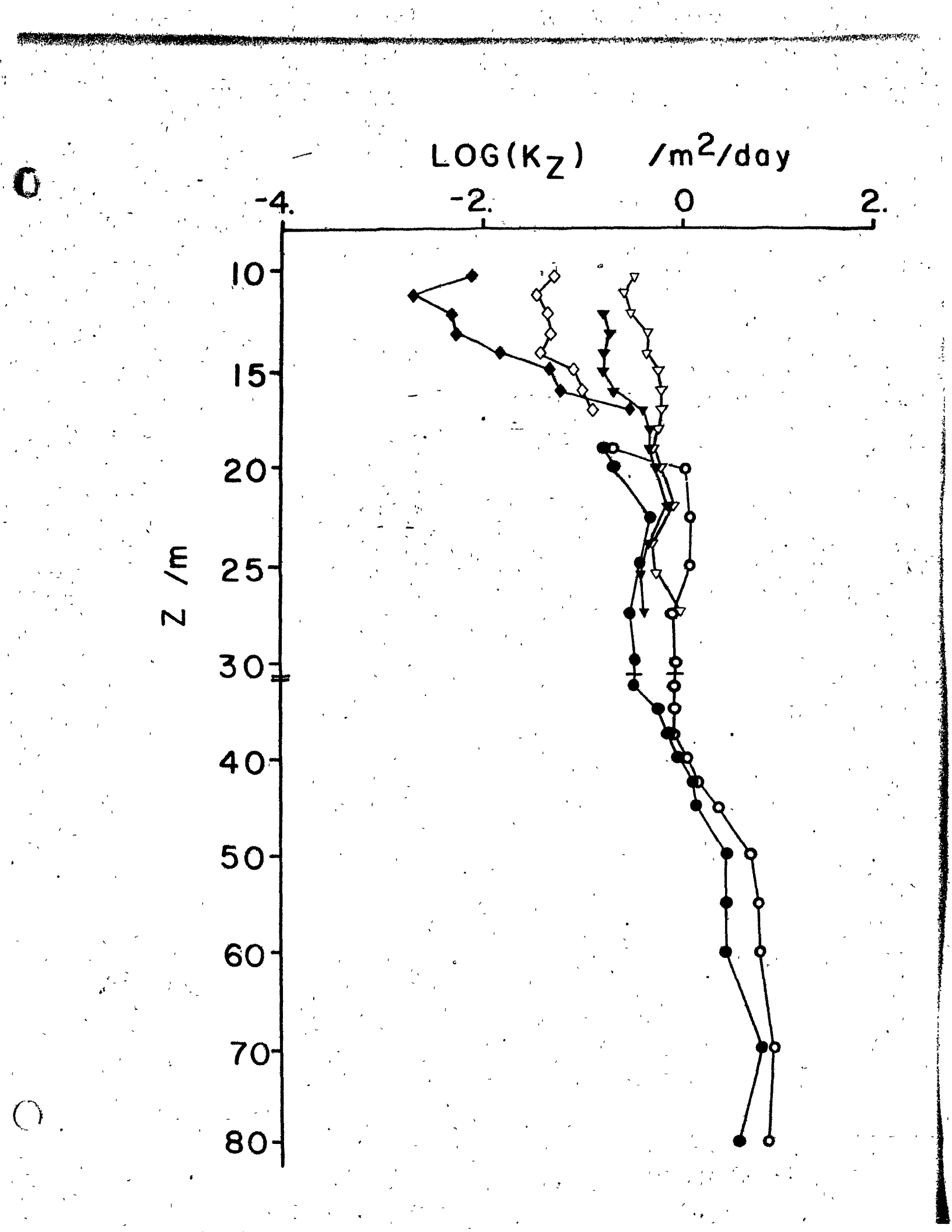

LOG(K_Z) /m²/day
-4.
-2.
0
2.
10
15
20
25
30
40
50
60
70
80
Z /m

Fig. 3. Gradients in oxygen concentration measured within the three separate hypolimnetic basins of Lake Memphremagog. Symbols are the same as in Fig. 2. Positive gradients were calculated when the concentrations of oxygen measured near the upper boundary of the hypolimnion were lower than the concentrations measured deeper in the water column.

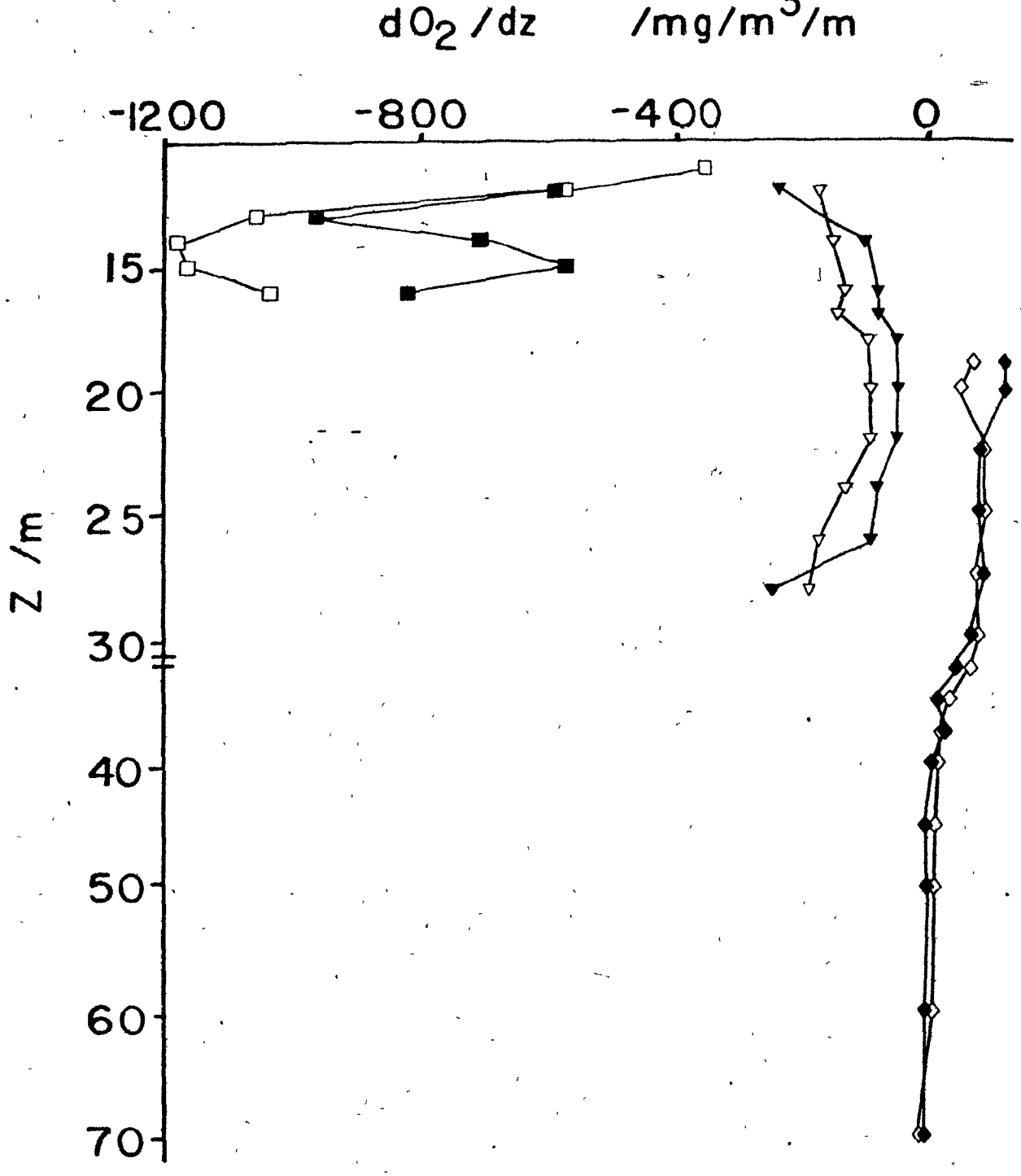

dO2 /dz /mg/m3/m
-1200
-800
-400
0
15
20
25
30
40
50
60
70
Z /m

Fig. 4a. Rates of oxygen consumption within each stratum (● 1979 ○ 1980), total oxygen transport into each stratum (▲ 1979 △ 1980), and the net mass of oxygen added to the stratum by transport (◆ 1979 ◇ 1980) into the hypolimnion of the north basin of Lake Memphremagog.

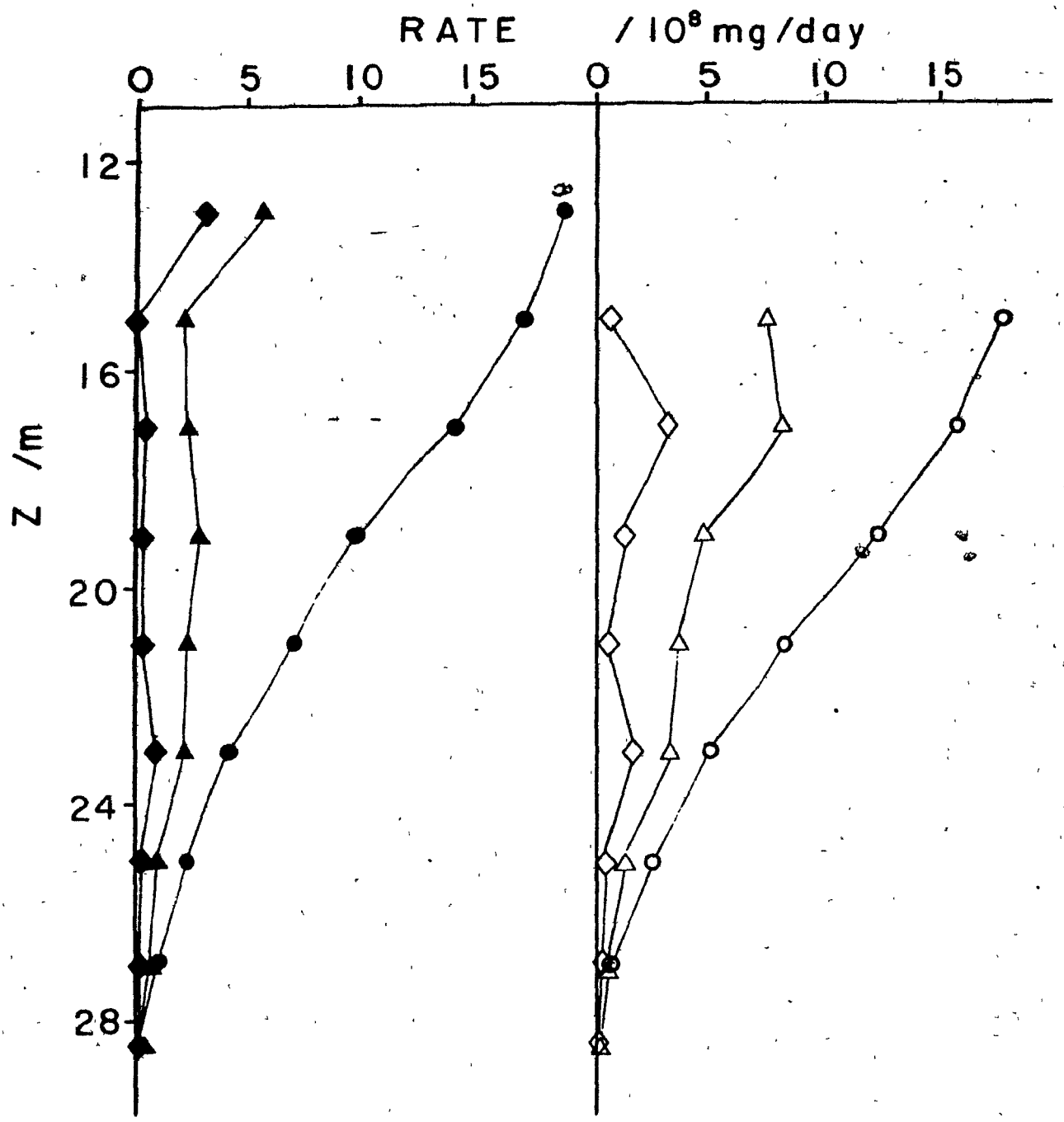

RATE / 10⁸ mg/day
0
5
10
15
0
5
10
15
12
16
20
24
28
Z /m
a

Fig. 4b. Summary of the rates of oxygen consumption within each stratum, total oxygen transported into each stratum, and the net mass of oxygen added to the stratum by turbulent transport within the hypolimnion of Lake Lovering. Symbols are the same as in Fig. 4a.

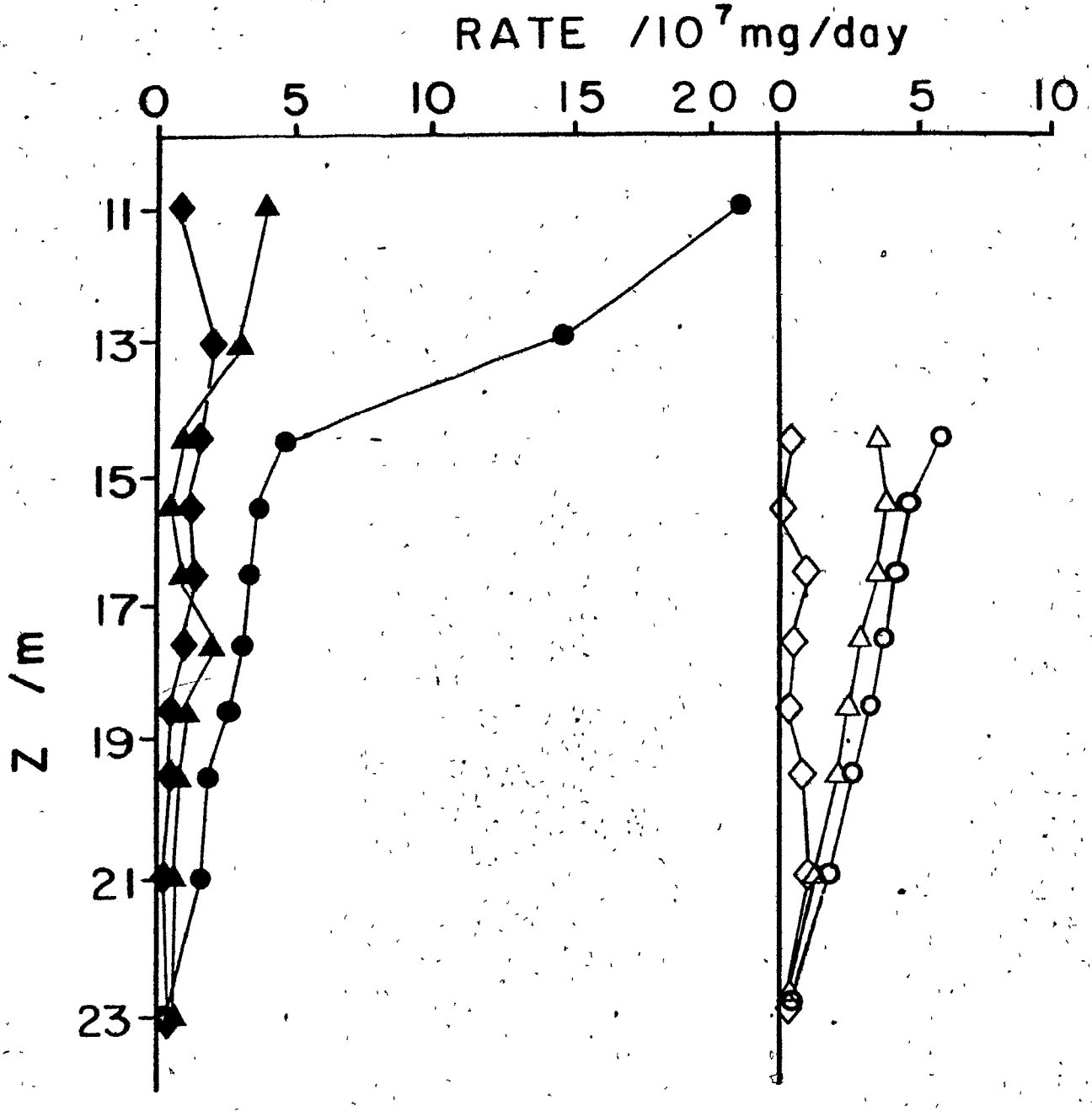

RATE /10⁷mg/day
0
5
10
15
20
0
5
10
11
13
15
17
19
21
23
Z /m

Fig. 5. Correlation (R^2=0.71) between the mass of oxygen transported across the upper boundary of each stratum (FLUX at Z) and the mass of oxygen transported through the lower boundary of the stratum (FLUX at Z+1). The letter A is used to denote 1 observation. When 2 observations are superimposed B is used, etc.

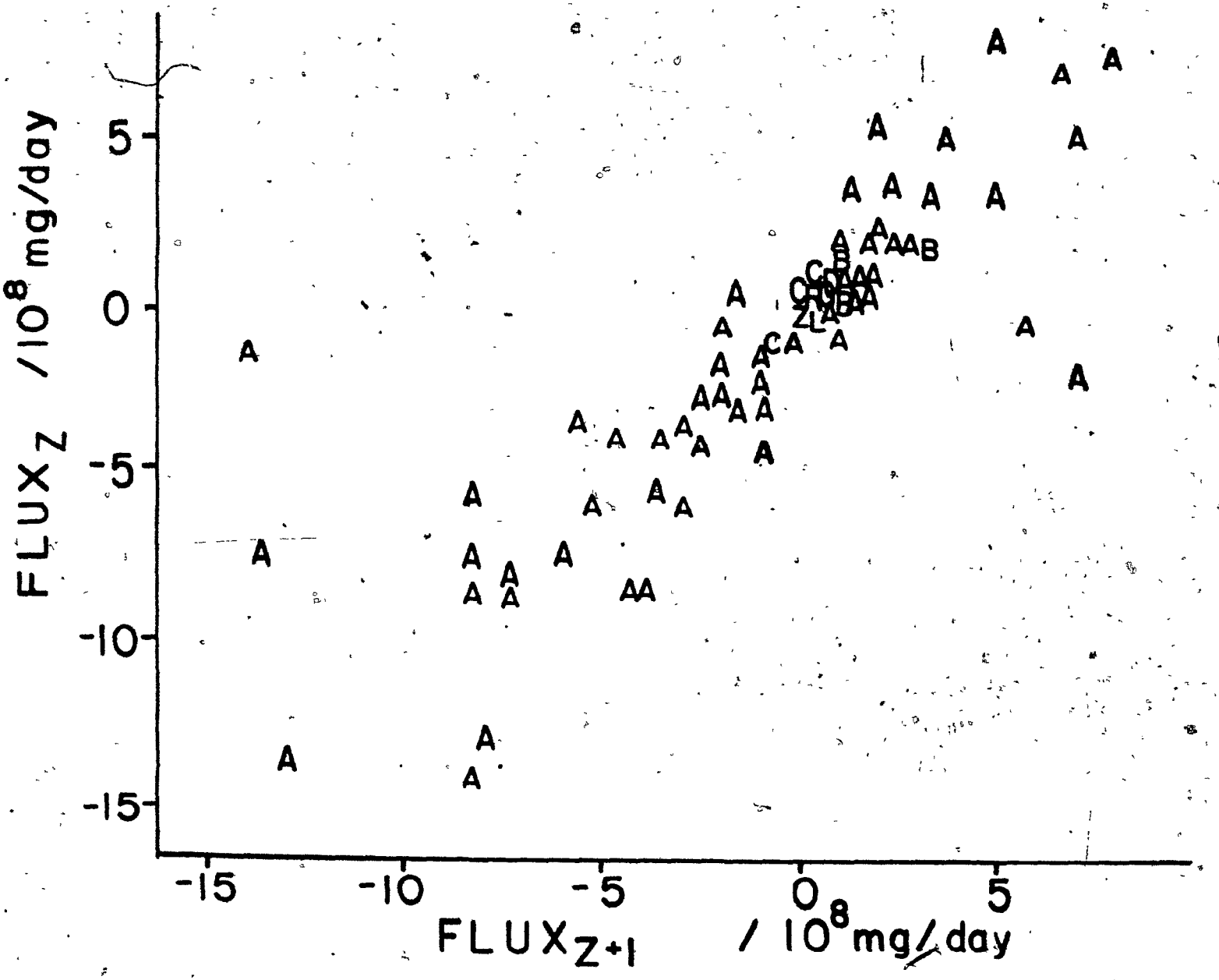

FLUX$_Z$ /10^8 mg/day
FLUX$_{Z+1}$ /10^8 mg/day
5
0
-5
-10
-15
-15
-10
-5
0
5

Fig. 6a. Rates of oxygen consumption in each stratum of the hypolimnion of the north basin of Lake Memphremagog expressed per unit of sediment area and corrected for the vertical transport of oxygen between adjacent strata (● 1979, O 1980).

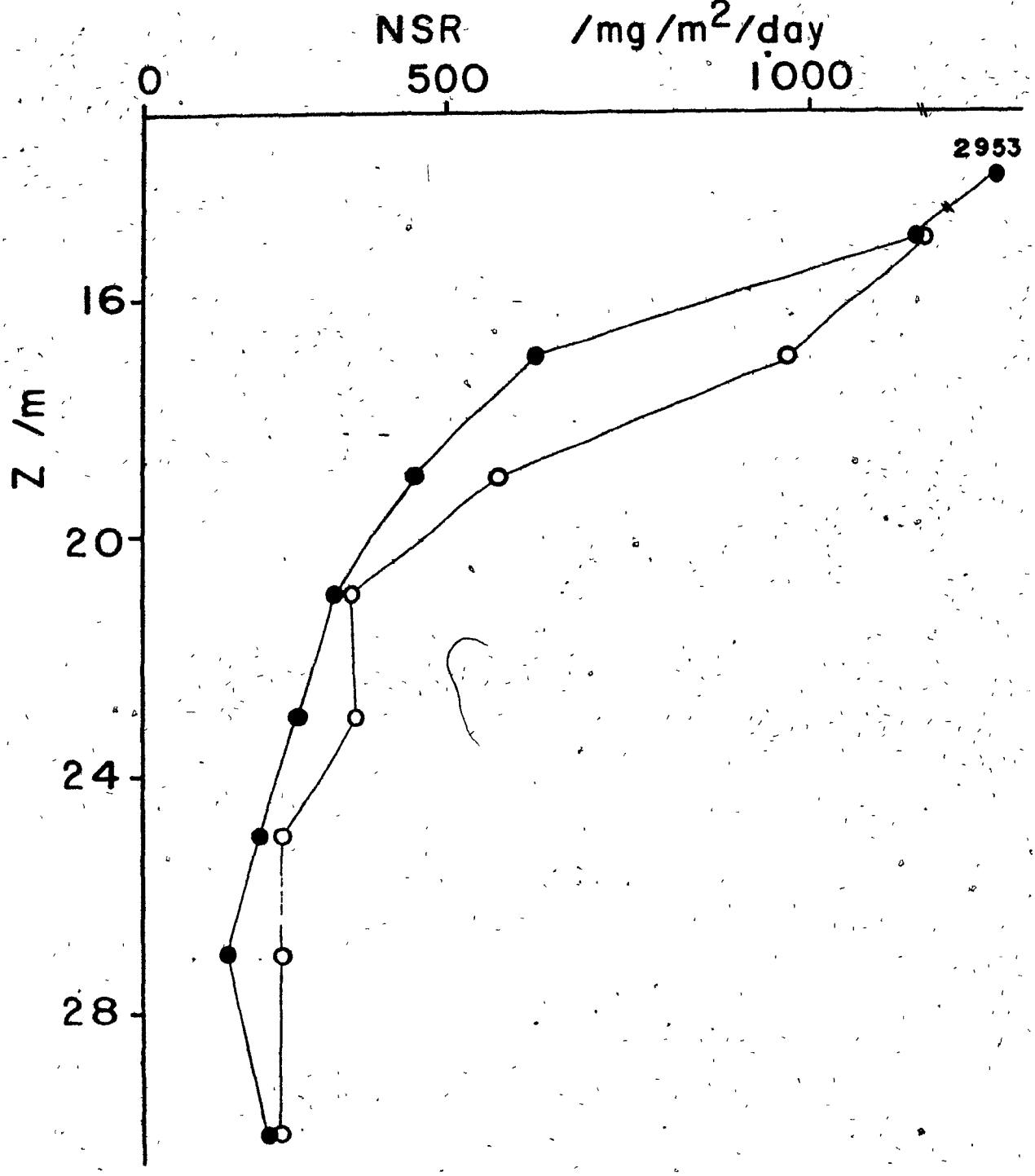

NSR /mg/m²/day
0
500
1000
2953
16
20
24
28
Z /m

Fig. 6b. Rates of oxygen consumption in each stratum of the central basin of Lake Memphremagog corrected for the turbulent transport of oxygen between adjacent strata.

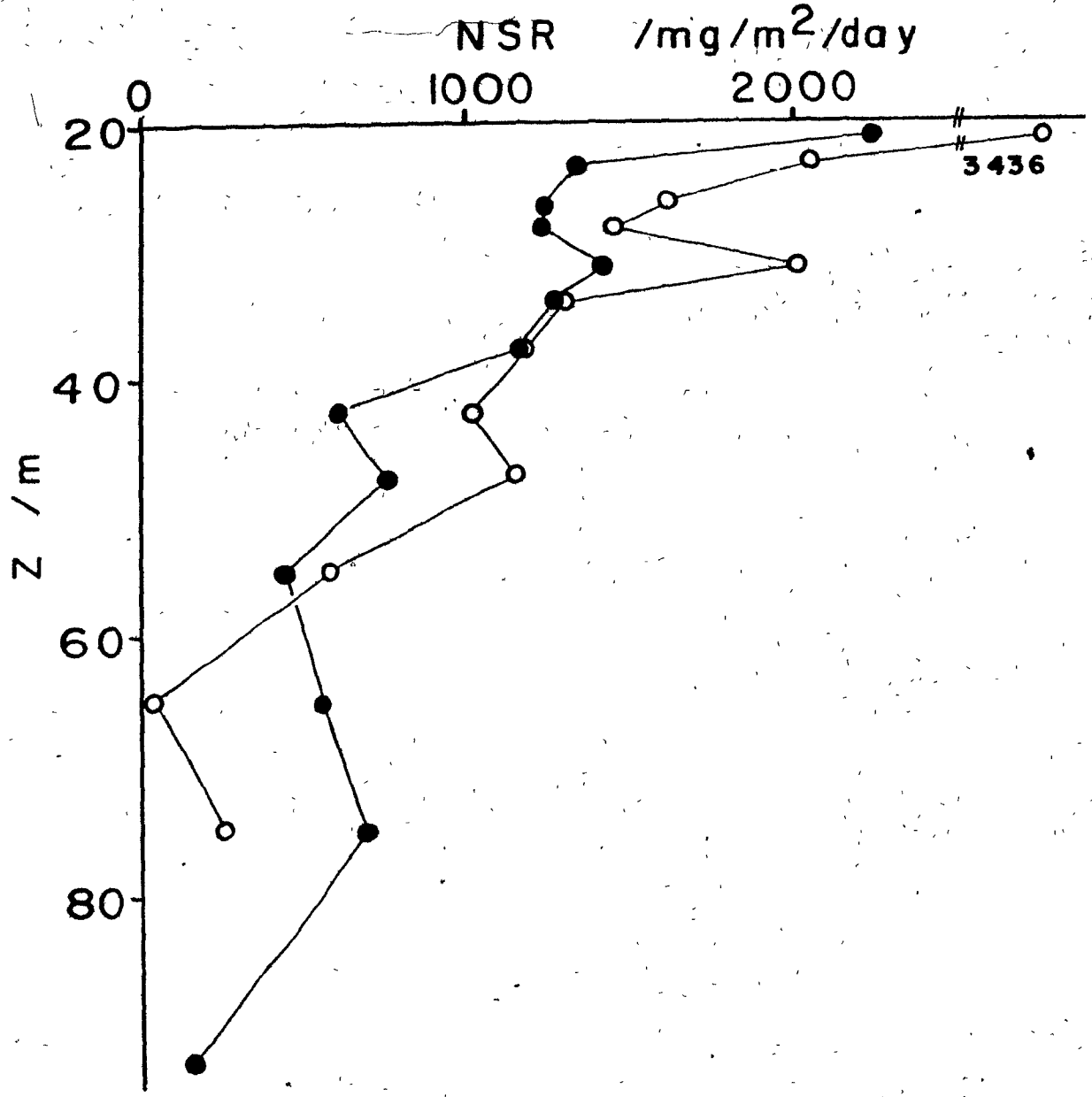

NSR /mg/m2/day
0
1000
2000
3436
20
40
60
80
Z /m

Fig. 6c. Rates of oxygen consumption, corrected for vertical transport of oxygen, within the hypolimnion of Lake Lovering.

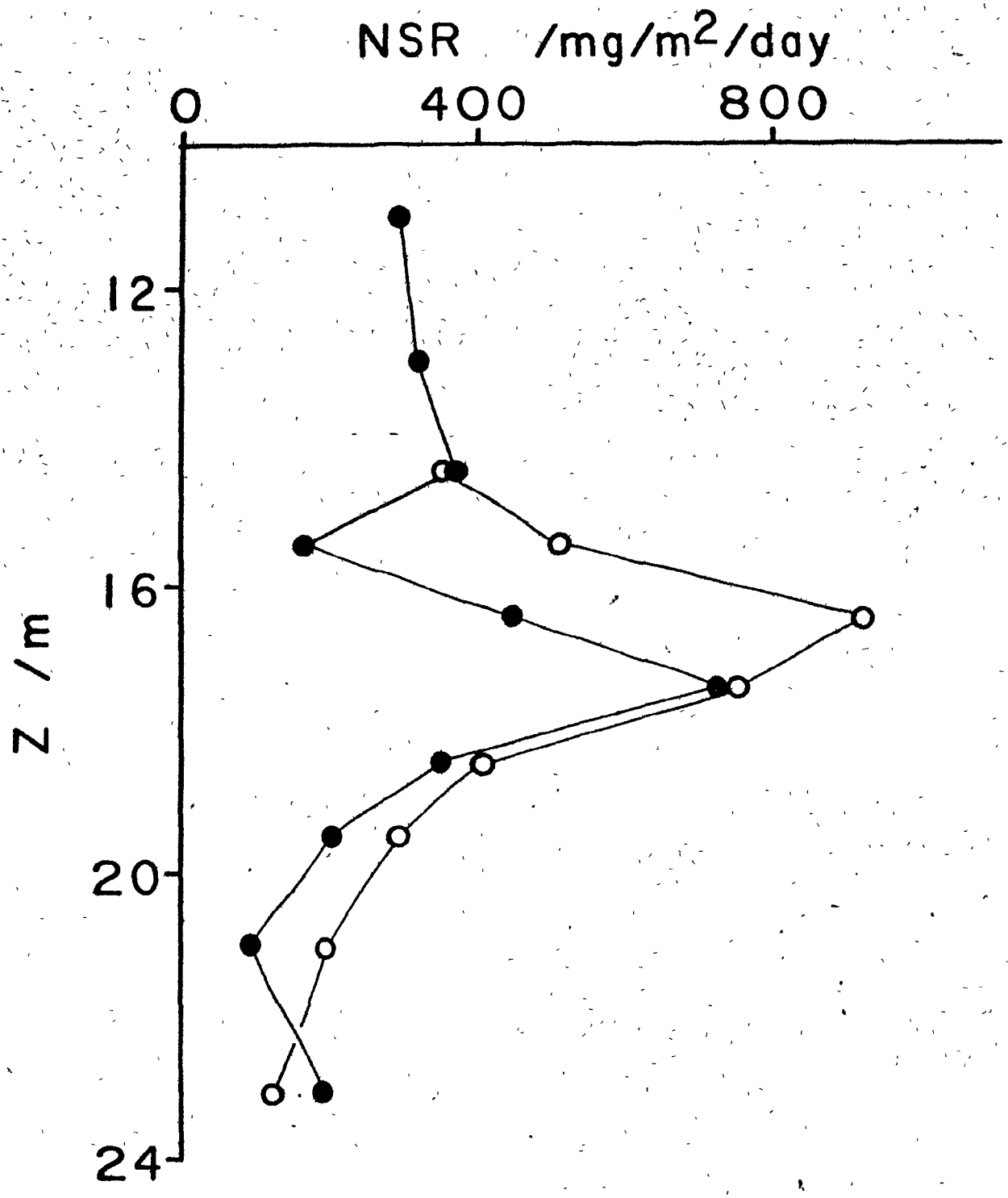
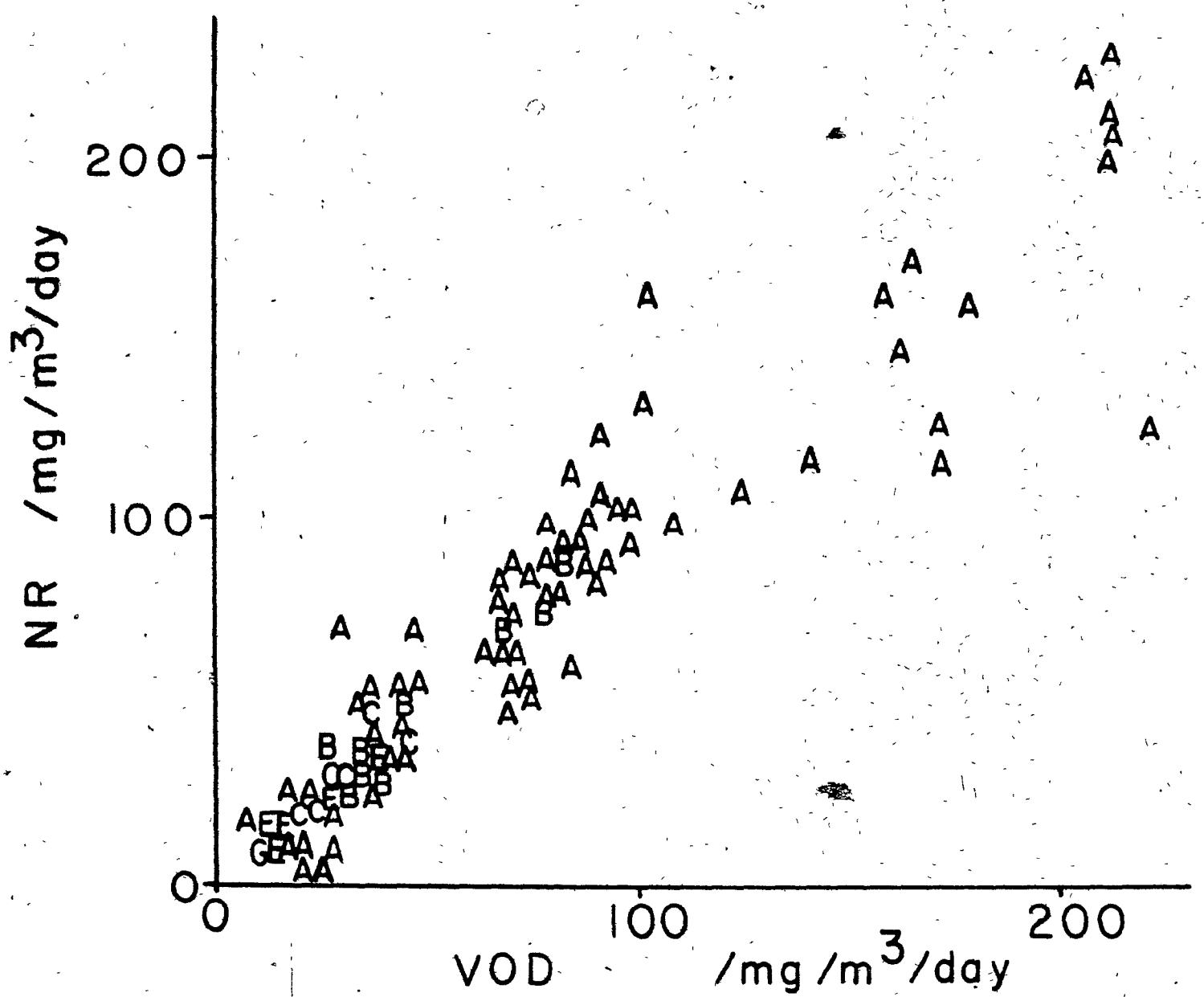

NSR /mg/m²/day
0
400
800
12
16
20
24
Z /m

Fig 7. VOD values measured in each stratum of all lakes regressed against the rates of oxygen consumption corrected for the vertical transfer of oxygen between adjacent strata of the hypolimnion. The slope of the line is not significantly different than 1.0. The letter A denotes a single observation, B denotes two superimposed observations, etc. NR is the corrected rate of oxygen consumption.


200
100
0
NR /mg/m3/day
0
100
200
VOD /mg/m3/day

CHAPTER ELEVEN

DECOMPOSITION

IN THE

HYPOLIMNETIC WATER COLUMN

INTRODUCTION

In the hypolimnion of lakes, decomposition of organic matter in the water column and in the sediments consumes oxygen. These two sinks for dissolved oxygen usually exceed the magnitude of the inputs of oxygen by photosynthesis and vertical transport. As a result, the concentration of oxygen in the hypolimnion decreases throughout the period of thermal stratification. Several methods of predicting rates of hypolimnetic oxygen consumption have been developed. Based upon their empirical models, Cornett and Rigler (1979, 1980), Charlton (1980) and Walker (1979) developed conceptual models to explain the empirical predictions made by the models. The objective of this paper is to test several of the hypotheses derived from these empirical models, and to compare these explanations of the mechanisms of oxygen depletion, with those developed by earlier workers (Thienemann 1926, 1928; Alsterberg 1927; Strom 1931; Hutchinson 1938, 1957).

Earlier this century, Thienemann (1926, 1928) and Alsterberg (1927) observed that, all other factors being equal, the morphometry of a lake affected the rate that oxygen concentrations in the hypolimnion decreased. A lake with a large, thick hypolimnetic water column exhibited lower rates of oxygen depletion ($mg/m^3/day$) than a lake with a thin hypolimnion. Both authors postulated that this occurred because sediment respiration was a more important sink for oxygen within the hypolimnion than respiration in the water column. This hypothesis predicts that hypolimnia or individual hypolimnetic strata with a high ratio of water volume to contiguous sediment area will be less subject to oxygen depletion even if the rates of water column respiration and sediment respiration are constant in different strata

and in different lakes. Strom (1931) and Hutchinson (1938) believed that they could eliminate the influence of lake morphometry upon the calculation of rates of oxygen depletion by expressing the rate per square meter of surface area of the plane delimiting the upper boundary of the hypolimnion. This calculation is usually termed an Areal Hypolimnetic Oxygen Deficit (AHOD). Because the horizontal dimensions of a lake are far greater than its depth, the area of the upper boundary of the hypolimnion is approximately equivalent to the area of bottom sediments adjacent to the waters of the hypolimnion.

Empirical tests of the AHOD model by Cornett and Rigler (1979, 1980), Chapra and Dobson (1979), Walker (1979) and Charlton (1980) suggest that all other factors being equal, the AHOD technique does not eliminate the influence of the morphometry of the hypolimnion upon the calculated rate of oxygen consumption. Each study observed that a lake with a thicker hypolimnion had a higher AHOD value than a lake with a thin hypolimnion of similar hypolimnetic temperature and surface water production. Therefore, one or more of the assumptions that Hutchinson (1938) and Strom (1931) made must be wrong. When they formulated the AHOD method, Hutchinson and Strom made several unstated assumptions. First they assumed that the observed net change in hypolimnetic oxygen concentrations is produced solely by respiration in the water column and at the sediment surface. Then both types of respiration were postulated to be proportional to the rate of sedimentation of organic matter into the hypolimnion. Hutchinson and Strom also assumed that benthic and pelagic photosynthesis did not add significant quantities of oxygen to the hypolimnion. Several hypotheses question the validity of these assumptions. These alternatives have

been proposed to explain the discrepancy between the AHOD model and the measured AHOD values. Cornett and Rigler (1979, 1980) hypothesized that AHOD values are influenced by physical transport. More oxygen was postulated to be transferred by physical mixing across the upper boundary of the hypolimnion in lakes with shallow hypolimnia. This hypothesis is correct (Cornett and Rigler 1983). However the average amounts of oxygen transferred across the hypolimnetic boundary is less than 5% of the measured AHOD. This is not sufficient to explain the variation in AHOD values of greater than 150 $mg/m^2/day$ in lakes that differ in maximum depth by 20 m (Cornett and Rigler 1980). The measured rate of oxygen depletion is approximately equal to the net rate of respiration in the hypolimnion.

An alternative explanation of the influence of morphometry upon AHOD values postulates that respiration in the water column of the hypolimnion is a significant sink for oxygen. Then if respiration in the water column is more efficient per gram of sedimenting organic matter than respiration at the sediment surface, deeper lakes could have higher areal rates of water column respiration provided that the residence time of a particle in the hypolimnetic water column is proportional to the thickness of the water column (Cornett and Rigler 1979, 1980; Charlton 1980). This hypothesis is only logically valid if organic matter that is not respired in the water column of a shallow hypolimnion does not cause a proportional increase in sediment respiration. Therefore a larger fraction of the organic matter sedimented into the hypolimnion must be stored or decomposed anaerobically in the sediments of a shallow lake than in a deep lake (Charlton 1980). Corrollaries of this hypothesis are that increases in

productivity in lakes of similar depth will also result in increases in the mass of oxygen respired in the hypolimnetic water column, and increases in the ratio of water column respiration to total respiration. The rate of sediment respiration must remain approximately constant.

The objective of this paper is to present direct measurements of the respiration of oxygen in the hypolimnetic water column that test the hypotheses stated above.

We thank H. L'Hereux, B. Isings and S. Cameron for assistance in the field. J. Lardner, C. Nagy, E. Ryan and L. Chant helped to prepare the manuscript.

METHODS

During 1979 and 1980 hypolimnetic oxygen concentrations and rates of respiration in the water column were measured in 12 lakes located in the eastern townships of Quebec, Canada (approx. 45° 16' N, 72° 9' W). During the period of thermal stratification, each lake was sampled 6 to 10 times at approximately regular intervals. On each sampling date duplicate temperature profiles were measured and 16 to 36 samples were collected to measure the oxygen concentration in different hypolimnetic strata (Cornett and Rigler 1983a). Samples collected from 3 to 5 strata from within the hypolimnion were used to estimate the concentration of chlorophyll *a* and the amount of respiration occurring in the water column. Rates of respiration in the water column were measured by concentrating the particulate matter (<250 μm) in 250 or 500 mL water samples onto 45 mm, 0.45 μm filters (Cornett and Rigler 1983b). The filters were resuspended in 60 ml glass bottles and the rate of respiration was determined by measuring the change in oxygen

concentration of a sample that respired for 1 day compared against a control sample. Slightly different methods were used during 1979 and 1980. In 1979 no attempt was made to maintain the in situ oxygen concentrations. The water samples were brought back to the laboratory before the experiments were started. In 1980 every experiment was started at the time the samples were collected. Filters were resuspended in water at the in situ concentration of oxygen. Since the ambient oxygen concentration does not influence rates of oxygen consumption (Zobell and Stadler 1936), this change in experimental design did not influence the experiments. The experimental design used in 1979 employed control samples that were fixed with Winkler reagents (Carpenter 1965) approximately 1 hour after the filter was added to the bottle. In 1980 control samples were treated identically to the respiring samples. At the start of the experiment 200 µl of saturated NaN_3 was added to control samples to stop all respiration. Then these control samples were incubated for 24 hours in the same containers as the respiring samples. In both years of study all incubations were 1 day in duration. All experiments were conducted in the dark at the in situ temperature. In each stratum the variance-weighted rate of water column respiration (WRR) was calculated during the same period as the oxygen concentrations were measured.

In each stratum the total rate of oxygen depletion was calculated by regressing the measured oxygen concentrations against the Julian day the samples were collected (Cornett 1982). The average rate of oxygen depletion within the hypolimnion was calculated by regressing the volume-weighted average concentration of oxygen measured on each day against the appropriate sampling day (Cornett and Rigler 1983a).

Volumetric rates of oxygen depletion (VOD in $mg/m^3/day$) within the entire hypolimnion, and within each stratum were corrected for the net amount of oxygen transported into the stratum by turbulent mixing. Vertical transport of oxygen was estimated by multiplying the vertical eddy diffusivity coefficient calculated from the rate of hypolimnetic heating using the flux gradient method (Powell and Jassby 1974), times the measured gradient in oxygen concentration (Cornett and Rigler 1983a,c). The corrected rates of oxygen depletion are termed net respiration (NR). The rate of oxygen consumption by the hypolimnetic sediments (SRR) is calculated as the difference between the rate of net respiration and the water column respiration (WRR). The rates are expressed per square meter of sediment area by multiplying the difference by the mean depth of the hypolimnion.

RESULTS AND DISCUSSION

Rates of respiration were measured in the water column of 7 lakes during 1979 and 12 lakes during 1980. In individual hypolimnetic strata WRR covered a very broad range: from 3.9 to 80.5 $mg/m^3/day$. In 6 lakes there was no systematic difference in the rate of respiration in the different strata that were sampled (Fig. 1a). In 2 lakes the highest WRR values were measured near the upper boundary of the hypolimnion (Fig. 1b). Higher VOD values were also measured in the same strata of these lakes. Lakes that have higher rates of oxygen depletion near the upper boundary of the hypolimnion are termed negative heterograde (Birge and Juday 1911; Hutchinson 1957). Birge and Juday (1911) hypothesized that the increased VOD values resulted from increased rates of microbial decomposition. They believed that

particulate matter collected in these strata because the strong density gradient decreased the settling velocity of the sedimenting particles. Shapiro (1959) suggested an alternative hypothesis. In Lake Washington, he calculated that the increased rates of oxygen depletion in these upper strata could be accounted for solely by the respiration of large numbers of copepods that congregated in the metalimnion of the lake. However Shapiro (1959) did not measure respiration by other size classes of organisms. In fact, his calculations were also very variable and could only account for an average of 68% (±10%) of the respiration in the strata. Measures of respiration made in this study suggest that approximately 55% of the respiration in the strata at the top of the hypolimnion can be attributed to oxygen consumption by organisms other than zooplankton. These WRR values were also much higher in the upper strata than those measured deeper in the hypolimnion (Fig. 1b).

In several shallow lakes, the WRR values were higher near the top of the hypolimnion and in the strata near the maximum depth of the lakes (Zmax) (Fig. 1c).

The observed increase in WRR in strata adjacent to the lake bottom is consistent with the studies of Kusnetzow and Karsinkin (1931) (cited by Hutchinson 1957) and Rudd and Hamilton (1973) who observed large numbers of bacteria and higher ATP concentrations in the thermocline and in the deepest strata of the hypolimnion. Increased WRR values near Zmax were not measured in every lake. However the strata immediately above Zmax were not sampled in many of the deeper lakes. Therefore the different patterns of WRR measured in the lakes either reflect real differences between lakes, or the lack of

sufficient samples collected near the maximum depth. More samples were not collected near Zmax because these deep strata constitute a very small fraction of the total volume of the hypolimnion.

Volume weighted average WRR values within the hypolimnion ranged between 5.9 and 64.7 mg/m^3/day. Higher WRR values were measured in the shallow, more eutrophic lakes (Table 1). These rates constitute a very significant fraction of the total amount of oxygen consumed within the hypolimnion. Even in the very shallow or thin hypolimnia of small oligotrophic lakes, WRR is responsible for 15 to 45% of the measured VOD values. In the deepest lakes that were studied (Zmax > 80m), more than 50% of the total oxygen consumption occurred in the water column. In these lakes the absolute amount of oxygen transported into the hypolimnion averaged less than 5% of the measured VOD values. As a result, correcting the VOD values for the amount of oxygen turbulently mixed into or out of the hypolimnion changes the relative significance of WRR values very little.

Cornett and Rigler (1979, 1980) and Charlton (1980) postulated that the total amount of oxygen consumed within the water column would increase as the total mass of oxygen consumed within the hypolimnion increased in lakes that were either deeper or more productive. The pooled data from 2 years of study support this hypothesis (Fig. 2). Both papers also postulated that in a group of lakes with similar surface water production and biomass, the proportion of the VOD attributed to WRR would increase as the thickness of the hypolimnion increased. The relationship between the ratio of WRR:NR and ZH was postulated also to be a semi-logarithmic relationship. These hypotheses are consistent with our observations (Fig. 3). In these

oligotrophic lakes, the average fraction of the total respiration that occurred in the water column increased from 20% to 60% of VOD as the mean depth of the hypolimnion increased from 4 m to 45 m. There is however one lake that does not fit the pattern of the other 11 lakes.

Much higher WRR values were measured in Lake Truite than in the other small oligotrophic lakes (Fig. 3). The fraction of the total respiration that occurred within the water column was also much larger than in other lakes. This observation may reflect lower rates of respiration in the sediments of the lake or significant inputs of oxygen by photosynthesis. The second hypothesis is believed to be correct for two reasons. This is the only study lake in that detectable quantities of light reached the maximum depth of the lake. As the summer progressed oxygen concentrations in the upper strata increased. Since there was no oxygen transported across the upper boundary of the hypolimnion of Lake Truite this increase must be due to photosynthesis.

Cornett and Rigler (1979, 1980) and Charlton (1980) also postulated that in a group of lakes with similar surface water productivity and similar hypolimnetic temperatures, the respiration rate of the sediments would not be significantly different in shallow lakes than in deep lakes. Although this hypothesis cannot be tested rigorously until respiration by the sediments is measured directly, the difference between the total rate of oxygen consumption and WRR provides an estimate of the rate of oxygen consumption by the sediments. In the oligotrophic lakes that were studied, SRR is not correlated with the thickness of the hypolimnion (Fig. 4).

The hypothesis that the morphometry of the hypolimnion influences WRR but does not influence SRR (Cornett and Rigler 1979, 1980; Charlton 1980) has several corrollaries. The hypothesis is built upon the assumption that the rate of oxygen consumption within the water column of a hypolimnetic stratum is proportional to the amount of organic matter sedimented into the hypolimnion. The argument that WRR should be influenced by the variation in the input of organic matter along a gradient of hypolimnetic depth should also apply to the inverse set of conditions. Variation in the rate of sedimentation should also influence WRR in lakes with hypolimnia of similar mean depth. In models of phosphorus concentration, the annual retention of phosphorus by the lake sediments (inputs - outputs), is used to estimate sedimentation. Areal phosphorus retention (Rp in mg per square meter per year) can be estimated for any lake, using the mass balance model tested by Dillon and Rigler (1974). Since the amount of phosphorus is a fixed fraction of organic matter (Redfield et al 1963), this argument predicts that the amount of oxygen consumed in the water column should increase as Rp increases. In two groups of lakes with similar hypolimnetic thickness but varying values of Rp, this hypothesis is correct (Fig. 5).

In lakes with similar hypolimnetic depth, but differing rates of sedimentation (measured by Rp), the fraction of the total hypolimnetic rate of respiration contributed by the water is also predicted to increase. This prediction is correct (Fig. 6). Over the range of Rp values measured in this study, there is a significant non-parametric correlation between the ratio of WRR:NR and the estimated retention of phosphorus (τ=0.7, $p < 0.05$). The ratio of WRR:NR ranged from 16% to

35%. However more detailed data are needed to determine the exact form of the relationship.

During 1979 the hypothesis that WRR is correlated with the input of organic matter was tested more rigorously by measuring directly the amount of organic matter in the water samples that were used for experiments to determine WRR values. The concentration of chlorophyll a (uncorrected for phaeophytins) was chosen as a measure of biomass for several reasons. Chlorophyll measures the amount of autochthonous organic matter of recent origin, present in the water. Since the hypotheses mentioned above only discussed this type of organic matter, the operational measure should reflect this fact. Secondly, organic material of algal origin appears to be much more readily decomposed than allochthonous material (Hesslein et al 1980). It is the decomposition of these materials that will consume oxygen within the hypolimnion. Finally measurements of chlorophyll a within the hypolimnion can be compared to those made in the surface waters of the lake to determine if there is a direct relationship between the biomass of algae in the trophogenic zone, and that in the hypolimnion.

The hypothesis that WRR is correlated with the concentration of hypolimnetic chlorophyll a is complicated by the fact that the temperature within the hypolimnion of the study lakes varied from 4°C to 12°C. Therefore the hypothesis was tested with a multiple regression model of the form

$$WRR = bo + b^1T + b^2C + b^3T*C \qquad (1)$$

where C is the average summer concentration of chlorophyll a, and T is

the average summer temperature of the stratum. The regression with the smallest residual mean square was

$$WRR = 5.17 + 1.20T*C \qquad (2)$$

WRR is correlated with the amount of organic matter in the hypolimnetic water column (Fig. 7). The interraction term explained more variation in WRR than either the chlorophyll concentration or temperature terms regressed alone or together upon the measured WRR values.

Although this is the first study that has directly measured the amount of oxygen consumed by the particulate material in the hypolimnetic water column of lakes, many statements about the significance of respiration in the water column of lakes have been made (Table 2). All of these previous, often conflicting, statements were based upon indirect estimates of the significance of respiration within the water column. Hutchinson (1957) placed dark bottles of hypolimnetic water in the hypolimnion of Lindsley Pond and Quassapang Lake for one week. The change in oxygen concentration inside the bottles was approximately equal to the change within the water column. Hutchinson (1957) concluded that 100% of the oxygen consumption in the hypolimnion occurred in the water column. However, bacteria multiply rapidly within glass bottles (Zobell 1937, 1943). Hutchinson's BOD type of experiment would substantially overestimate in situ respiration. His results are much higher than the results obtained in any of the shallow lakes investigated during this study.

Hayes and MacAulay (1959) reached exactly the opposite

conclusion to Hutchinson. They concluded that all hypolimnetic respiration occurred in the sediments. Hayes and MacAulay (1959) measured the rate of oxygen consumption in 6 small lakes and compared those rates to the rates of oxygen consumption of cores of mud measured in the laboratory. There was no statistically significant difference between the rate of oxygen consumption by the sediments and the calculated amount of oxygen consumed in the hypolimnion. However the results were so erratic that they must be discounted. The measured SRR values ranged from 88 to 247% of the calculated areal hypolimnetic oxygen deficit. The lakes were small, highly coloured with humic substances, and very little light penetrated into the hypolimnion. Therefore it is unlikely that the observation that sediment respiration exceeded VOD values can be explained by photosynthetic inputs of oxygen or the physical transport of oxygen into the hypolimnion. It is more likely that the conclusion of Hayes and MacAulay (1959) that grab samples of mud respire at the same rate as hypolimnetic sediments is erroneous. Hargrave (1975) demonstrated that disturbed sediments can respire at much higher rates than the constant rates of respiration measured in undisturbed sediment samples.

Kleerekoper (1953) and Lawacz (1964) also concluded that respiration in the hypolimnetic water column was not important. They based this conclusion upon the observation that the loss of ignition (LOI) of samples collected in sediment traps, suspended at the upper boundary of the hypolimnion, was the same as the LOI of material collected at the maximum depth of the lake. Unfortunately some types of sediment traps select particles (Gardner 1979; Burns and Bloesch 1979). The traps employed in both studies were likely to underestimate

the actual amount of organic matter falling into the hypolimnion. Since the sediment traps were left in the water for long periods of time, it is possible that much of the sedimenting organic matter was already decomposed before it was sampled. The comparison of the change in LOI values of sediment traps and the bottom sediments further assumes that the flux of particulates is one way down. Many studies show that sediment traps also collect material that is resuspended from the lake bottom.

The results of this study are consistent with the hypotheses of Lund et al (1963), Kimmel et al (1975), Lasenby (1975), and Rich (1979). All of these authors measured the amount of oxygen consumed by the sediments and concluded that rates of sediment respiration were not sufficient to account for all of the oxygen depletion observed in the hypoliminion. However, one major study of SRR did conclude that there was no respiration in the hypolimnetic water column (Hargrave 1971). Hargrave measured SRR in the hypolimnion of Lake Esrom. However, since he started to measure the rate of oxygen consumption by the sediment cores immediately after they were collected, it is possible that his experiments overestimated the in situ rate of sediment oxygen consumption by liberating reduced substances when the cores were disturbed during sampling. Based upon the results of this study, 25 to 40% of the total amount of oxygen consumed within the hypolimnion of Lake Esrom should be respired within the hypolimnetic water column of a shallow and highly productive lake.

The fraction of the total amount of hypolimnetic oxygen consumption occurring within the water column is not constant. It is influenced by the thickness of the hypolimnion and by the amount of

organic matter sedimenting into the water column. Because respiration by the sediments does not appear to be influenced by the morphometry of the hypolimnion, respiration by the particulate matter in the water column is more important in deep lakes than in shallow lakes. However, this pattern will not be observed if photosynthesis supplies significant amounts of oxygen to the hypolimnion. Photosynthesis is hypothesized to influence the observed rates of oxygen depletion in shallow, clear lakes. Significant inputs of oxygen by photosynthesis into the hypolimnion of other lakes have also been reported by Wetzel et al (1972), Kimmel et al (1975), Provini (1975) and Mitchell and Burns (1978). These results are consistent with Hutchinson's (1938) hypothesis that oxygen might be added to the hypolimnion of lakes less than 20 m maximum depth. However, Hutchinson also argued that the morphometry of the hypolimnion would not influence the amount of hypolimnetic oxygen depletion occurring in the water column of deeper lakes (Zmax 20 to 70 m). This study demonstrates that the mass of oxygen consumed in the water column and the relative significance of water column respiration are proportional to the logarithm of the mean thickness of the hypolimnetic water column. Respiration in the sediments does not appear to be influenced by the morphometry of the hypolimnion.

Hutchinson (1938, 1957) also hypothesized that the oxidation of dissolved allochthonous organic matter would consume significant quantities of oxygen in the hypolimnetic water column. Several lines of reasoning suggest that WRR measures the decomposition of autochthonous carbon rather than allochthonous substances. Allen (1972), Wetzel and Otsuki (1973) and Hesslein et al (1980) have all

shown that dissolved organic compounds are not readily metabolised. In this study WRR values measured in very oligotrophic lakes with highly coloured waters, were no higher than rates measured in clear oligotrophic lakes. Attempts to add secchi depth as an independent variable to the regression of WRR against the interraction between stratum temperatures and measured concentrations of chlorophyll a were not successful. The respiration measured in this study was associated with particulate material greater than 0.45 m in diameter. If dissolved allocthonous organic matter was an important metabolite, the concentration of 500 ml of particulate matter in a 67 ml bottle would severely alter the amount of substrate available for respiration and this would decrese the measured rates of respiration. However, the concentration of organic matter onto filters, to measure rate of oxygen consumption, did not alter the rates of respiration (Cornett and Rigler 1983b). All of these observations suggest that allocthonous, dissolved, organic compounds are not rapidly decomposed. Significant amounts of autochthonous organic matter are decomposed in the water column of the hypolimnion.

YEAR	LAKE	ZH	NR	WRR
1979	Central	45.0	12.4	8.2
	Magog	2.5	216.1	57.3
	Lovering	4.0	78.0	17.7
	Massawippi	35.1	16.3	7.9
	North	7.3	79.4	14.1
	Orford	20.1	15.1	5.9
	Truite	3.2	64.7	30.0
1980	Brompton	9.0	44.4	8.8
	Central	45.1	14.6	7.9
	Fitch	3.3	163.6	35.3
	Little Brompton	6.3	67.6	10.6
	Magog	3.7	184.9	64.7
	Lovering	4.0	104.9	17.5
	Lyster	16.4	21.2	5.7
	Massawippi	35.1	20.4	12.3
	North	7.3	89.4	20.0
	Orford	19.8	20.6	8.4
	Stukley	8.9	35.4	6.4
	Truite	2.8	74.3	22.1

Table 1. Summary of the volume-weighted, mean summer rates of net respiration (NR $mg/m^3/day$), corrected for oxygen transport, and WRR values ($mg/m^3/day$) and mean thickness of the hypolimnia (ZH m) in the 12 study lakes. Central, North and Fitch are three separate basins of lake Memphremagog.

Fig. 1a. Average summer VOD values (circles) and WRR values (squares) measured in Lake Brompton during 1979 (open) and 1980 (filled) plotted against the depth of the stratum below the lake surface (Z m).

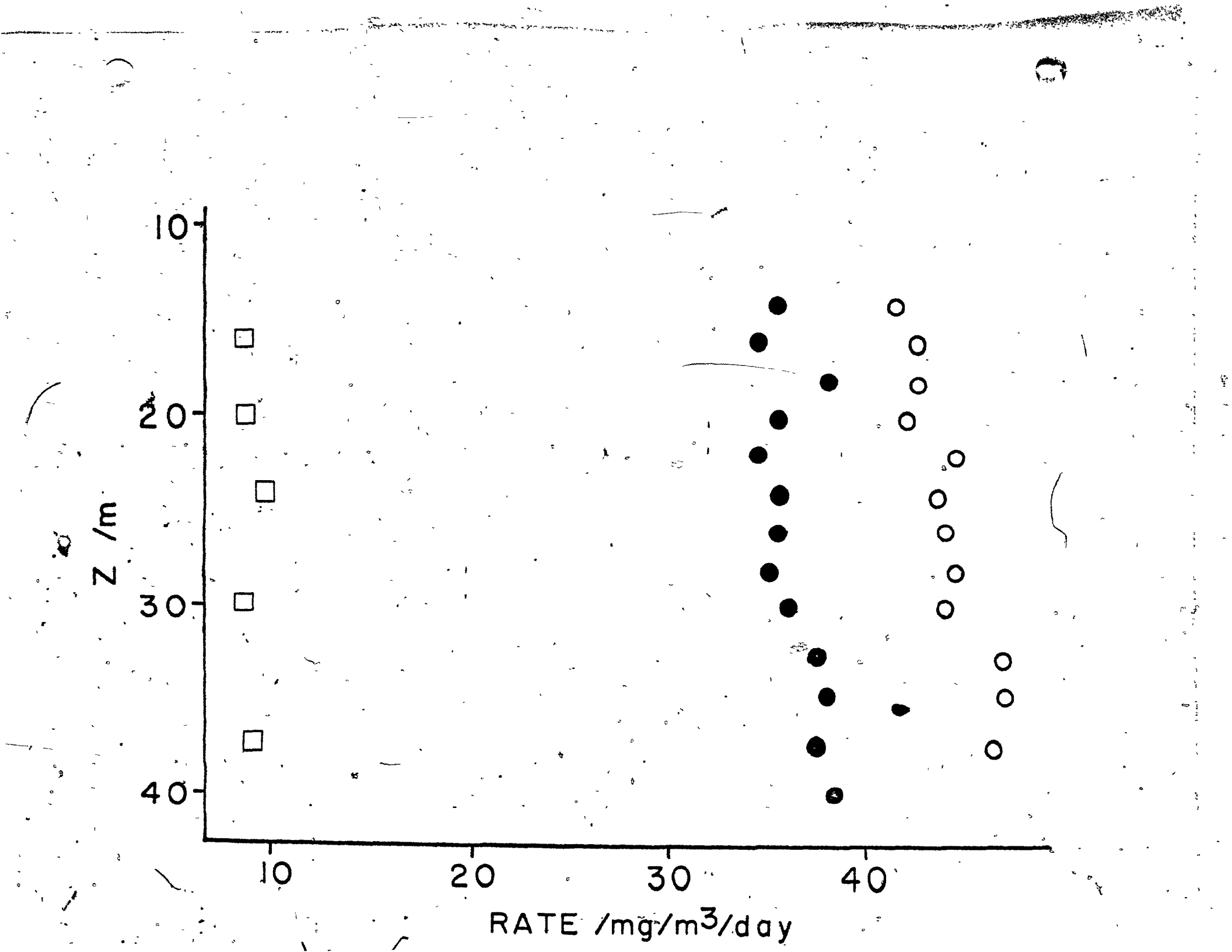

10
20
30
40
Z /m
10
20
30
40
RATE /mg/m3/day

Fig. 1b. VOD values (circles) and WRR values (triangles) measured in central basin of Lake Memphremagog during 1979 and 1980. Units and symbols are the same as Fig. 1a.

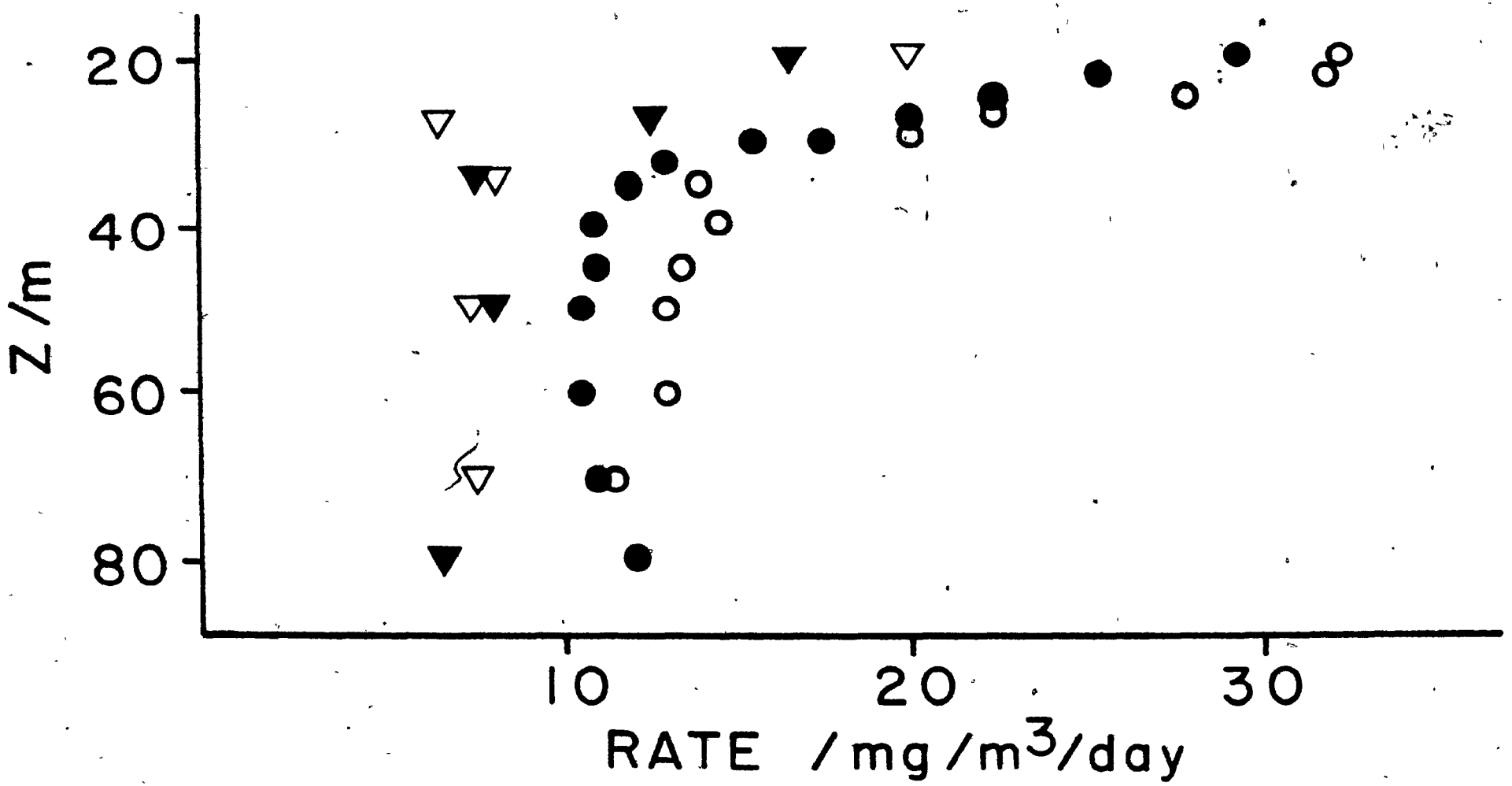

20
40
60
80
Z/m
10
20
30
RATE /mg/m3/day

Fig. 1c. WRR values and VOD values measured in the north basin of Lake Memphremagog during 1979 and 1980. Units and symbols as in Fig. 1a.

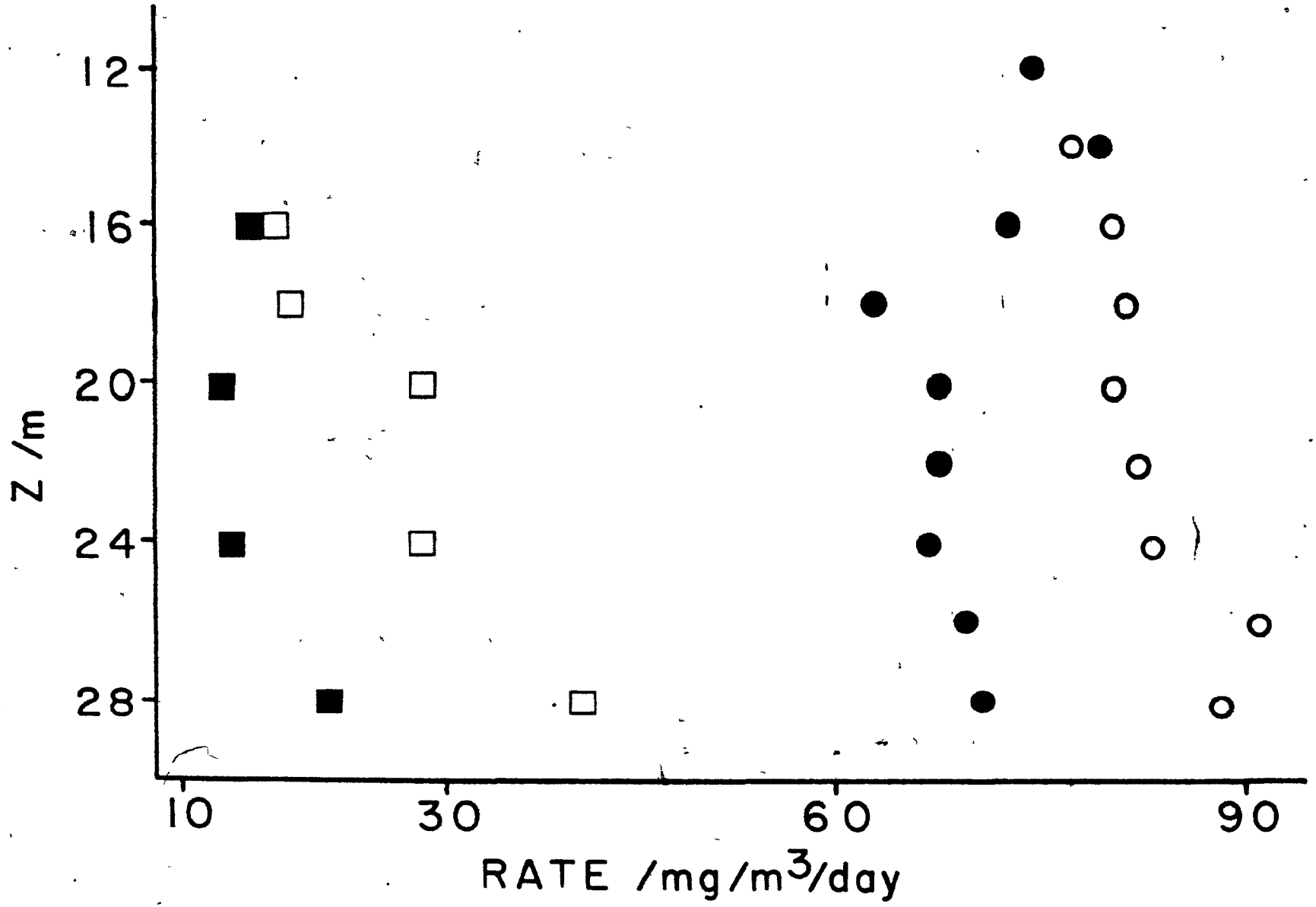

12
16
20
24
28
Z /m
10
30
60
90
RATE /mg/m3/day

Fig. 2. Average rates of respiration measured in the hypolimnetic water column plotted against the rate of oxygen depletion in the hypolimnion. The integrated rates are expressed in mg/day because the division of these values by a common denominator could bias the comparison (Atchley et al 1975).

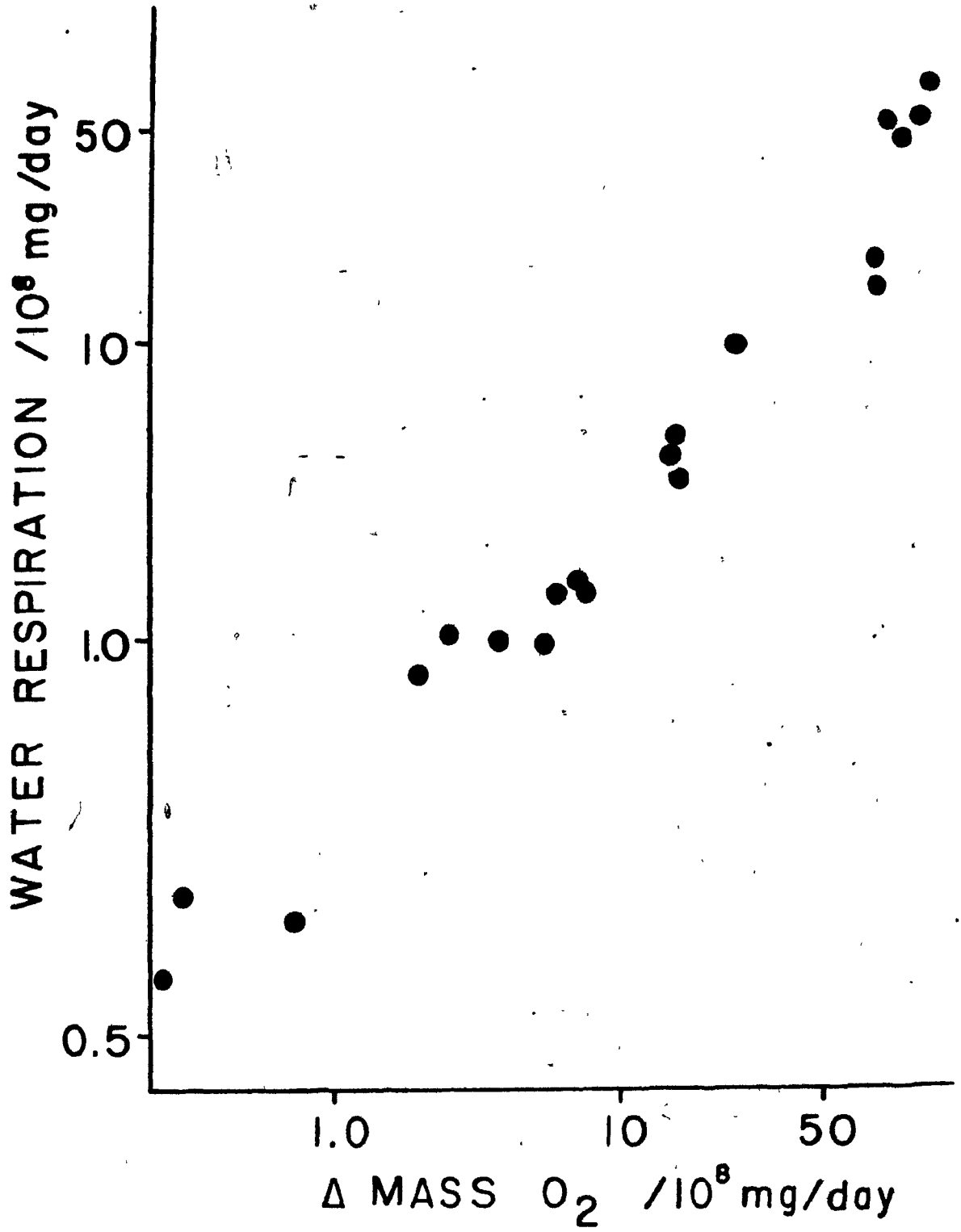

WATER RESPIRATION /10⁸ mg/day
50
10
1.0
0.5
1.0
10
50
Δ MASS O2 /10⁸ mg/day

Fig. 3. The percentage of the total mass of oxygen respired in the hypolimnion which occurred in the water column. Only lakes with mean summer phosphorus concentrations less than 13 ug/L are included in the comparison. The open circles are Lake Truite.

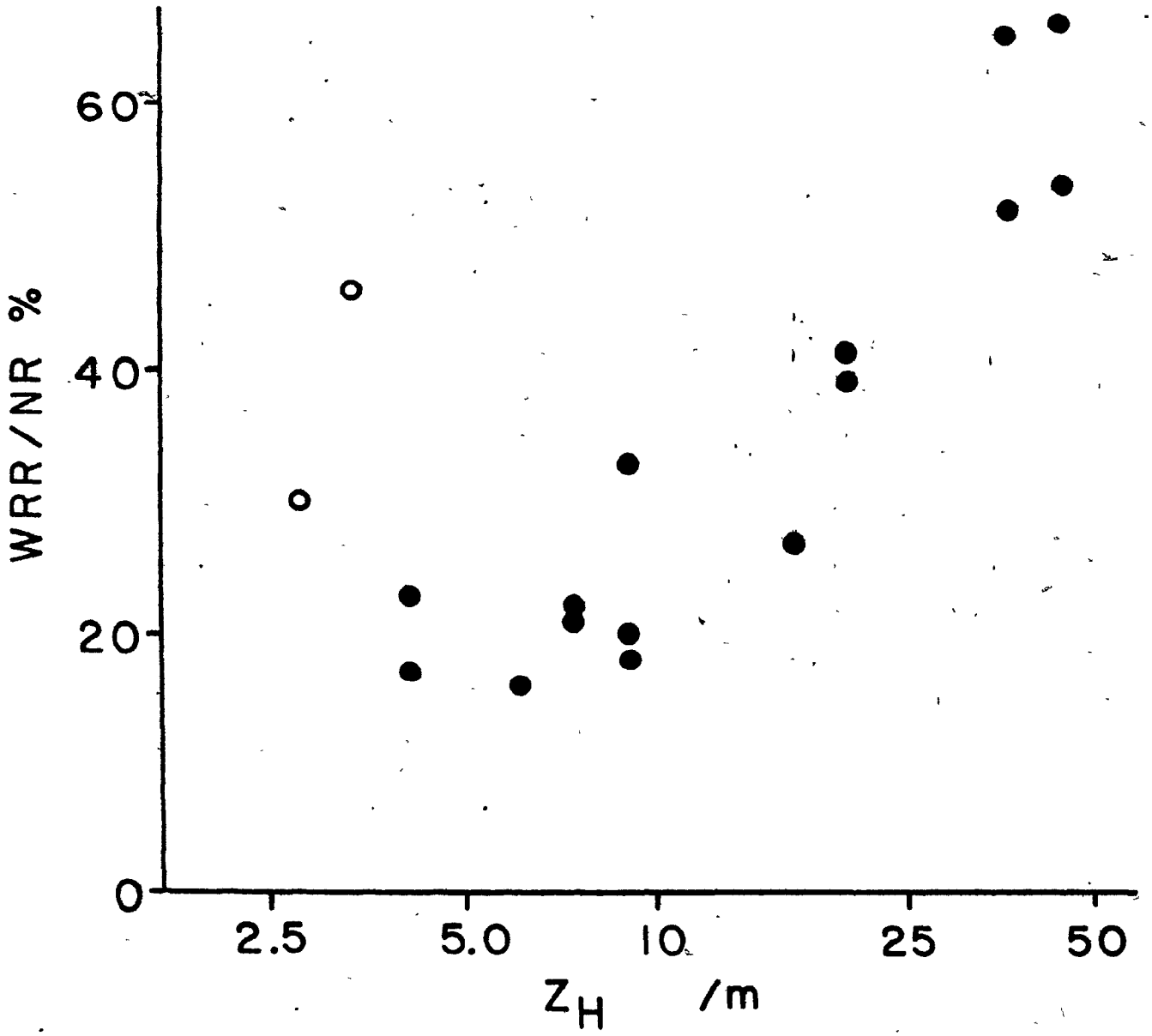

WRR/NR %
60
40
20
0
2.5
5.0
10
25
50
Z_H /m

Fig. 4. Rates of sediment respiration (SRR) estimated as the difference between measured values of NR and WRR. The SRR values do not appear to be influenced by the thickness of the hypolimnion.

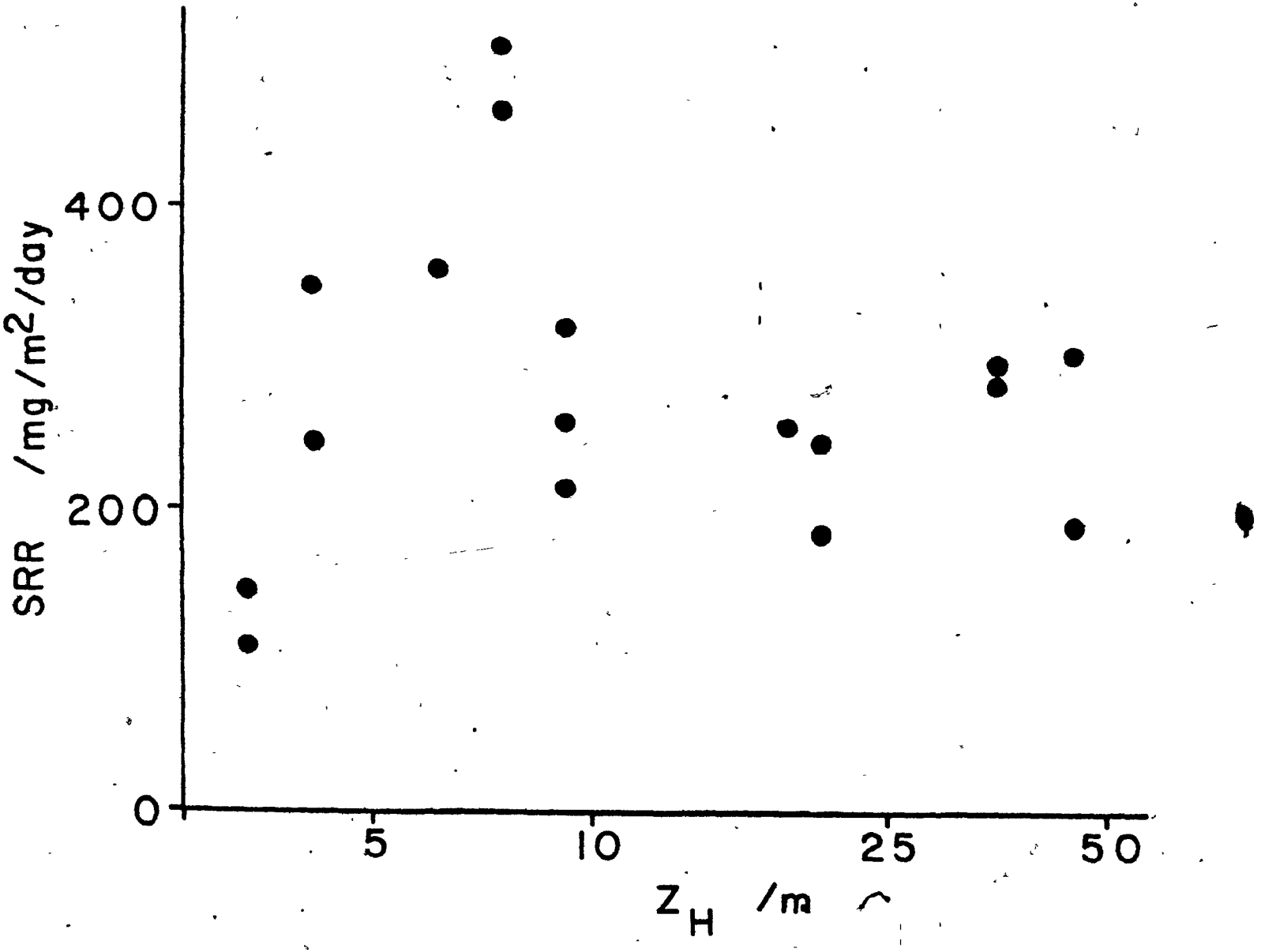

SRR /mg/m²/day
400
200
0
5
10
25
50
Z_H /m

Fig. 5. Integrated rates of water column respiration plotted against the estimated annual retention of phosphorus in the lake sediments (Rp). The lakes were divided into three groups based upon their depth Group one consisted of lakes with a mean hypolimnetic depth less than 4.0 m (O). Group two lakes had values of ZH between 4.0 m and 9.0 m (●).Insufficient data were collected from deeper lakes (ZH>9.0 m to make the same comparison. Therefore the third group of lakes are not included on the graph.

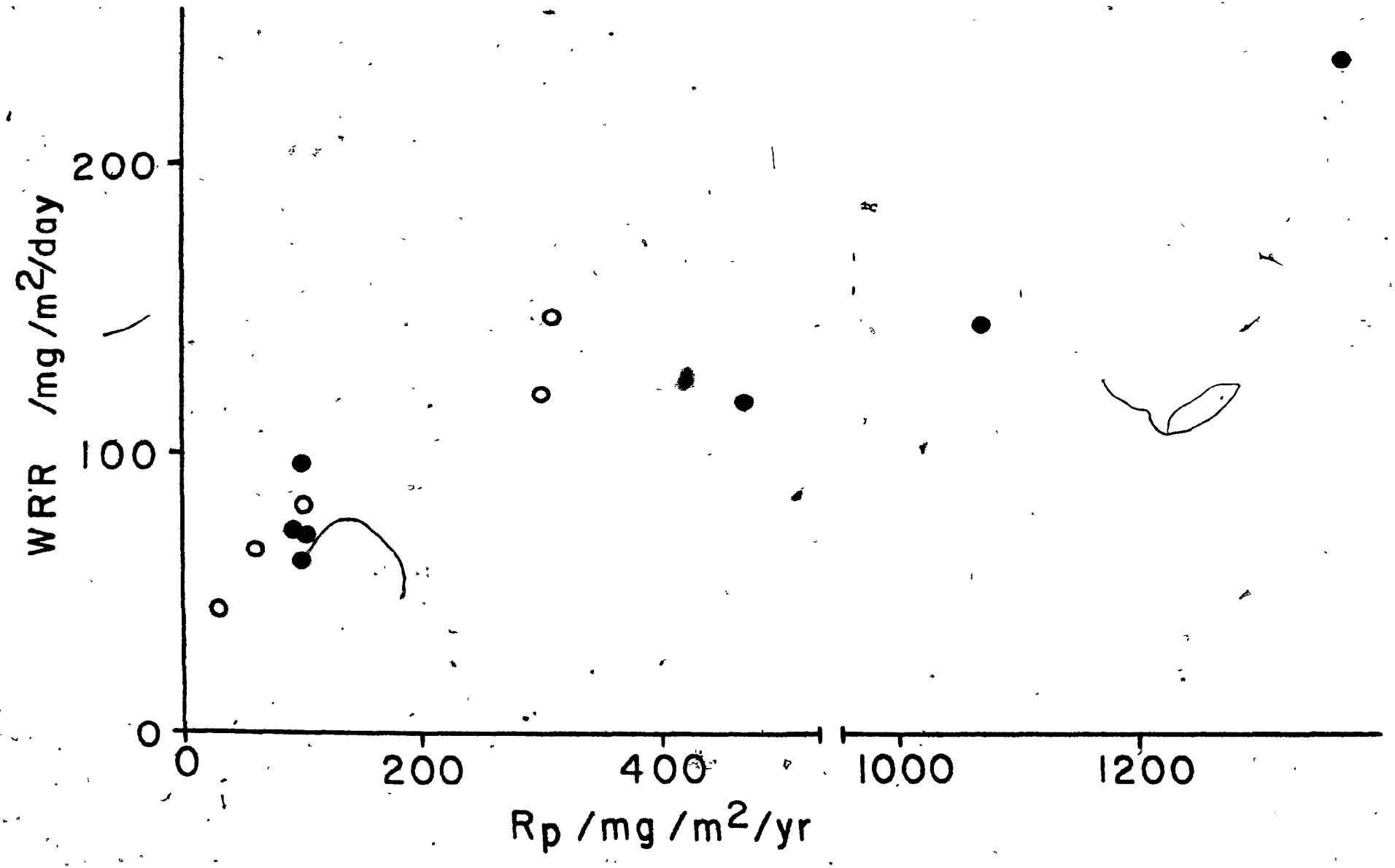

WRR /mg/m2/day
200
100
0
0
200
400
1000
1200
Rp /mg/m2/yr

Fig. 6. Ratio of WRR:NR measured in lakes of differing phosphorus retentions. The lakes were divided into 3 groups using the same criterion described in Fig. 5. Lake Truite (▽) does not fit the pattern.

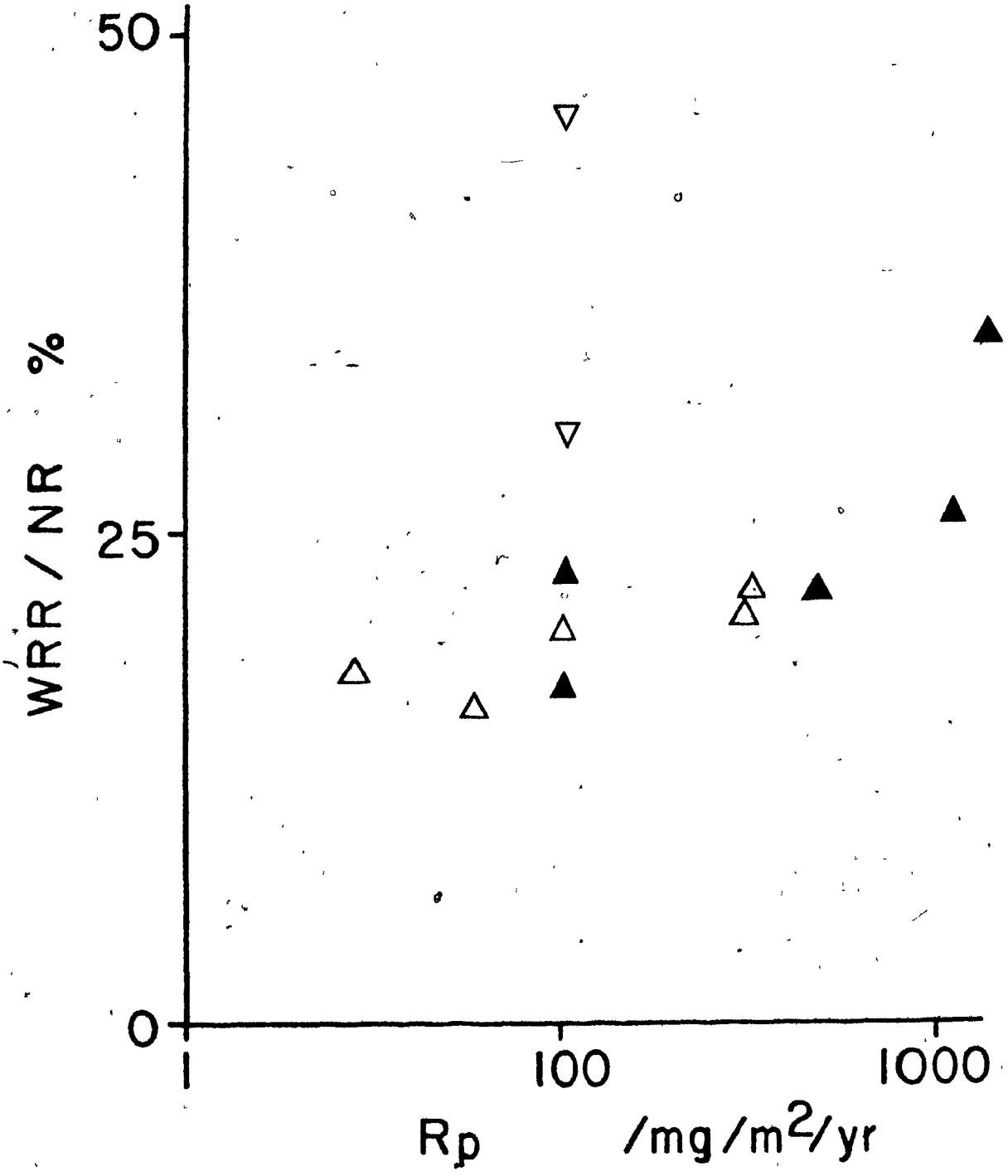
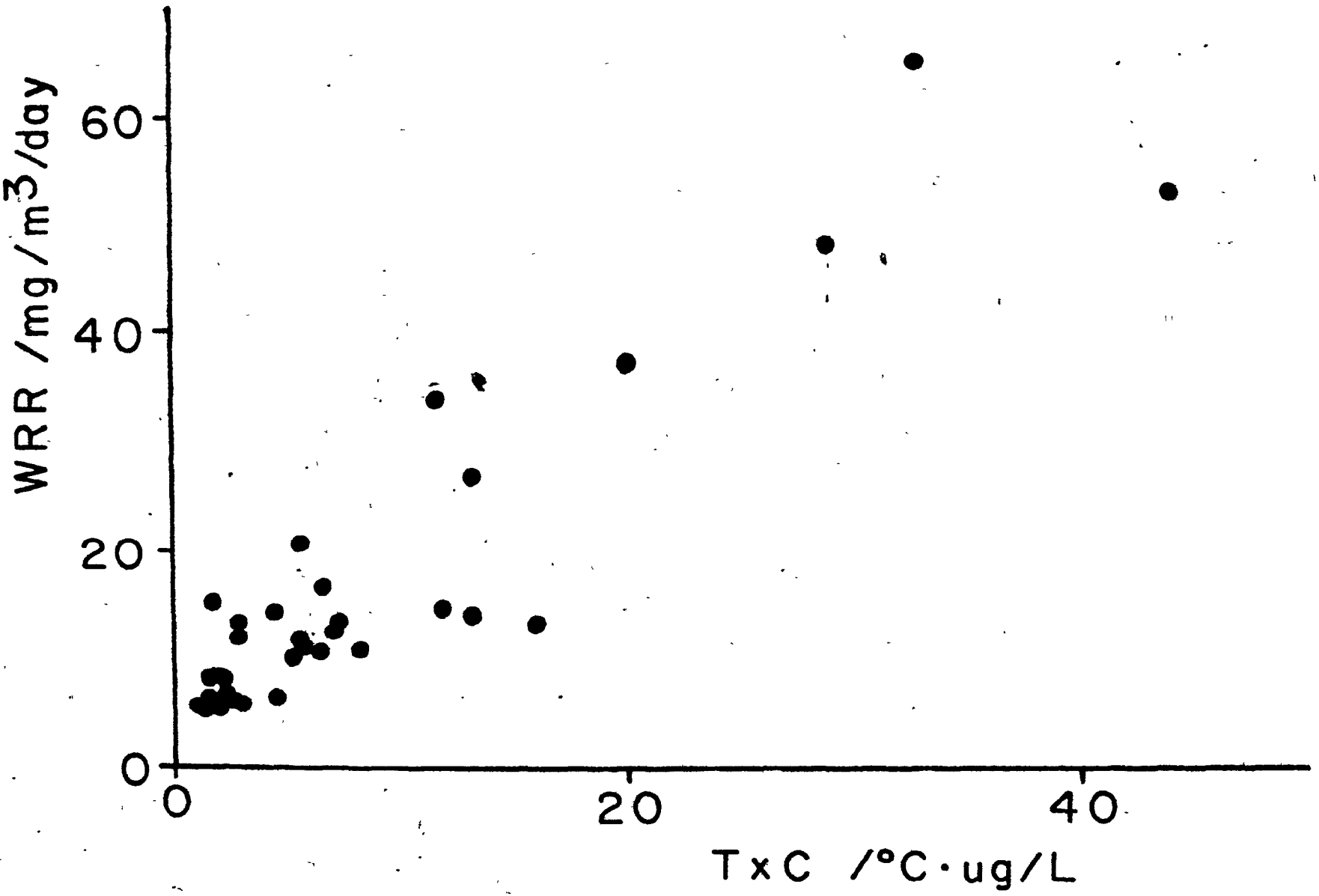

50
25
0
WRR / NR %
100
1000
Rp /mg/m²/yr

Fig. 7. Correlation between measured WRR values and the product of the measured concentration of chlorophyll a (C) multipled by the average summer temperature (T) of the stratum.


WRR /mg/m3/day
60
40
20
0
0
20
40
TxC /°C·ug/L

CHAPTER TWELVE

A SIMPLE METHOD TO PREDICT CHANGES IN HYPOLIMNETIC OXYGEN CONCENTRATION

Introduction

When organic matter produced in the surface waters of a lake, sediments into the hypolimnion, it may be either permanently buried in the sediments, or decomposed in the water column or sediments. In most lakes aerobic decomposition of the sedimenting organic matter consumes significant amounts of oxygen within the hypolimnion. As a result, the concentration of oxygen in the hypolimnion decreases throughout the period of thermal stratification. Because hypolimnetic oxygen depletion is accelerated by nutrient enrichment (Edmondson 1962, 1966; Bazin and Saunders 1971; Jones and Bachman 1974; Dillon et al 1978; Hamm 1978; Freeman and Canale 1979) several studies have attempted to develop models that can predict the rate that oxygen is consumed within the hypolimnion (Lasenby 1975; Cornett and Rigler 1979; Walker 1979; Charlton 1980). To date all of these papers have focused upon methods of predicting the areal hypolimnetic oxygen deficit (AHOD). The attention this method has received, resulted principally from two studies. First the calculation of the rate of oxygen depletion per square meter of hypolimnetic sediment area was originally believed to eliminate the influence of lake morphometry upon the comparison of AHOD values between different lakes (Thienemann 1926, 1928; Strom 1931; Hutchinson 1938). Secondly, Hutchinson (1938) published results documenting a very tight correlation between the AHOD values and estimates of seston concentrations in the trophogenic zones of 4 lakes. The first assumption was recently shown to be incorrect (e.g. Cornett and Rigler 1980; Charlton 1980), and

Hutchinson's results have not been reproduced by several subsequent studies (Riley 1939; Deevey, 1940; Lasenby 1975). Therefore the expression of a rate of hypolimnetic oxygen depletion as an AHOD value does not appear to have any advantages over the conceptually simpler method of calculating the change in oxygen concentration per unit volume ($mg/m^3/day$). In fact the AHOD method has several disadvantages. First, the magnitude of the calculated AHOD value depends upon the depth chosen as the upper boundary of the hypolimnion (Lasenby 1975). Unfortunately there is no single definition accepted by all limnologists. Secondly the AHOD is a ratio created when investigators divide the rate at which the mass of oxygen in the hypolimnion is depleted (mg/day) by the surface area (m^2) of the plane that delimits the upper boundary of the hypolimnion. The area term can also appear as part of the independent variable if the mean depth of the hypolimnion is included as a regressor variable. Under some circumstances this may bias the results of the regression (Atchley et al 1976). The most serious problem with the AHOD models is that the AHOD values cannot be predicted with a high degree of accuracy (Cornett and Rigler 1983). As a result, predicted AHODs cannot be used as the first step in a model that will accurately predict changes in oxygen concentrations in the hypolimnion. In addition an AHOD value cannot be related directly to the change in oxygen concentration in a depth stratum of the hypolimnion because it is a volume weighted rate of oxygen depletion. An alternative and more direct approach is needed.

The objective of this paper is to present and test a simple empirical model that can directly predict changes in hypolimnetic oxygen concentrations in $mg/m^3/day$ in each stratum of the hypolimnion. The fulfillment of this objective can eliminate many of the disadvantages of the AHOD technique.

We are grateful to J. Lardner, E. Ryan and L. Hurtubise for their assistance to prepare the manuscript. H. L'Hereux, B. Isings, S. Cameron and O. Choulik assisted with the field observations.

Methods

Measurements of hypolimnetic temperature and oxygen concentrations, total phosphorus concentrations in the trophogenic zone, the annual hydrologic residence time and lake morphometry were collected from studies of 29 temperate lakes reported in the literature. A listing of the data is available (Cornett 1982, Appendix 7). In every lake where sufficient measurements were available, data from 5 separate hypolimnetic strata were studied. In each stratum, the volumetric rate of oxygen consumption during thermal stratification (VOD $mg/m^3/day$) was calculated by regressing the measured O_2 concentrations (mg/m^3) against the Julian day the samples were collected. Only oxygen concentrations greater than 0.5 mg/L were included in the rate calculation. The average temperature

in each stratum was calculated from individual measurements of temperature made over the same period of time as the VOD calculation. Whenever the original measurements of phsoporus concentration were published, the average concentration of phosphorus in the trophogenic zone also was calculated over the period of stratification. In some lakes the average summer value could not be calculated. Therefore the average annual concentration was used instead. The fraction of the phosphorus loaded to the lake, retained by the sediments and calculated using an empirical relationship between phosphorus retention and the annual areal water load discharged from the lake (Ostrofsky 1978). Then the measured phosphorus concentration in the surface waters was used with the mass balance model tested by Dillon and Rigler (1974) to estimate the areal mass of phosphorus sedimented from the water column each year (Cornett and Rigler 1979).

The earliest studies of Birge and Juday (1911) and Thienemann (1926, 1928) and more recent studies (Lund et al 1963; Lasenby 1975; Cornett and Rigler 1980) all support the hypothesis that the mass of oxygen consumed in different strata of the hypolimnion is not a constant. The morphometry of the hypolimnion influences the rate of oxygen consumption within the hypolimnion. The simplest method of parameterizing this influence is to assume that the sediments and water both exert a demand for oxygen upon the reservoir of oxygen in a stratum. If the rates of respiration in the water and at the sediment surface are both approximately the same in different strata, then

the observed rate of oxygen consumption will be highest in strata with the lowest ratio of water volume to sediment area. Each stratum was arbitrarily defined to be 1 m thick. Then the volume of the stratum was calculated (Hutchinson 1957). The area of sediments in contact with the stratum was estimated as the difference between the area within the contour at the depth of the upper boundary of the stratum, and the area within the lower boundary of the stratum. Two methods of calculating the ratio of stratum volume to sediment area were investigated. The areas were calculated either by linearly interpolating between depths at which areas were measured or the interpolations were done using a cubic spline polynomial fit to the morphometry data (Ahlberg et al 1967). The difference between the methods (less than 5%) was much less than the uncertainty in the original morphometry.

The regression model developed using the literature data (see Results) was tested using measurements of the same variables collected in a detailed field study of oxygen depletion in 12 lakes located in the eastern townships of Quebec, Canada (approx. Lat. 45016'N Long. 7209'W). Details of the sampling and analytical procedures are presented by Cornett and Rigler (1983). The same data are used in this analysis.

Results and Discussion

Estimates of rates of oxygen depletion were calculated in 124 separate strata of 29 lakes using published oxygen concentrations or oxygen isopleths (Table 1). The data were examined in a preliminary analysis by constructing scatter grams of the VOD values plotted separately against each of the three main variables. The plot of V/SA against VOD suggested that the relationship between the two variables was not linear (Fig. 1). Estimates of V/SA were transformed to a logarithmic scale. This transformation was used in all subsequent analyses. Then the VOD estimates were regressed on Ln(V/SA), Rp, T and all of the first order and second order interractions between these three independent variables (Table 2). From that analysis, individual terms were deleted in a stepwise manner, beginning with the term with the lowest partial F value. However several terms were not orthogonal to the respective interraction terms (Table 2). When two variables had similar partial F values and displayed a high degree of collinearity (Gunst and Mason 1979), two regressions were analysed. One of the variables was deleted from each regression. Then the variable of the pair with the lowest partial F value was deleted. Terms were deleted until the model wtih the lowest residual sum of squares was determined. The regression model that best described the VOD values was (Table 3)

$$VOD = -6.6 + .0081\ T*Rp + 11.07\ T - 2.32\ T*Ln(V/SA). \qquad (1)$$

This relationship explained 83% of the variance in VOD values in the lakes investigated (Fig. 2). To check the adequacy of this regression, the residuals (observed - predicted VOD values) were examined for trends and patterns (Draper and Smith 1966). The results of equation (1) are consistent with the analysis of Charlton (1979, 1980) who argued that rates of oxygen depletion in the hypolimnion are influenced by the multiplicative effects of temperature, morphometry and the input of organic matter. However part of the significance of the interraction terms may be attributable to correlations between different variables (Table 4). Many lakes with high phosphorus retention also have a warm hypolimnion.

The utility of this regression was tested on a completely independent set of data collected from 12 lakes studied during the summers of 1978, 1979, and 1980. The lakes were chosen to cover the broadest possible range of VOD values, phosphorus retentions, temperatures and morphometry (Table 5). Because of the diversity of lake types chosen, this data set provides a good independent test of the regression model developed earlier. The predictions made using equation (1) agree very well with the rates of oxygen depletion measured in 260 strata (Fig. 3). The average absolute difference between the predicted and observed values was 0.017 mg/L/day. The residuals tended to be larger at higher rates of oxygen consumption. This may reflect natural variability of lakes in the response to higher nutrient loadings. However the larger residuals may also

reflect the limited amount of data available at rates of oxygen depletion in excess of 100 $mg/m^3/day$. The field work conducted in this study, and previous studies has focused more intensely upon oligotrophic systems.

The regression model predicts the vertical variation in rates of oxygen consumption very well. The central basin of Lake Memphremagog and the hypolimnion of Lake Massawippi both develop negative heterograde oxygen curves during the period of thermal stratification. The model correctly predicts that the rate of oxygen depletion in the strata at the top of the hypolimnion will be greater than the rates measured deeper in the water column (Fig. 4). In many other lakes VOD values are higher near the maximum depth of the lake (Zmax), than values observed near the thermocline. Equation (1) was also tested in lakes with this characteristic. The model correctly predicts higher rates of oxygen depletion near Zmax in Lake Stukely (Fig. 5) and in Lake Magog (Fig. 6). In these test lakes, the measured VOD values ranged from 9.5 to 254 $mg/m^3/day$. In most cases the predicted rates fall within the 95% confidence intervals of the measured VOD values, or the predictions fall between the rates measured in successive years. There are exceptions to this conclusion. The deviation of the predicted values from measured values may reflect imperfections in the equation, or in the test data. The predictions are sensitive to errors in the measured morphometry of the stratum and these may be quite large.

To provide the best equation for future studies, the literature data were pooled with the VOD rates measured at 5 depths in each of the lakes investigated in this study. The least squares regression coefficients with the minimum residual variance calculated using a variance-weighted regression (Table 6) (Draper and Smith 1966) are

$$VOD = 9.87 + .0145\ T*Rp + 7.82\ T - 2.50T*Ln(V/SA) \qquad (2)$$

The regression explains 91% of the variance in the measured VOD values. The high R^2 value, the test of the model just presented, and the small standard error of estimate (8.7 $mg/m^3/day$) are evidence that this equation can predict VOD values with a high degree of accuracy.

Equation (2) can also be used to predict how hypolimnetic oxygen concentrations will be altered by changes in the amount of nutrients (phosphorus) added to the lake from anthropogenic sources. Because the stratum temperature variable interacts with the phosphorus retention term, the regression equation predicts that increased nutrient inputs will have a larger effect upon rates of hypolimnetic oxygen depletion in a lake with a warm hypolimnion than in a lake with a cold hypolimnion (Fig. 7). The model also predicts that any increases in VOD values will be most pronounced in lakes with lower areal water loads (Fig. 7). However these predictions make very important assumptions. First they assume that the fraction of the phosphorus retained in the sediments does not depend upon the amount

of phosphorus loaded to the lake (Rigler, unpubished). Then the predictions assume that the response of a single lake to increased nutrient loading will be the same as the variation between lakes that receive different phosphorus loads. The model also assumes that the response to a change in nutrient input will be instantaneous. At the present time these assumptions remain untested. In future studies, they must be tested very carefully. Equation (2) also predicts that rates of oxygen depletion are sensitive to changes in hypolimnetic temperature. Temperatures within the hypolimnion can vary between years (Stewart 1975; Charlton 1980). Therefore experimental designs to test this model must include unfertilized control lakes.

This model of hypolimnetic oxygen depletion does not use the AHOD concept (Strom 1931; Hutchinson 1938, 1957). Further tests of our model are required and encouraged. Hopefully testing of this model will occur sooner than the 50 year gap betwen the development and rigorous testing of the AHOD concept (Cornett and Rigler 1979, 1980; Charlton 1980).

VARIABLE	MEAN	MIN	MAX
VOD	54.	4.7	209
P	29	3.9	206
Rp	350	22.	1140
T	7.4	4.0	15.0
V:SA	40	0.3	254

Table 1. Summary of estimates of rates of oxygen depletion (VOD $mg/m^3/day$), trophogenic phosphorus concentration (P ug/L), estimated phosphorus retention (Rp $mg/m^2/yr$), stratum temperature (T°C), and the ratio of stratum volume to contiguous sediment area (V:SA m).

This table summarizes data for 131 strata from the same set of lakes that were studied in Chapter 8. The raw data are presented in the appendicies.

SOURCE	DF	SS
Model	7	196379.0***
RP	1	26.9NS
T	1	566.3NS
Ln(V/SA)	1	452.6NS
T*Ln(V/SA)	1	16.4NS
T*Rp	1	1118.1NS
Rp*Ln(V/SA)	1	77.9NS
Rp*T*ln(V/SA)	1	639.9NS
Residual	116	36120.7

Table 2. ANOVA table for complete regression containing all possible interraction terms between the three main variables. In this table and all subsequent tables asteri denote levels of significance at probability levels of 0.05 (*), 0.01 (**) and greater than 0.001 (***). None of the individual terms in the regression is significant because of a high degree of collinearity between many of the terms.

SOURCE	DF	ESTIMATE	SE
bo	1	6.5891	7.08764NS
T*Rp	1	0.0081	0.00086***
T	1	11.0718	1.15175***
T*Ln(V/SA)	1	-2.3229	0.1461***

Table 3. Summary of the parameter estimates and standard errors of estimate (SE) of the regression model with the lowest residual mean square.

	V/SA	Rp	T
VOD	-0,46***	0.52***	0.65***
V/SA		0.09NS	-0.05NS
Rp			0.05***

Table 4. Simple correlation coefficients between untransformed variables examined in the regression analysis (N=129).

VARIABLE	MEAN	MIN	MAX
VOD	59.5	6.6	224.9
P	9.0	3.9	59.2
Rp	234.5	25.0	1360.
T	7.0	4.0	12.0
V:SA	21.2	0.8	130.4

Table 5. Summary of the estimates of lake parameters measured in 12 lakes which were studied in order to test the literature model.

SOURCE	DF	ESTIMATE	SE	STB
bo	1	9.870	3.213**	
T	1	7.822	0.562****	0.32
T*Rp	1	0.0144	0.00052****	0.66
T*Ln(VS/A)	1	-2.499	0.0590****	0.89
Residual	257		8.766	

Table 6. Weighted least squares regression claculated by pooling data from published VOD values and the VOD values measured in this study. STB are the standardized b values (Snedecor and Cochran 1967).

Fig. 1. Rates of oxygen depletion in each stratum plotted against the ratio of the volume of the stratum:to the area of sediments contiguous to the stratum.

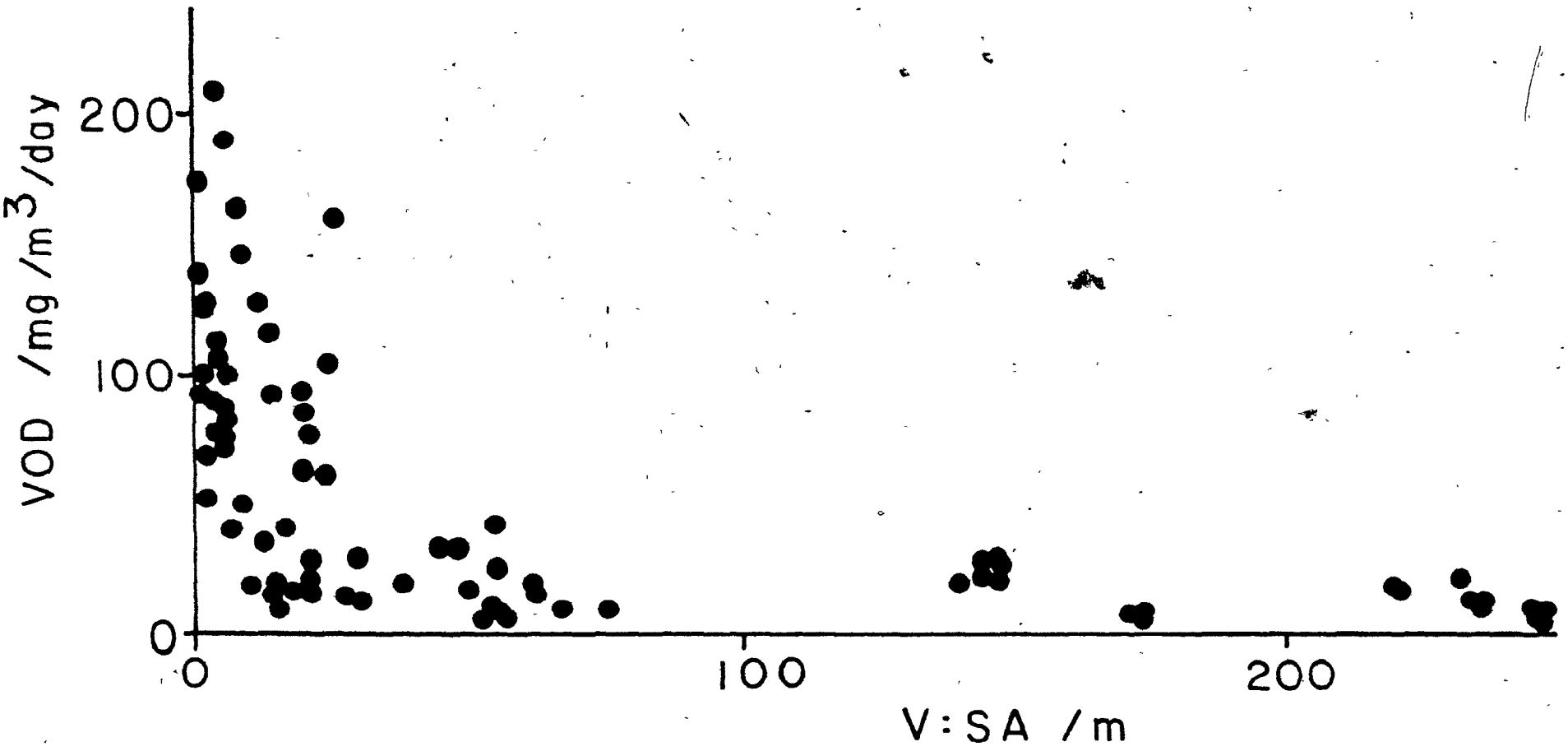

VOD /mg /m3 /day
200
100
0
0
100
200
V:SA /m

Fig. 2. Predicted VOD values calculated using (1) plotted against the measured values.

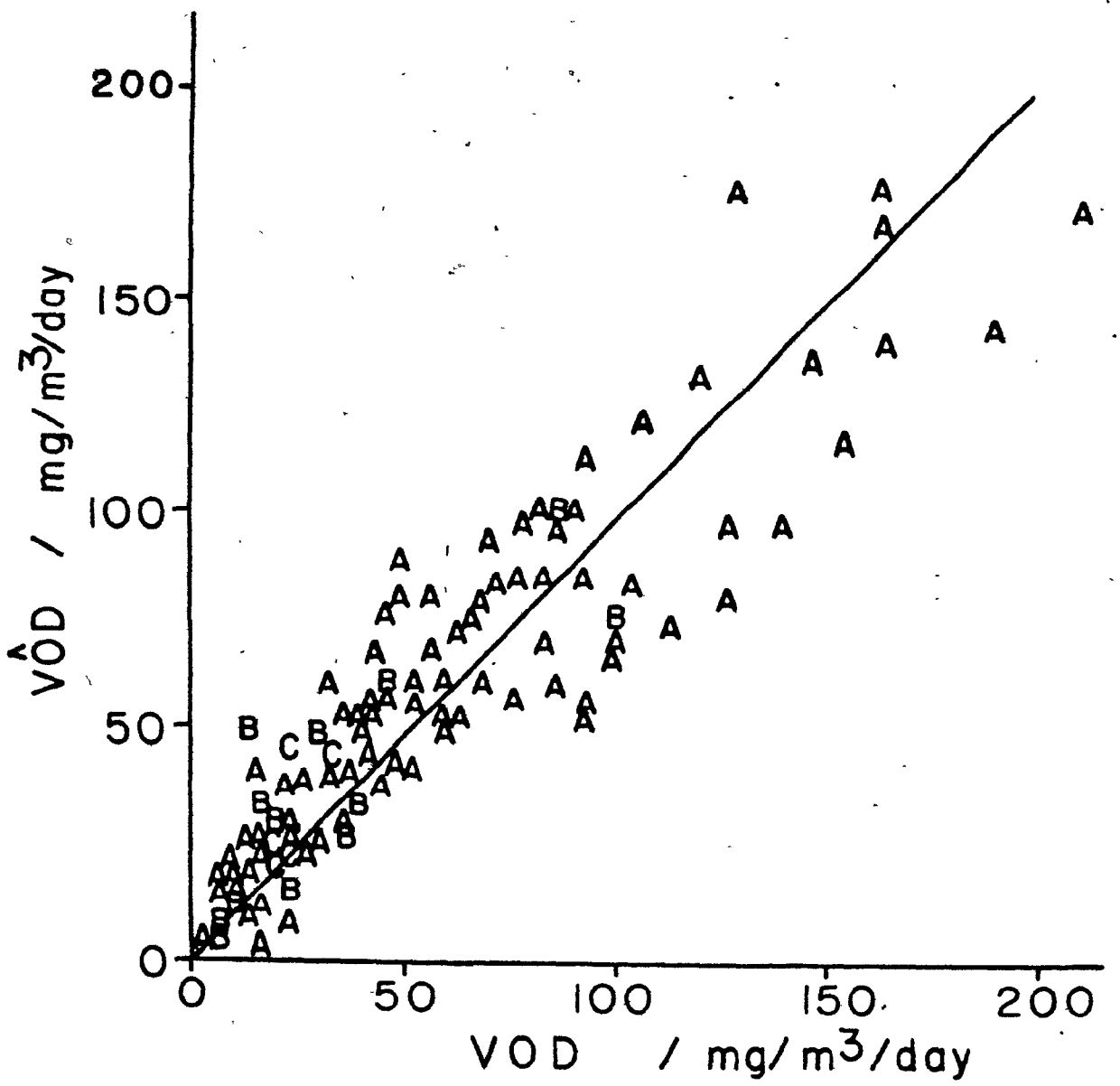
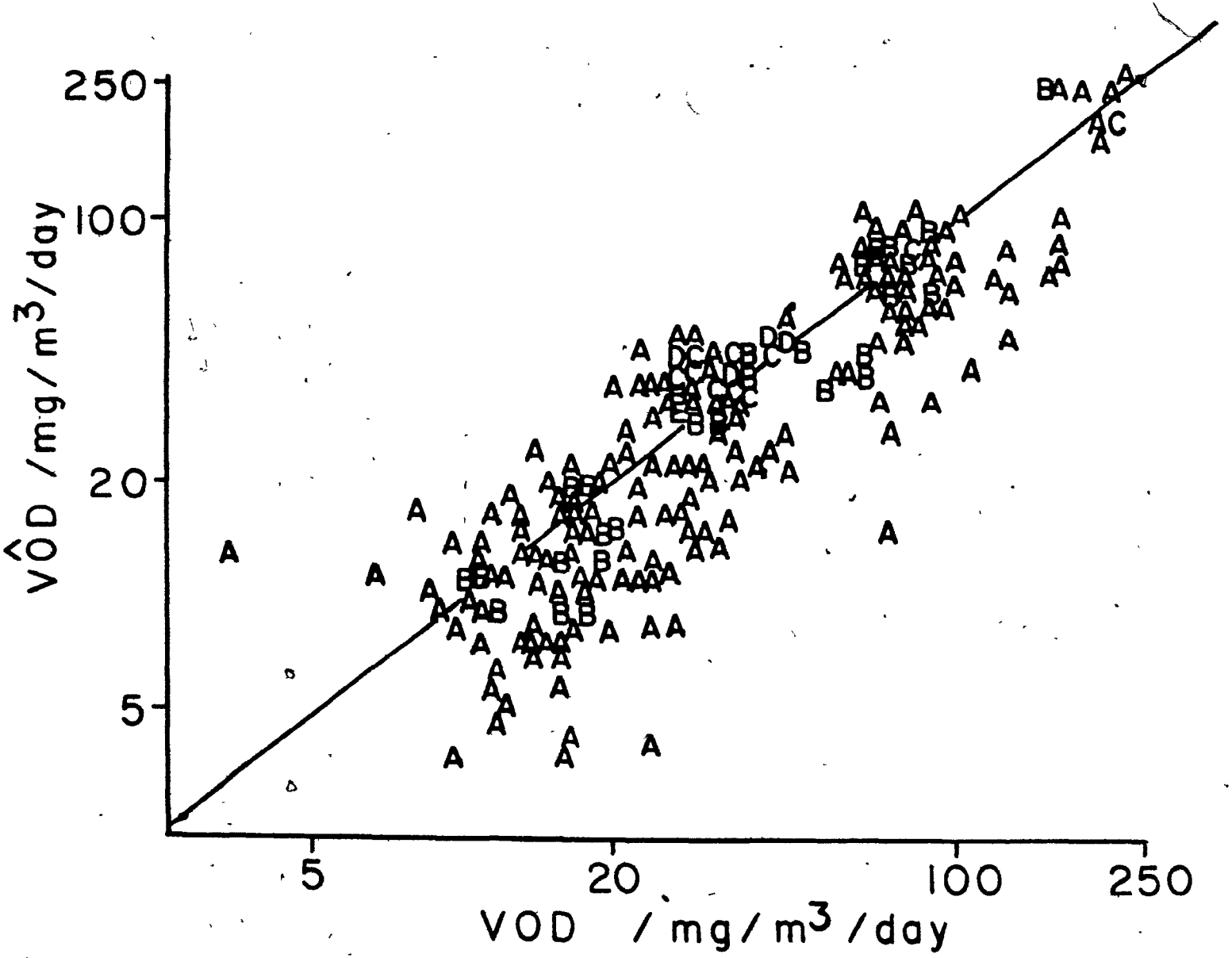

200
150
100
50
0
0
50
100
150
200
V̂OD / mg/m3/day
VOD / mg/m3/day

Fig. 3. Predicted VOD values calculated using (1), plotted against the VOD values measured on the group of 12 study lakes which were not included in the original regression analysis.


250
100
20
5
$\hat{VOD}$ /mg/m^3/day
5
20
100
250
VOD /mg/m^3/day

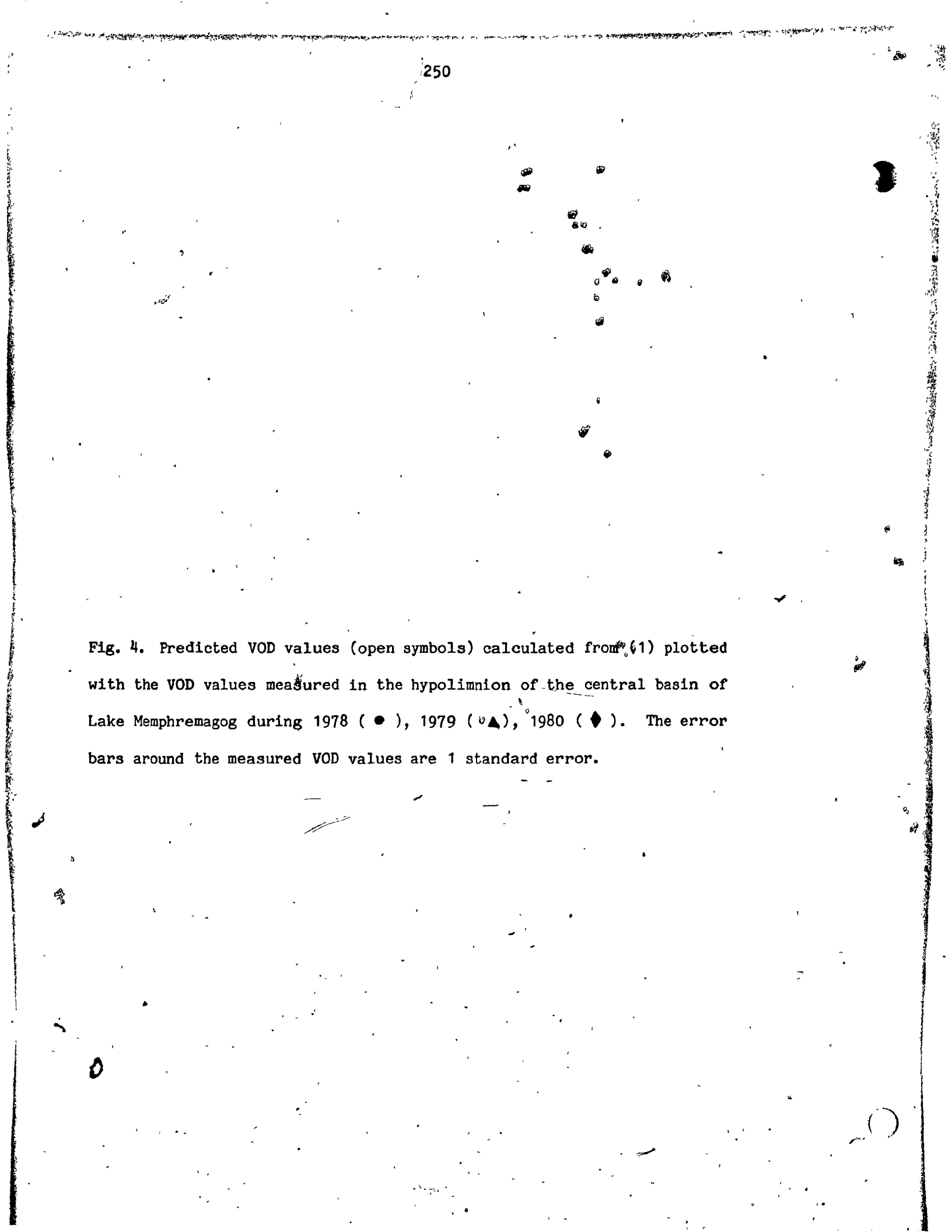


Fig. 4. Predicted VOD values (open symbols) calculated from (1) plotted with the VOD values measured in the hypolimnion of the central basin of Lake Memphremagog during 1978 (●), 1979 (▲), 1980 (◆). The error bars around the measured VOD values are 1 standard error.

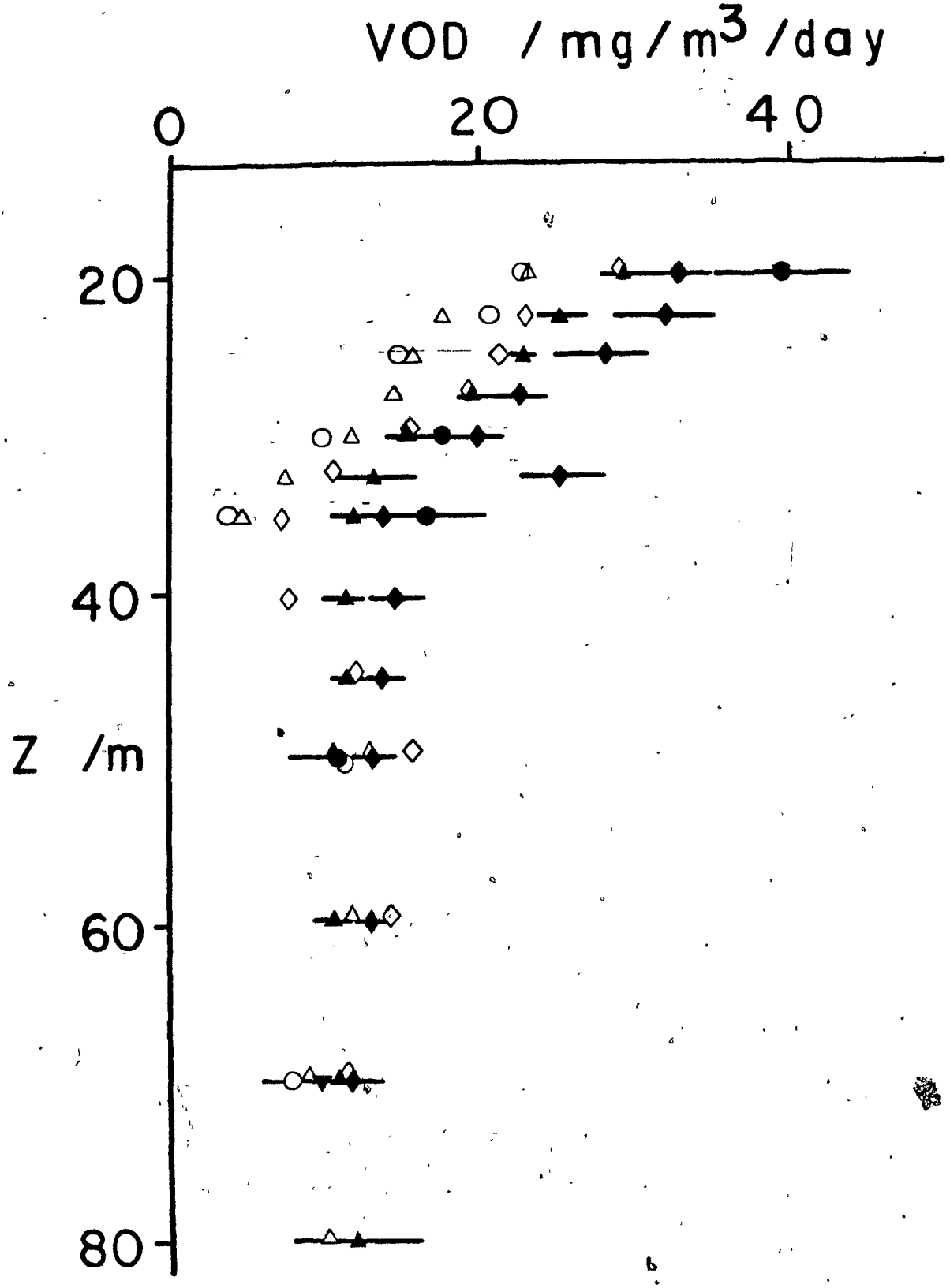

VOD / mg / m3 / day
0
20
40
20
40
60
80
Z /m

Fig. 5. Predited VOD values calculated from (1) plotted against VOD values measured in Lake Stukely. Symbols as in Fig. 4.

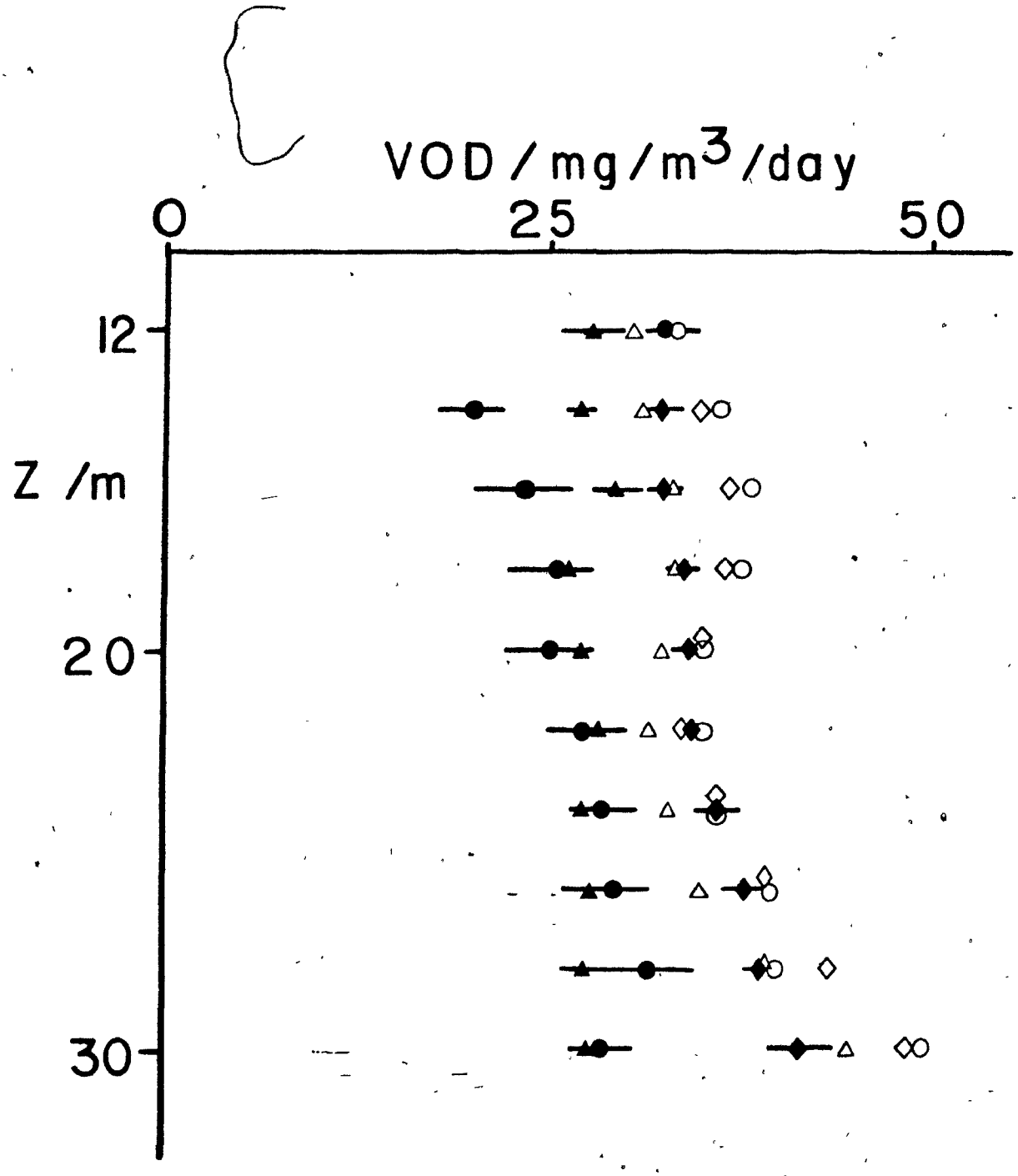

VOD / mg / m3 / day
0
2.5
5.0
12
Z /m
20
30

Fig. 6. Predicted VOD values calculated from (1) plotted against VODs measured in Lake Magog. The lake was not studied during 1978.

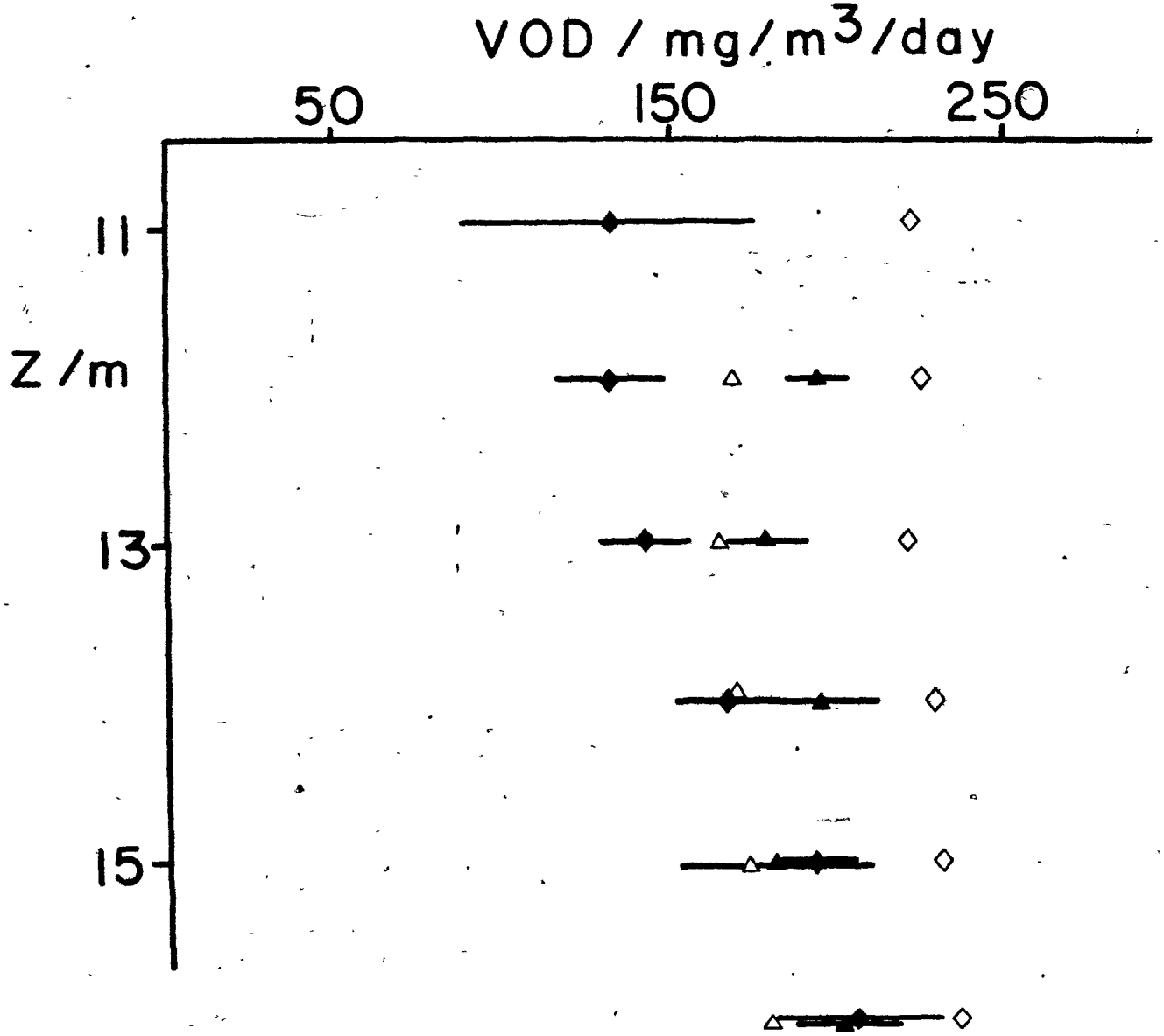
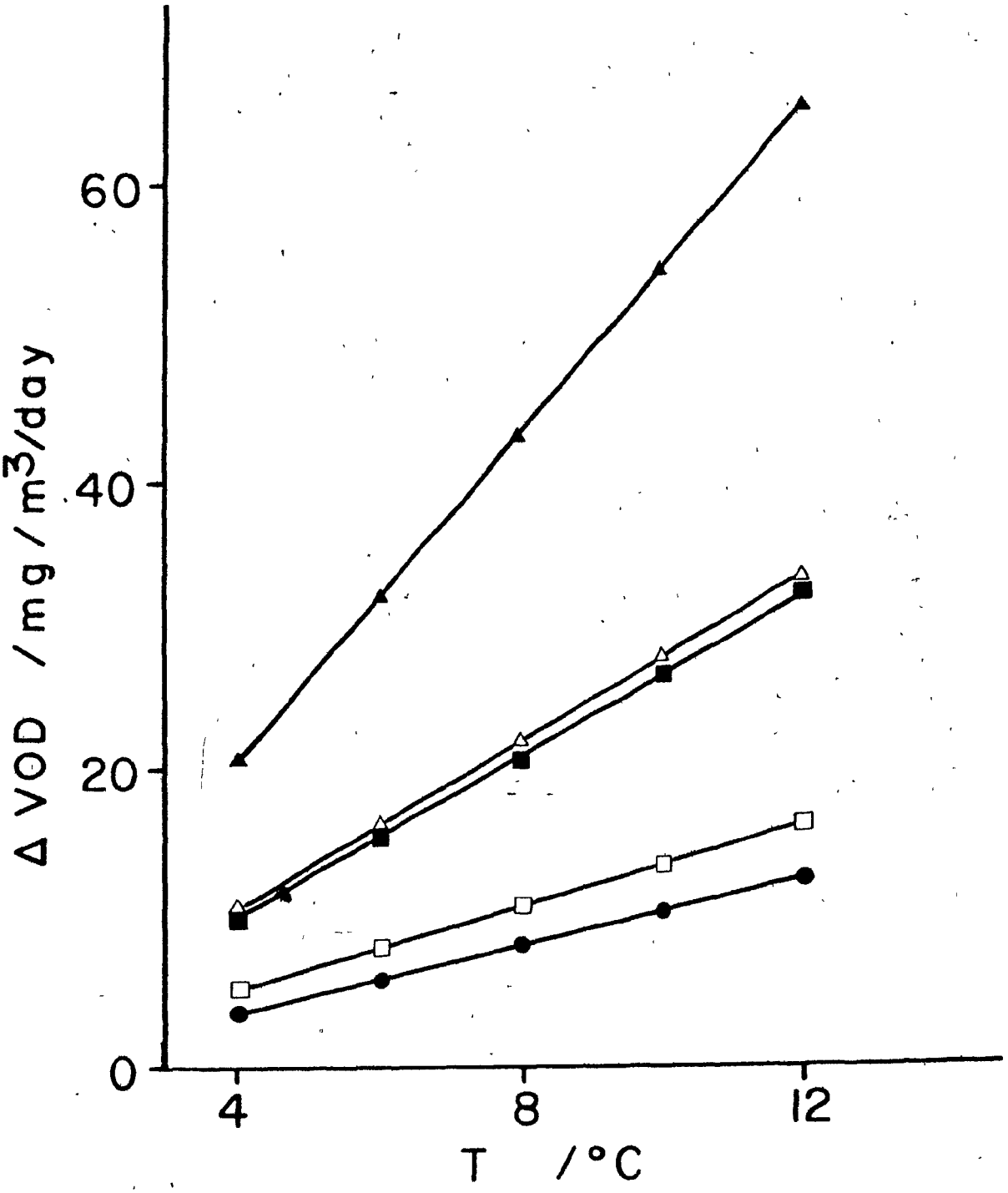

VOD / mg/m3/day
50
150
250
11
Z /m
13
15

Fig.7. Changes in the rate of oxygen depletion (ΔVOD) predicted from (2) when increasing amounts of anthropogenic phosphorus are loaded (L, mg $P/m^2/yr$) to lakes receiving two different water loads (qs) (● L=100, qs=2.5; ■ L=250, qs=2.5 ; □ L=250, qs=50; ▲ L=500, qs=2.5; △ L=500, qs=50).


60
40
20
0
Δ VOD /mg/m3/day
4
8
12
T /°C

CHAPTER THIRTEEN

CONCLUSIONS

CONCLUSIONS

The objective of this thesis was to develop and test a method of predicting the rate of oxygen depletion within the strata of the hypolimnion of lakes. This objective was accomplished by establishing a number of generalities about oxygen consumption in the hypolimnion.

Within the hypolimnion, oxygen concentrations decrease at a constant rate throughout the period of thermal stratification. The ambient concentration of oxygen does not influence the rate of oxygen consumption. Therefore neither respiration by the sediments nor respiration by the planktonic material within the water column is limited by the rate of oxygen supply.

The areal hypolimnetic oxygen deficit model (AHOD) developed by Thienemann (1928), Strom (1931) and Hutchinson (1938) was tested and found to be incorrect. The model predicts that AHOD values will not be influenced by the morphometry of the lake or the temperature of the hypolimnion. Measured rates of oxygen depletion were found to increase as the temperature of the hypolimnion increases. Higher AHOD values were also measured in lakes with a thicker hypolimnetic water column. Analysis of several multiple regressions suggests that the morphometry of the hypolimnion explains an amount of variation similar to that explained by the trophic status of the lake's surface waters.

The erroneous predictions of the AHOD model suggest that some of the assumptions made during the development of that method are incorrect. The assumption that no oxygen was physically transported into the hypolimnion by turbulent mixing was tested and found to be in error. The highest rates of transport were 15% of the observed AHOD values. More oxygen is transferred into the hypolimnion of shallow lakes than deep lakes. However

the quantities of oxygen transported are insufficient to explain all of the influence of lake morphometry upon the measured AHOD.

The morphometry of the hypolimnion exerts a stronger influence upon the amount of oxygen consumed within the hypolimnetic water column. The mass of oxygen respired by planktonic material increases from less than 20% of the total oxygen consumed in the hypolimnion of shallow oligotrophic lakes to greater than 60% in lakes with a very thick hypolimnion. The absolute rates of water column oxygen consumption are proportional to the concentration of particulate organic matter within the hypolimnion, and the ambient temperature of the stratum. Sediment respiration does not appear to be influenced by the morphometry of the hypolimnion.

Examination of the deficiencies in the AHOD model suggests an alternative conceptual model of oxygen depletion within the hypolimnion of lakes. Respiration within the water column is variable. It depends upon the input of organic matter and upon the ambient water temperature. Respiration by the sediments is also influenced by the temperature within the hypolimnion. However sediment respiration is not strongly influenced by the input of organic matter. Therefore the observed oxygen deficit (or the total amount of oxygen consummed within a stratum of the hypolimnion) will be proportional to the in situ temperature and to the input of organic matter. The rate that oxygen disappears from the water will be inversely proportional to the ratio of the volume of the stratum to the area of sediments that are horizontally contiguous to the stratum (V:SA). In the deepest strata of the hypolimnion, the measured change in oxygen concentration will be slightly lower than that expected from the total of sediment and water respiration because some oxygen is transferred between vertically contiguous strata.

Using this conceptual model, the statistical model which best describes the rate of oxygen depletion (VOD $mg/m^3/day$) is:

$$VOD = -6.6 + .0081T*Rp + 11.07T - 2.32T*Ln(V:SA)$$

where T is the average summer temperature of a stratum (C) and Rp is the estimated retention of phosphorus ($mg/m^2/yr$). The model was tested on an independent set of data collected from 12 lakes. The predictions agree very well with the measured rates of oxygen depletion. Further tests of this model in more eutrophic lakes and in lakes with changing surface water concentrations of nutrients will strengthen our confidence in this predictive equation.

I hope eventually to predict hypolimnetic oxygen concentrations (O_t), on any day after the onset of thermal stratification by

$$O_t = O_{to} - Ks*t \qquad (1)$$

where O_{to} is the oxygen concentration at the onset of stratification and O_t is the predicted oxygen concentration t days after the initial oxygen concentration was determined. Ks is the rate of oxygen consumption during the period of t days. To predict O_t without visiting the lake, it will be necessary to predict the date that stratification commences, the duration of thermal stratification, the oxygen concentration in the hypolimnion at the onset of thermal stratification, and the rate that oxygen is depleted from the hypolimnetic water column (Ks). This thesis has focused upon one parameter in the equation. The ability to predict the rate that oxygen concentrations change is the first step in the development of this model that will eventually be capable of predicting the influence of human activity in the environment upon ambient oxygen concentrations in the hypolimnion of lakes.

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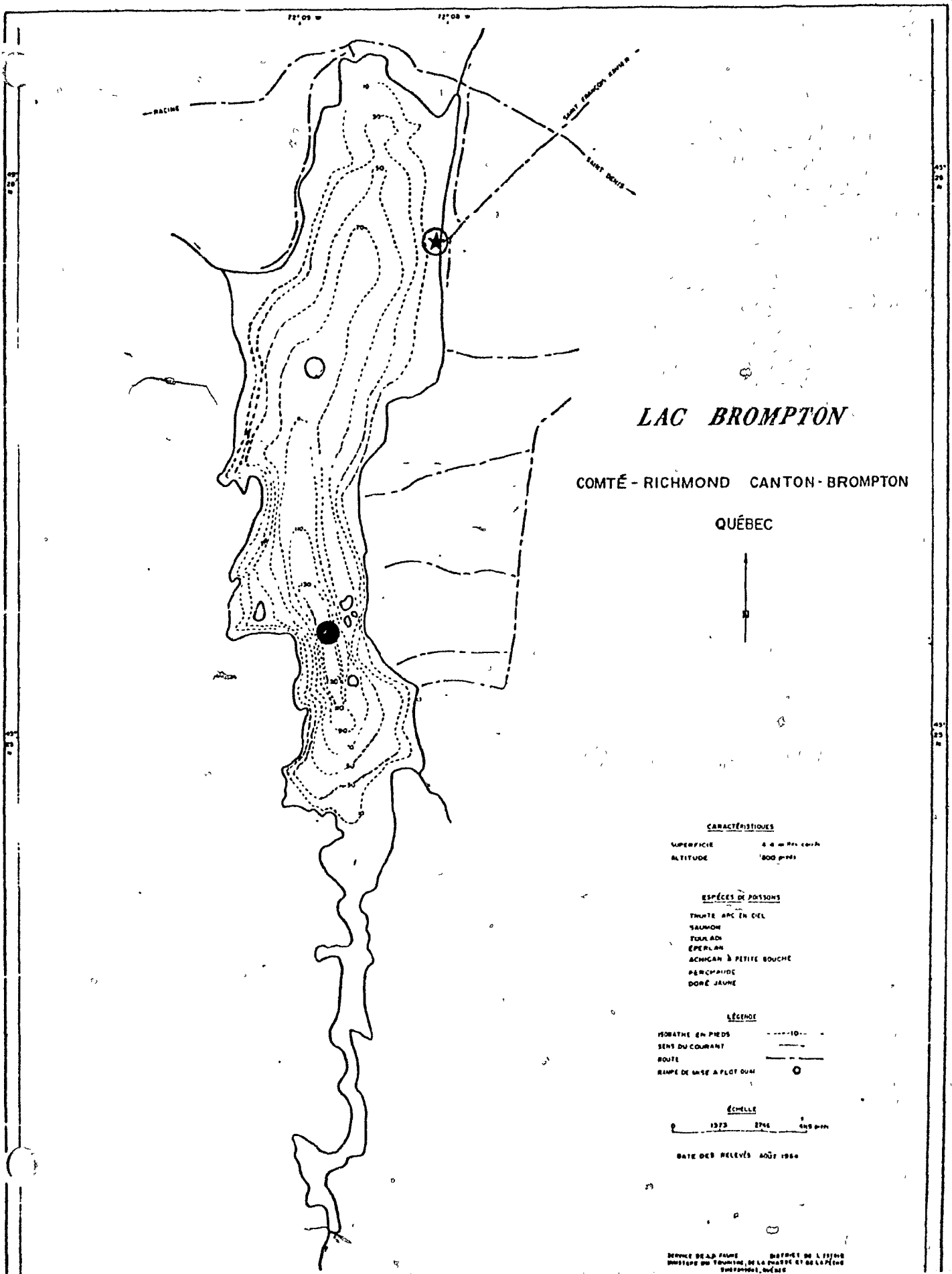
Appendix nine	Summary of the data collected from the literature used in the analysis of the AHOD model presented in Chapter six.	A 165

APPENDIX ONE

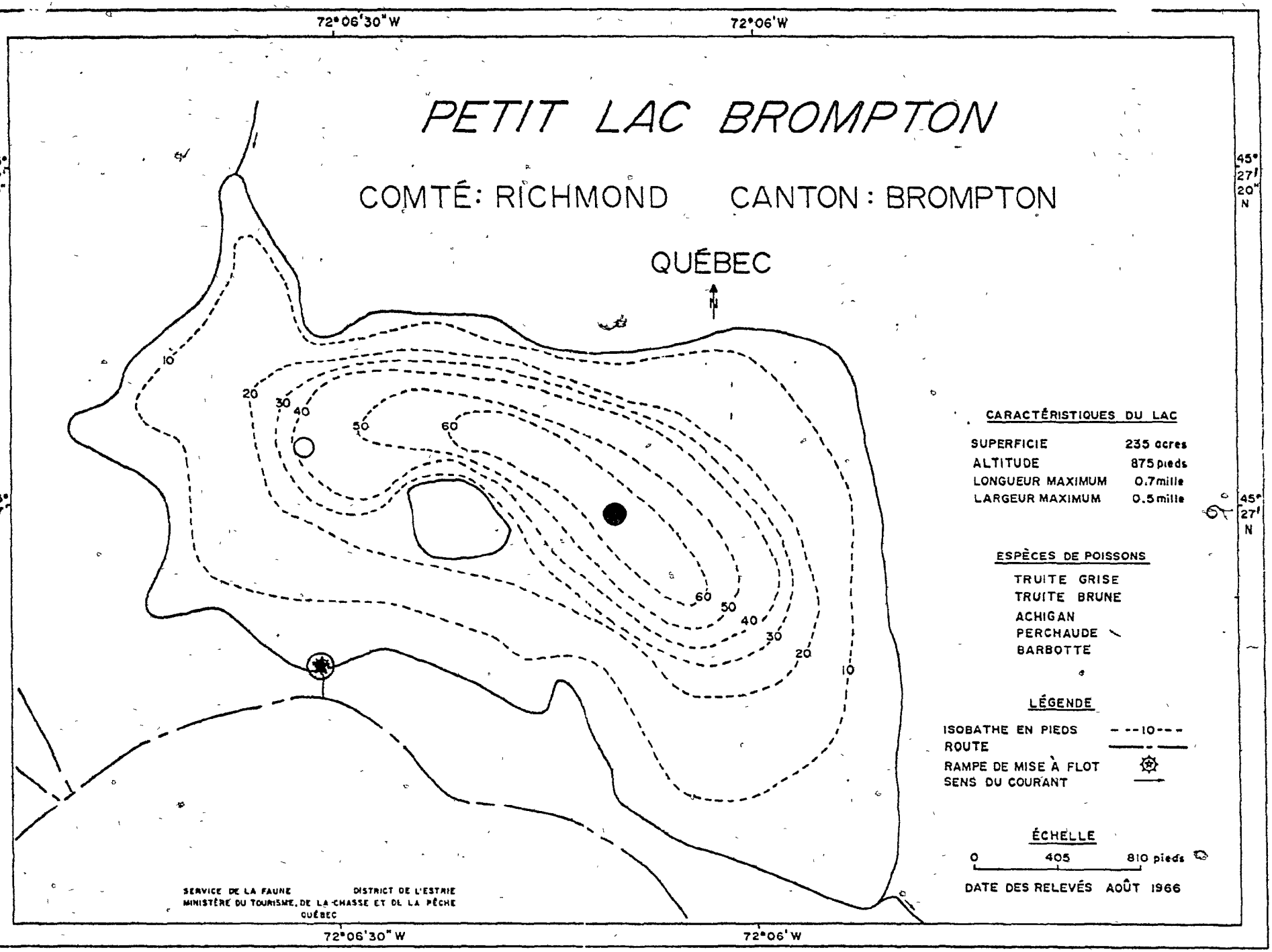
Sampling locations and morphometry of study lakes. The principal sampling site where oxygen and temperature profiles were measured is shown as a closed circle. The secondary site, where additional phosphorus and chlorophyll samples were collected, is indicated with an open circle. The access point to the lake is shown as a star.

Note: Lake Memphremagog was sampled from the McGill Univ. Field Station. The morphometry of each basin was obtained from the Government of Canada Hydrograph charts, not from the map which is shown.


72°09 W
72°08 W
RACINE
SAINT-FRANÇOIS-XAVIER
SAINT-DENIS
10
30
50
70
90
110
130
150
170
190
210
230
250
270
290
310
330
350
370
390
410
430
450
470
490
510
530
550
570
590
610
630
650
670
690
710
730
750
770
790

PETIT LAC BROMPTON

COMTÉ: RICHMOND CANTON: BROMPTON



CARACTÉRISTIQUES DU LAC

SUPERFICIE	235 acres
ALTITUDE	875 pieds
LONGUEUR MAXIMUM	0.7 mille
LARGEUR MAXIMUM	0.5 mille

ESPÈCES DE POISSONS

TRUITE GRISE
TRUITE BRUNE
ACHIGAN
PERCHAUDE
BARBOTTE

LÉGENDE

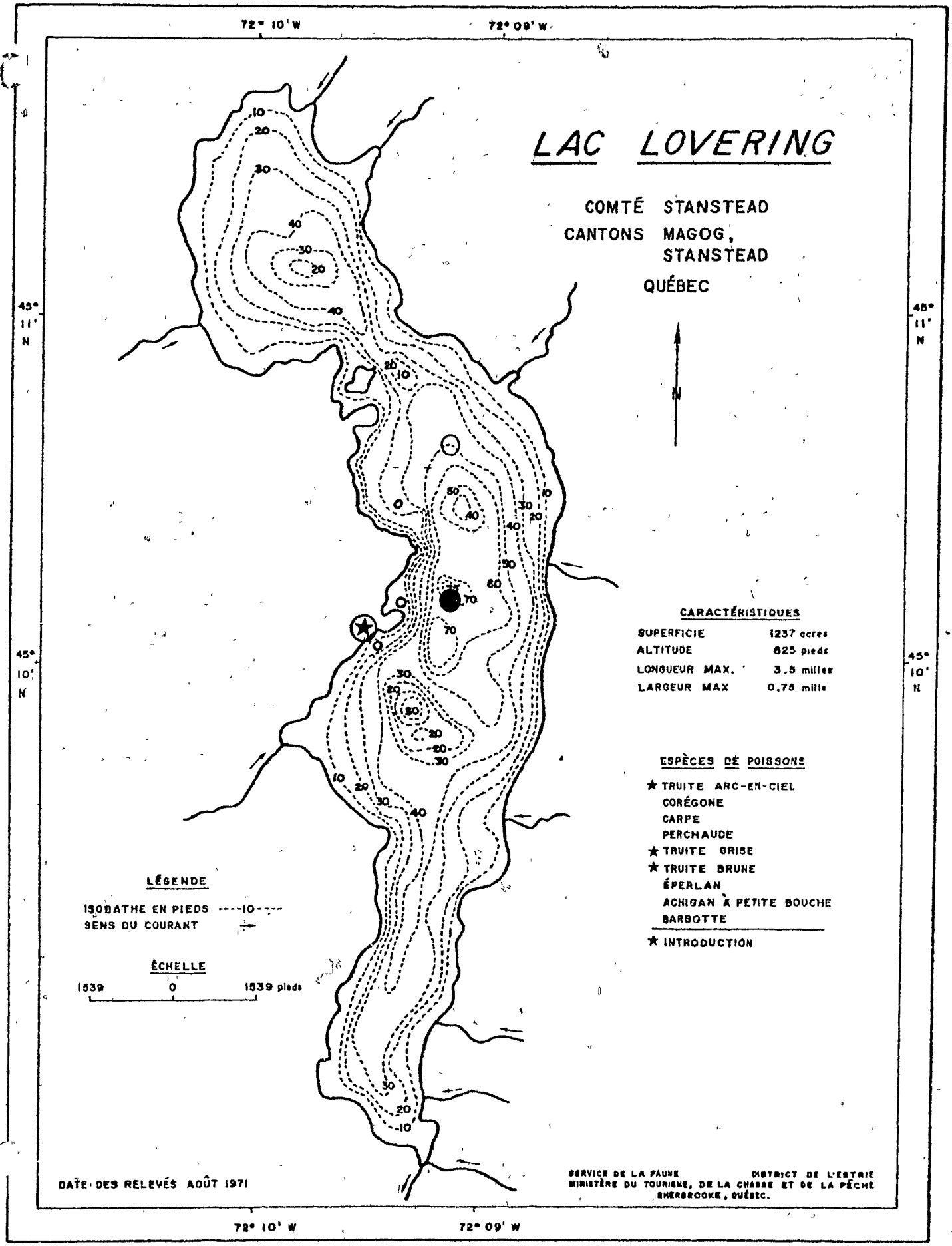
ISOBATHE EN PIEDS ---10---
ROUTE
RAMPE DE MISE À FLOT
SENS DU COURANT

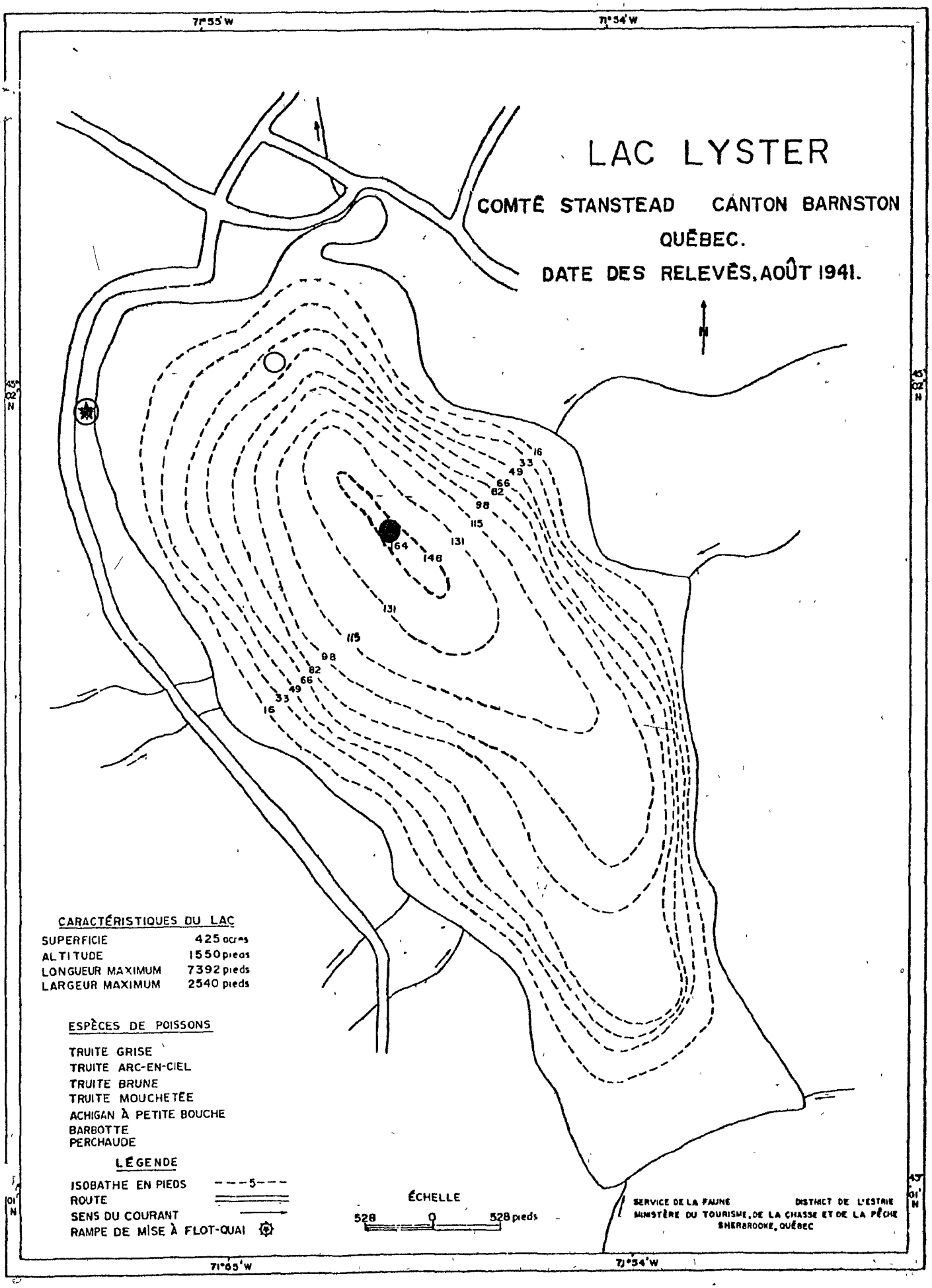
ÉCHELLE

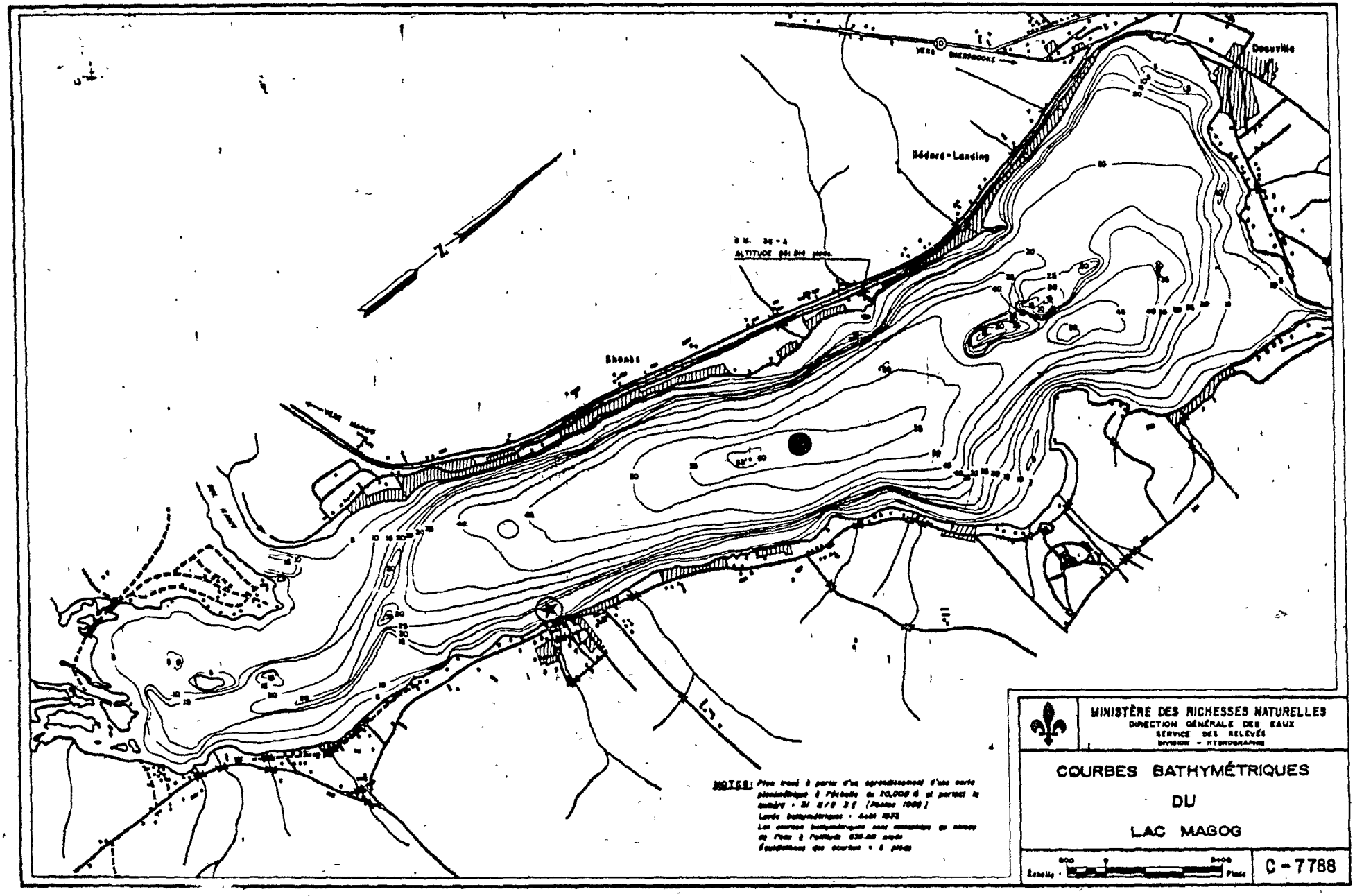
0 405 810 pieds

DATE DES RELEVÉS AOÛT 1966

SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE
MINISTÈRE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE
QUÉBEC


72° 10' W
72° 09' W
45° 11' N
45° 10' N
LAC LOVERING
COMTÉ STANSTEAD
CANTONS MAGOG, STANSTEAD
QUÉBEC
N
CARACTÉRISTIQUES
SUPERFICIE 1237 acres
ALTITUDE 625 pieds
LONGUEUR MAX. 3.5 milles
LARGEUR MAX 0.75 mille
ESPÈCES DE POISSONS
★ TRUITE ARC-EN-CIEL
CORÉGONE
CARPE
PERCHAUDE
★ TRUITE GRISE
★ TRUITE BRUNE
ÉPERLAN
ACHIGAN À PETITE BOUCHE
BARBOTTE
★ INTRODUCTION
LÉGENDE
ISOBATHE EN PIEDS ----10----
SENS DU COURANT
ÉCHELLE
1539 0 1539 pieds
DATE DES RELEVÉS AOÛT 1971
SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE
MINISTÈRE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE
SHERBROOKE, QUÉBEC.


71°55'W
71°54'W
45°02'N
45°01'N
LAC LYSTER
COMTÉ STANSTEAD CANTON BARNSTON
QUÉBEC.
DATE DES RELEVÉS, AOÛT 1941.
N
16
33
49
66
82
98
115
131
148
64
CARACTÉRISTIQUES DU LAC
SUPERFICIE 425 acres
ALTITUDE 1550 pieds
LONGUEUR MAXIMUM 7392 pieds
LARGEUR MAXIMUM 2540 pieds
ESPÈCES DE POISSONS
TRUITE GRISE
TRUITE ARC-EN-CIEL
TRUITE BRUNE
TRUITE MOUCHETÉE
ACHIGAN À PETITE BOUCHE
BARBOTTE
PERCHAUDE
LÉGENDE
ISOBATHE EN PIEDS ---5---
ROUTE
SENS DU COURANT
RAMPE DE MISE À FLOT-QUAI
ÉCHELLE
528 0 528 pieds
SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE
MINISTÈRE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE
SHERBROOKE, QUÉBEC
71°55'W
71°54'W


Vers Sherbrooke
Deauville
Bédard-Landing
Rhoads
Vers Magog
NOTES:
MINISTÈRE DES RICHESSES NATURELLES
DIRECTION GÉNÉRALE DES EAUX
SERVICE DES RELEVÉS
COURBES BATHYMÉTRIQUES
DU
LAC MAGOG
C-7788

LAC MASSAWIPPI

COMTÉ - STANSTEAD

CANTON - HATLEY

QUÉBEC

LÉGENDE

BATHYMÉTRIE EN PIEDS ---25---

ROUTE

RAMPE DE MISE À L'EAU

CARACTÉRISTIQUES

SUPERFICIE 1687 acres

ALTITUDE 880 pieds

ESPÈCES DE POISSONS

TRUITE ARC-EN-CIEL

TRUITE BRUNE

TRUITE GRISE

ÉPERLAN

BROCHET

CORÉGONE

LOTTE

ACHIGAN

PERCHAUDE

DORÉ

ÉCHELLE

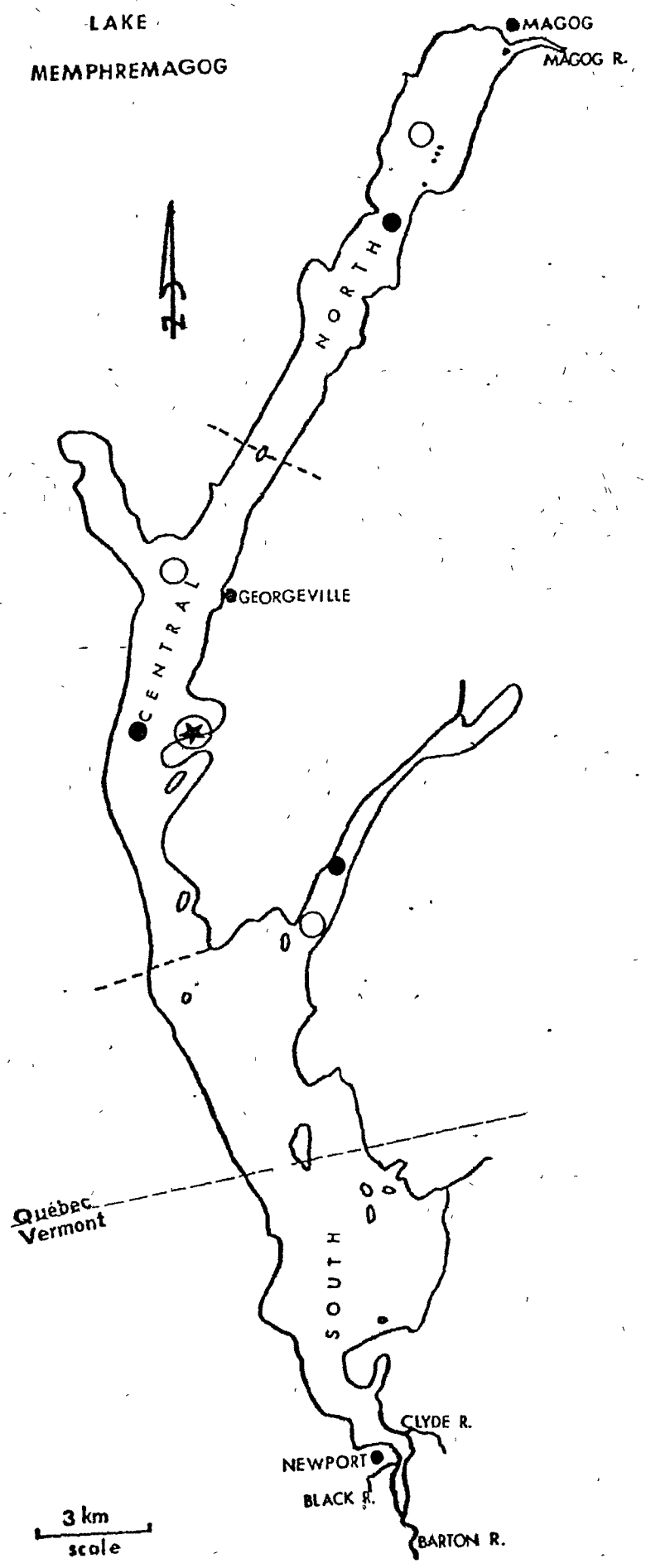
0 1 mille

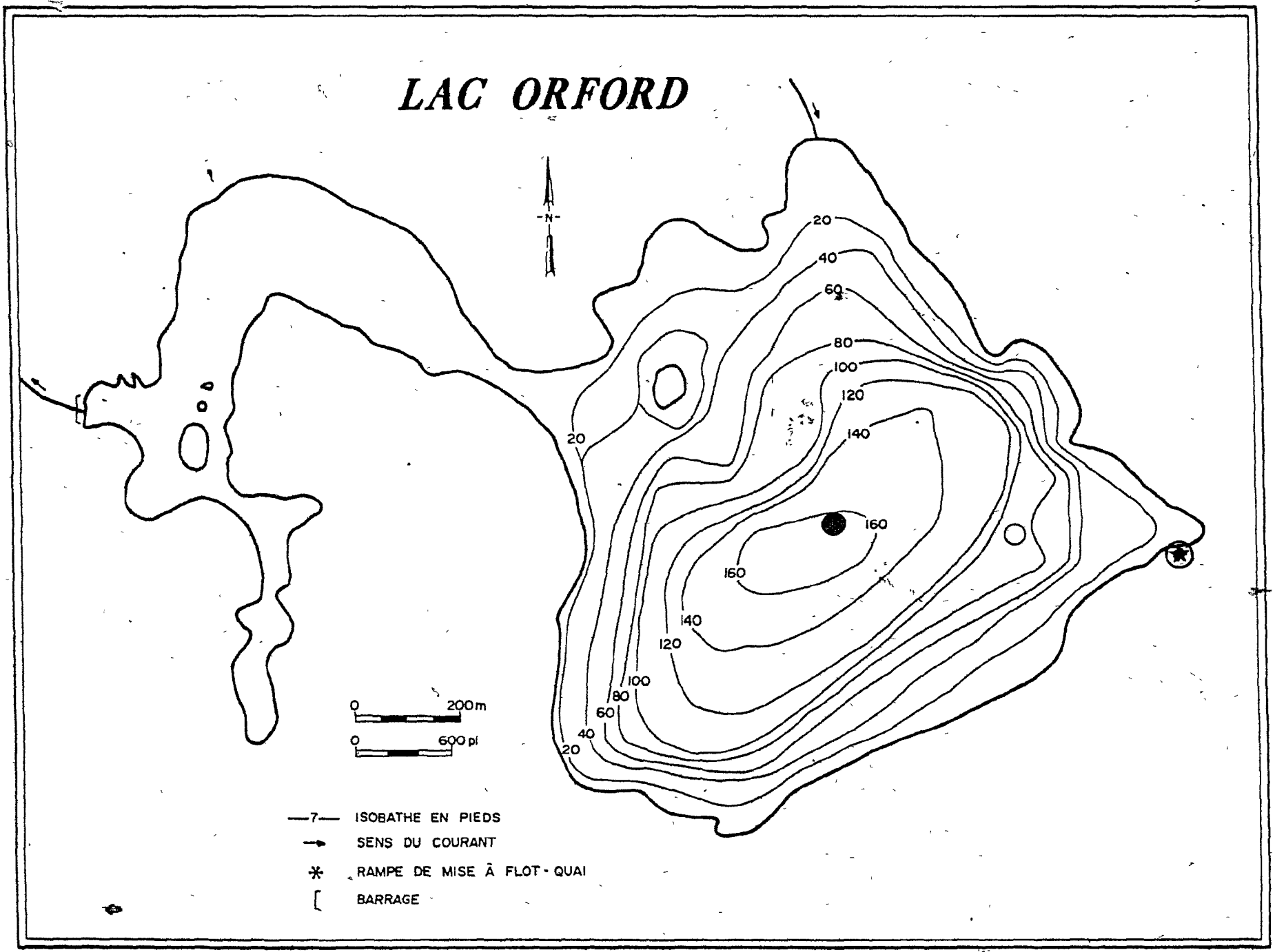
DATE DES RELEVÉS MAI 1990

SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE

DIRECTION GÉNÉRALE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE

GOUVERNEMENT DU QUÉBEC


LAKE
MEMPHREMAGOG
MAGOG
MAGOG R.
NORTH
CENTRAL
GEORGEVILLE
Québec
Vermont
SOUTH
CLYDE R.
NEWPORT
BLACK R.
BARTON R.
3 km
scale


LAC ORFORD
N
20
40
60
80
100
120
140
160
160
140
120
100
80
60
40
20
20
0 200m
0 600 pi
—7— ISOBATHE EN PIEDS
SENS DU COURANT
RAMPE DE MISE À FLOT - QUAI
BARRAGE

LAC STUKELEY

COMTÉ : SHEFFORD

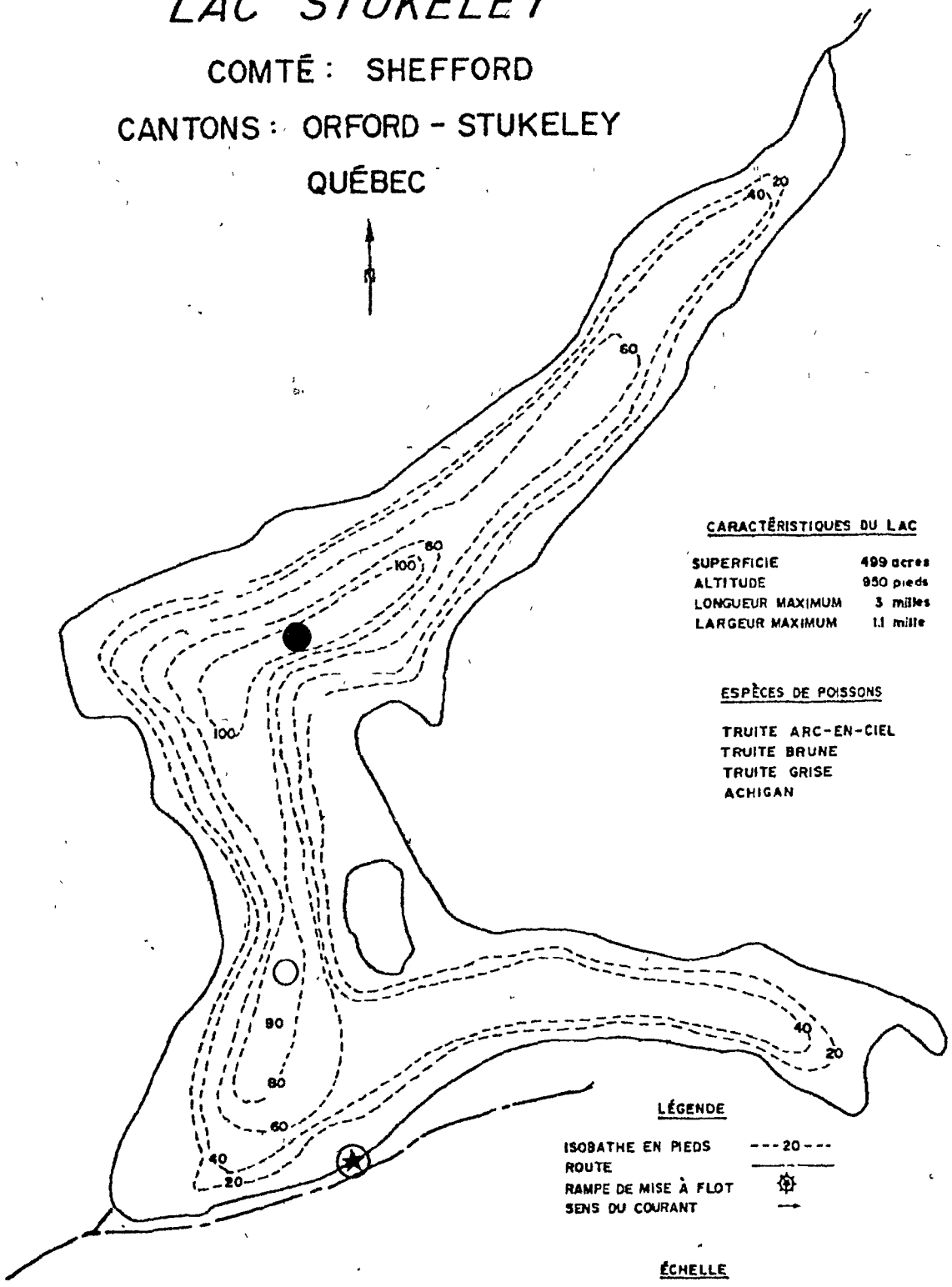
CANTONS : ORFORD - STUKELEY

QUÉBEC

72°17' W 72°16' W

45° 23' N

45° 22' N



CARACTÉRISTIQUES DU LAC

SUPERFICIE	499 acres
ALTITUDE	950 pieds
LONGUEUR MAXIMUM	3 milles
LARGEUR MAXIMUM	1.1 mille

ESPÈCES DE POISSONS

TRUITE ARC-EN-CIEL
TRUITE BRUNE
TRUITE GRISE
ACHIGAN

LÉGENDE

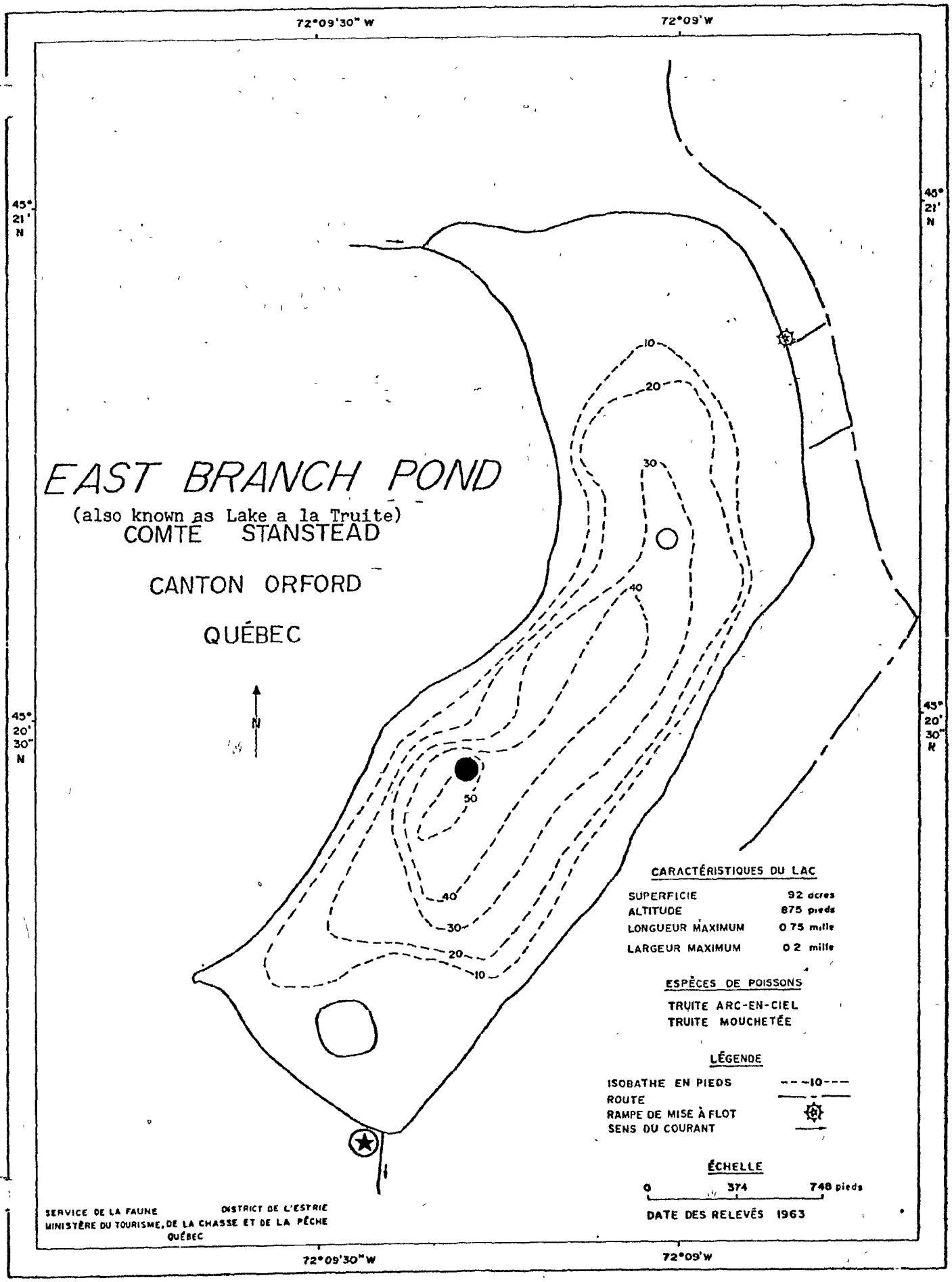
ISOBATHE EN PIEDS ---20---
ROUTE
RAMPE DE MISE À FLOT
SENS DU COURANT

ÉCHELLE

0 1056 2112 3168 pieds

DATE DES RELEVÉS JUILLET 1963

SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE
MINISTÈRE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE
QUÉBEC


72°09'30" W
72°09'W
45° 21' N
45° 20' 30" N
EAST BRANCH POND
(also known as Lake a la Truite)
COMTÉ STANSTEAD
CANTON ORFORD
QUÉBEC
N
10
20
30
40
50
CARACTÉRISTIQUES DU LAC
SUPERFICIE 92 acres
ALTITUDE 875 pieds
LONGUEUR MAXIMUM 0 75 mille
LARGEUR MAXIMUM 0 2 mille
ESPÈCES DE POISSONS
TRUITE ARC-EN-CIEL
TRUITE MOUCHETÉE
LÉGENDE
ISOBATHE EN PIEDS
ROUTE
RAMPE DE MISE À FLOT
SENS DU COURANT
ÉCHELLE
0 374 748 pieds
DATE DES RELEVÉS 1963
SERVICE DE LA FAUNE DISTRICT DE L'ESTRIE
MINISTÈRE DU TOURISME, DE LA CHASSE ET DE LA PÊCHE
QUÉBEC

APPENDIX TWO

Summary of morphometry interpolated from the morphometric maps presented in Appendix One and mean temperatures measured in each study lake. The columns (c) of output are:

1. Lake name.
2. Year of study.
3. Depth below the lake surface (m).
4. Lake area at stated depth (m2).
5. Volume below stated depth (m3).
6. Mean temperature (celcius) measured at depth over the period June 1 - August 31.
7. Mean temperature (celius) at depth integrated to remove any possible influence of the uneven sampling intervals.
8. Volume weighted average temperature (June 1 - August 31) below specified depth.

If insufficient data were collected to determine the integrated average temperature then columns 6 and 7 are omitted. Note: Due to a mistake in the program used to convert resistances to temperatures, the temperatures, for 1980 only, listed in this appendix are 0.16 C low. This error was corrected in all analyses by adding 0.16 to the stated temperature.

BROMPTON	1979	0.0	9950000.	0.1185D+09	21.23	20.32	13.82
BROMPTON	1979	1.00	8859396.	0.1091D+09	21.21	20.51	13.25
BROMPTON	1979	2.00	7843019.	0.1008D+09	21.14	20.71	12.64
BROMPTON	1979	3.00	6975096.	0.9340D+08	20.91	20.29	12.01
BROMPTON	1979	4.00	6327048.	0.8677D+08	20.81	19.68	11.40
BROMPTON	1979	5.00	5905801.	0.8067D+08	20.60	19.30	10.79
BROMPTON	1979	6.00	5653782.	0.7491D+08	20.00	18.06	10.18
BROMPTON	1979	7.00	5510612.	0.6933D+08	19.22	18.02	9.55
BROMPTON	1979	8.00	5415914.	0.6387D+08	18.44	17.30	8.85
BROMPTON	1979	9.00	5309311.	0.5850D+08	16.37	15.05	8.16
BROMPTON	1979	10.00	5138695.	0.5327D+08	13.43	11.74	7.66
BROMPTON	1979	11.00	4902536.	0.4825D+08	10.42	10.33	7.31
BROMPTON	1979	12.00	4618426.	0.4348D+08	8.99	7.83	7.12
BROMPTON	1979	13.00	4303989.	0.3902D+08	8.15	7.91	7.05
BROMPTON	1979	14.00	3976852.	0.3488D+08	7.72	7.61	6.96
BROMPTON	1979	15.00	3654640.	0.3106D+08	7.45	7.28	6.90
BROMPTON	1979	16.00	3353361.	0.2756D+08	7.29	7.22	6.86
BROMPTON	1979	17.00	3075402.	0.2435D+08	7.18	7.10	6.81
BROMPTON	1979	18.00	2816327.	0.2141D+08	7.05	7.05	6.78
BROMPTON	1979	19.00	2571650.	0.1871D+08	6.92	7.22	6.73
BROMPTON	1979	20.00	2336883.	0.1626D+08	6.84	6.97	6.67
BROMPTON	1979	22.00	1879588.	0.1204D+08	6.75	6.78	6.62
BROMPTON	1979	24.00	1437074.	0.8732D+07	6.70	6.69	6.57
BROMPTON	1979	26.00	1045867.	0.6261D+07	6.64	6.66	6.53
BROMPTON	1979	28.00	746016.	0.4487D+07	6.59	6.57	6.49
BROMPTON	1979	30.00	551198.	0.3206D+07	6.57	6.51	6.47
BROMPTON	1979	32.50	404735.	0.2026D+07	6.55	6.49	6.45
BROMPTON	1979	35.00	299852.	0.1149D+07	6.53	6.46	6.43
BROMPTON	1979	37.50	201890.	0.5219D+06	6.50	6.43	6.42

BROMPTON	1980	0.0	9950000.	0.1185D+09	19.82	18.69	13.95
BROMPTON	1980	1.00	8859396.	0.1091D+09	19.70	18.63	13.54
BROMPTON	1980	2.00	7843019.	0.1008D+09	19.55	18.53	13.13
BROMPTON	1980	3.00	6975096.	0.9340D+08	19.42	18.44	12.70
BROMPTON	1980	4.00	6327048.	0.8677D+08	19.36	18.38	12.27
BROMPTON	1980	5.00	5905801.	0.8067D+08	19.16	18.23	11.81
BROMPTON	1980	6.00	5653782.	0.7491D+08	18.97	17.98	11.32
BROMPTON	1980	7.00	5510612.	0.6933D+08	18.53	17.82	10.79
BROMPTON	1980	8.00	5415914.	0.6387D+08	17.51	17.28	10.21
BROMPTON	1980	9.00	5309311.	0.5850D+08	16.32	15.93	9.62
BROMPTON	1980	10.00	5138695.	0.5327D+08	13.58	13.44	9.12
BROMPTON	1980	11.00	4902536.	0.4825D+08	12.40	12.41	8.73
BROMPTON	1980	12.00	4618426.	0.4348D+08	11.14	11.50	8.38
BROMPTON	1980	13.00	4303989.	0.3902D+08	10.04	10.12	8.10
BROMPTON	1980	14.00	3976852.	0.3488D+08	9.26	9.31	7.91
BROMPTON	1980	15.00	3654640.	0.3106D+08	8.81	8.84	7.77
BROMPTON	1980	16.00	3353361.	0.2756D+08	8.58	8.64	7.65
BROMPTON	1980	17.00	3075402.	0.2435D+08	8.18	8.19	7.54
BROMPTON	1980	18.00	2816327.	0.2141D+08	8.02	8.01	7.47
BROMPTON	1980	19.00	2571650.	0.1871D+08	7.85	7.83	7.41
BROMPTON	1980	20.00	2336883.	0.1626D+08	7.73	7.72	7.35
BROMPTON	1980	22.00	1879588.	0.1204D+08	7.56	7.50	7.26
BROMPTON	1980	24.00	1437074.	0.8732D+07	7.40	7.37	7.19
BROMPTON	1980	26.00	1045867.	0.6261D+07	7.33	7.25	7.15
BROMPTON	1980	28.00	746016.	0.4487D+07	7.29	7.20	7.12
BROMPTON	1980	30.00	551198.	0.3206D+07	7.26	7.16	7.10
BROMPTON	1980	32.50	404735.	0.2026D+07	7.22	7.12	7.07
BROMPTON	1980	35.00	299852.	0.1149D+07	7.19	7.08	7.05
BROMPTON	1980	37.50	201890.	0.5219D+06	7.17	7.05	7.04

CENTRAL	1979	0.0	21642000.	0.1007D+10	20.55	20.35	8.62
CENTRAL	1979	1.00	21477266.	0.9855D+09	20.36	20.04	8.36
CENTRAL	1979	2.00	21194716.	0.9642D+09	20.11	19.66	8.11
CENTRAL	1979	3.00	20872532.	0.9432D+09	19.94	19.49	7.85
CENTRAL	1979	4.00	20490899.	0.9225D+09	19.86	19.40	7.59
CENTRAL	1979	5.00	20029000.	0.9022D+09	19.66	19.25	7.33
CENTRAL	1979	6.00	19480795.	0.8824D+09	19.54	19.20	7.07
CENTRAL	1979	7.00	18877350.	0.8633D+09	19.34	18.93	6.80
CENTRAL	1979	8.00	18264507.	0.8447D+09	18.96	18.63	6.53
CENTRAL	1979	9.00	17687110.	0.8267D+09	18.70	18.33	6.27
CENTRAL	1979	10.00	17175000.	0.8093D+09	18.31	17.49	6.02
CENTRAL	1979	11.00	16804994.	0.7923D+09	17.55	16.50	5.79
CENTRAL	1979	12.00	16511805.	0.7756D+09	16.07	15.12	5.57
CENTRAL	1979	13.00	16277119.	0.7593D+09	14.13	13.79	5.38
CENTRAL	1979	14.00	16067621.	0.7431D+09	12.94	13.02	5.21
CENTRAL	1979	15.00	15812000.	0.7271D+09	11.70	11.80	5.05
CENTRAL	1979	16.00	15599068.	0.7114D+09	10.47	10.36	4.91
CENTRAL	1979	17.00	15322150.	0.6959D+09	9.09	9.02	4.81
CENTRAL	1979	18.00	15034698.	0.6808D+09	8.19	8.27	4.72
CENTRAL	1979	19.00	14752164.	0.6659D+09	7.71	7.66	4.65
CENTRAL	1979	20.00	14475000.	0.6512D+09	7.15	7.19	4.59
CENTRAL	1979	22.50	13958168.	0.6157D+09	6.41	6.54	4.46
CENTRAL	1979	25.00	13486000.	0.5814D+09	5.92	6.02	4.35
CENTRAL	1979	27.50	12981053.	0.5483D+09	5.44	5.32	4.27
CENTRAL	1979	30.00	12546000.	0.5164D+09	5.15	5.06	4.22
CENTRAL	1979	32.50	12280000.	0.4854D+09	4.89	4.75	4.17
CENTRAL	1979	35.00	12050000.	0.4548D+09	4.72	4.63	4.14
CENTRAL	1979	37.50	11800000.	0.4246D+09	4.57	4.47	4.11
CENTRAL	1979	40.00	11501000.	0.3952D+09	4.44	4.39	4.09
CENTRAL	1979	42.50	11180000.	0.3674D+09	4.36	4.34	4.07
CENTRAL	1979	45.00	10780000.	0.3418D+09	4.29	4.25	4.05
CENTRAL	1979	50.00	9978000.	0.2982D+09	4.20	4.19	4.02
CENTRAL	1979	55.00	9060000.	0.2612D+09	4.13	4.12	4.01
CENTRAL	1979	60.00	7878000.	0.2258D+09	4.07	4.04	3.99
CENTRAL	1979	70.00	6844000.	0.1554D+09	4.03	4.01	3.98
CENTRAL	1979	80.00	5661000.	0.9271D+08	3.99	4.00	3.96
CENTRAL	1979	90.00	4607000.	0.4088D+08	3.95	3.96	3.94

CENTRAL	1980	0.0	21640000.	0.1007D+10	18.51	18.99	8.36
CENTRAL	1980	1.00	21477266.	0.9855D+09	18.18	18.54	8.13
CENTRAL	1980	2.00	21194716.	0.9642D+09	17.96	18.34	7.91
CENTRAL	1980	3.00	20872532.	0.9432D+09	17.82	18.17	7.68
CENTRAL	1980	4.00	20490899.	0.9225D+09	17.70	18.06	7.44
CENTRAL	1980	5.00	20029000.	0.9022D+09	17.58	17.95	7.20
CENTRAL	1980	6.00	19480795.	0.8824D+09	17.35	17.71	6.97
CENTRAL	1980	7.00	18877350.	0.8633D+09	17.09	17.43	6.73
CENTRAL	1980	8.00	18264507.	0.8447D+09	16.75	17.12	6.50
CENTRAL	1980	9.00	17687110.	0.8267D+09	16.29	16.79	6.27
CENTRAL	1980	10.00	17175000.	0.8093D+09	15.64	15.99	6.05
CENTRAL	1980	11.00	16804994.	0.7923D+09	15.05	15.35	5.85
CENTRAL	1980	12.00	16511805.	0.7756D+09	13.80	13.91	5.66
CENTRAL	1980	13.00	16277119.	0.7593D+09	12.44	12.60	5.49
CENTRAL	1980	14.00	16067621.	0.7431D+09	11.59	11.88	5.35
CENTRAL	1980	15.00	15812000.	0.7271D+09	10.64	10.72	5.22
CENTRAL	1980	16.00	15599068.	0.7114D+09	9.83	9.91	5.10
CENTRAL	1980	17.00	15322150.	0.6959D+09	9.07	9.14	5.01
CENTRAL	1980	18.00	15034698.	0.6808D+09	8.53	8.60	4.92
CENTRAL	1980	19.00	14752164.	0.6659D+09	8.01	8.09	4.84
CENTRAL	1980	20.00	14479000.	0.6512D+09	7.70	7.76	4.77
CENTRAL	1980	22.50	13958168.	0.6157D+09	7.06	7.12	4.62
CENTRAL	1980	25.00	13490000.	0.5814D+09	6.56	6.61	4.49
CENTRAL	1980	27.50	12981053.	0.5483D+09	5.95	6.00	4.38
CENTRAL	1980	30.00	12546000.	0.5164D+09	5.47	5.51	4.30
CENTRAL	1980	32.50	12280000.	0.4854D+09	5.08	5.09	4.23
CENTRAL	1980	35.00	12050000.	0.4548D+09	4.82	4.82	4.18
CENTRAL	1980	37.50	11800000.	0.4246D+09	4.63	4.63	4.15
CENTRAL	1980	40.00	11501000.	0.3952D+09	4.48	4.47	4.12
CENTRAL	1980	42.50	11180000.	0.3674D+09	4.38	4.38	4.09
CENTRAL	1980	45.00	10780000.	0.3418D+09	4.31	4.31	4.07
CENTRAL	1980	50.00	9978000.	0.2982D+09	4.23	4.22	4.05
CENTRAL	1980	55.00	9060000.	0.2612D+09	4.17	4.16	4.03
CENTRAL	1980	60.00	7878000.	0.2258D+09	4.11	4.11	4.01
CENTRAL	1980	70.00	6844000.	0.1554D+09	4.03	4.04	3.98
CENTRAL	1980	80.00	5661000.	0.9271D+08	4.01	3.99	3.96
CENTRAL	1980	90.00	4607000.	0.4088D+08	3.95	3.95	3.94

FITCH	1979	0.0	2803000.	0.2807D+08	21.09	20.71	17.01
FITCH	1979	1.00	2675483.	0.2533D+08	20.95	20.88	16.60
FITCH	1979	2.00	2546046.	0.2272D+08	20.73	20.37	16.13
FITCH	1979	3.00	2412766.	0.2024D+08	20.61	20.20	15.62
FITCH	1979	4.00	2273725.	0.1789D+08	20.49	20.04	15.04
FITCH	1979	5.00	2127000.	0.1569D+08	20.12	19.96	14.34
FITCH	1979	6.00	1972176.	0.1364D+08	19.86	19.53	13.52
FITCH	1979	7.00	1814856.	0.1175D+08	19.57	19.14	12.58
FITCH	1979	8.00	1662148.	0.1001D+08	18.74	17.93	11.54
FITCH	1979	9.00	1521160.	0.8421D+07	17.60	16.59	10.45
FITCH	1979	10.00	1399000.	0.6963D+07	14.87	14.22	9.39
FITCH	1979	11.00	1298621.	0.5615D+07	11.89	11.19	8.59
FITCH	1979	12.00	1206354.	0.4363D+07	10.02	9.37	8.14
FITCH	1979	13.00	1104378.	0.3206D+07	8.84	8.69	7.83
FITCH	1979	14.00	974867.	0.2163D+07	7.99	7.95	7.60
FITCH	1979	15.00	800000.	0.1271D+07	7.65	7.67	7.47
FITCH	1979	16.00	568433.	0.5825D+06	7.46	7.41	7.37
FITCH	1979	17.00	294747.	0.1483D+06	7.43	7.37	7.39

FITCH	1980	0.0	2803000.	0.2807D+08	7.75	19.29	15.78
FITCH	1980	1.00	2675483.	0.2533D+08	7.75	19.09	15.41
FITCH	1980	2.00	2546046.	0.2272D+08	7.75	18.90	15.00
FITCH	1980	3.00	2412766.	0.2024D+08	8.24	18.57	14.54
FITCH	1980	4.00	2273725.	0.1789D+08	16.91	18.35	14.03
FITCH	1980	5.00	2127000.	0.1569D+08	16.73	18.21	13.44
FITCH	1980	6.00	1972176.	0.1364D+08	16.50	18.00	12.73
FITCH	1980	7.00	1814856.	0.1175D+08	15.79	17.12	11.94
FITCH	1980	8.00	1662148.	0.1001D+08	15.15	16.35	11.12
FITCH	1980	9.00	1521160.	0.8421D+07	14.37	15.45	10.19
FITCH	1980	10.00	1399000.	0.6963D+07	12.44	12.97	9.34
FITCH	1980	11.00	1298621.	0.5615D+07	10.66	11.02	8.71
FITCH	1980	12.00	1206354.	0.4363D+07	9.22	9.42	8.29
FITCH	1980	13.00	1104378.	0.3206D+07	8.54	8.64	8.04
FITCH	1980	14.00	974867.	0.2163D+07	8.11	8.17	7.87
FITCH	1980	15.00	800000.	0.1271D+07	7.79	7.87	7.77
FITCH	1980	16.00	568433.	0.5825D+06	7.65	7.75	7.73
FITCH	1980	17.00	294747.	0.1483D+06	7.61	7.73	7.72

P. BROMPTON	1980	0.0	714300.	0.4714D+06	20.19	19.66	14.85
P. BROMPTON	1980	1.00	645654.	0.4034D+06	20.03	19.81	14.02
P. BROMPTON	1980	2.00	574158.	0.3424D+06	19.92	19.51	13.01
P. BROMPTON	1980	3.00	496960.	0.2888D+06	19.73	19.23	11.83
P. BROMPTON	1980	4.00	413246.	0.2432D+06	19.11	18.55	10.50
P. BROMPTON	1980	5.00	331666.	0.2061D+06	18.20	17.62	9.12
P. BROMPTON	1980	6.00	263621.	0.1765D+06	16.21	15.41	7.85
P. BROMPTON	1980	7.00	218325.	0.1526D+06	12.25	11.76	6.94
P. BROMPTON	1980	8.00	193180.	0.1321D+06	9.29	8.94	6.42
P. BROMPTON	1980	9.00	181610.	0.1135D+06	7.77	7.58	6.14
P. BROMPTON	1980	10.00	176787.	0.9557D+05	7.01	6.88	5.94
P. BROMPTON	1980	11.00	170350.	0.7816D+05	6.54	6.44	5.78
P. BROMPTON	1980	12.00	153359.	0.6184D+05	6.20	6.11	5.65
P. BROMPTON	1980	13.00	119786.	0.4808D+05	5.94	5.87	5.55
P. BROMPTON	1980	14.00	84460.	0.3795D+05	5.75	5.68	5.49
P. BROMPTON	1980	15.00	71298.	0.3046D+05	5.64	5.56	5.46
P. BROMPTON	1980	16.00	97328.	0.2230D+05	5.54	5.47	5.45
P. BROMPTON	1980	17.00	21226.	0.1091D+05	5.51	5.44	5.44

LOVERING	1979	0.0	5210000.	0.4423D+08	22.24	21.79	17.47
LOVERING	1979	1.00	4846097.	0.3921D+08	22.05	21.67	16.93
LOVERING	1979	2.00	4496388.	0.3454D+08	21.97	21.50	16.29
LOVERING	1979	3.00	4175066.	0.3020D+08	21.77	21.02	15.58
LOVERING	1979	4.00	3890805.	0.2617D+08	20.42	20.12	14.80
LOVERING	1979	5.00	3626611.	0.2241D+08	19.81	19.40	13.98
LOVERING	1979	6.00	3358039.	0.1892D+08	19.45	19.20	12.99
LOVERING	1979	7.00	3063653.	0.1571D+08	16.96	17.24	11.88
LOVERING	1979	8.00	2738292.	0.1280D+08	13.92	14.07	11.02
LOVERING	1979	9.00	2382271.	0.1024D+08	11.88	12.07	10.54
LOVERING	1979	10.00	1999377.	0.8049D+07	11.18	11.36	10.23
LOVERING	1979	11.00	1614602.	0.6243D+07	10.78	10.81	9.98
LOVERING	1979	12.00	1260950.	0.4809D+07	10.50	10.40	9.80
LOVERING	1979	13.00	968352.	0.3701D+07	10.28	10.32	9.64
LOVERING	1979	14.00	744604.	0.2850D+07	9.96	9.88	9.49
LOVERING	1979	15.00	587859.	0.2189D+07	9.67	9.69	9.41
LOVERING	1979	16.00	493729.	0.1653D+07	9.52	9.57	9.33
LOVERING	1979	17.00	436788.	0.1189D+07	9.42	9.42	9.27
LOVERING	1979	18.00	381074.	0.7786D+06	9.31	9.29	9.23
LOVERING	1979	19.00	294594.	0.4380D+06	9.25	9.24	9.20
LOVERING	1979	20.00	185744.	0.1971D+06	9.20	9.20	9.17
LOVERING	1979	21.00	86113.	0.6349D+05	9.16	9.16	9.16
LOVERING	1979	22.00	25103.	0.1148D+05	9.12	9.16	9.20

LOVERING	1980	0.0	5210000.	0.4423D+08	21.04	19.95	16.67
LOVERING	1980	1.00	4846097.	0.3921D+08	20.92	19.93	16.24
LOVERING	1980	2.00	4496388.	0.3454D+08	20.73	19.76	15.76
LOVERING	1980	3.00	4175066.	0.3020D+08	20.48	19.51	15.20
LOVERING	1980	4.00	3890805.	0.2617D+08	20.27	19.30	14.55
LOVERING	1980	5.00	3626611.	0.2241D+08	19.62	18.64	13.79
LOVERING	1980	6.00	3358039.	0.1892D+08	18.29	16.61	13.08
LOVERING	1980	7.00	3063653.	0.1571D+08	16.68	16.00	12.44
LOVERING	1980	8.00	2738292.	0.1280D+08	15.48	14.91	11.73
LOVERING	1980	9.00	2382271.	0.1024D+08	13.64	13.17	11.15
LOVERING	1980	10.00	1999377.	0.8049D+07	12.55	12.06	10.77
LOVERING	1980	11.00	1614602.	0.6243D+07	11.95	11.48	10.49
LOVERING	1980	12.00	1260950.	0.4809D+07	11.60	11.17	10.24
LOVERING	1980	13.00	968352.	0.3701D+07	11.23	10.73	10.02
LOVERING	1980	14.00	744604.	0.2850D+07	10.89	10.67	9.82
LOVERING	1980	15.00	587859.	0.2189D+07	10.37	10.14	9.63
LOVERING	1980	16.00	493729.	0.1653D+07	10.14	9.90	9.52
LOVERING	1980	17.00	436788.	0.1189D+07	9.81	9.73	9.40
LOVERING	1980	18.00	381074.	0.7786D+06	9.63	9.52	9.27
LOVERING	1980	19.00	294594.	0.4380D+06	9.49	9.23	9.19
LOVERING	1980	20.00	185744.	0.1971D+06	9.41	9.21	9.18
LOVERING	1980	21.00	86113.	0.6349D+05	9.36	9.18	9.12
LOVERING	1980	22.00	25103.	0.1148D+05	9.31	9.10	8.98

LYSTER	1979	0.0	1710000.	0.3287D+08	20.82
LYSTER	1979	1.00	1613787.	0.3121D+08	20.80
LYSTER	1979	2.00	1520782.	0.2964D+08	20.77
LYSTER	1979	3.00	1434192.	0.2816D+08	20.75
LYSTER	1979	4.00	1357224.	0.2677D+08	20.63
LYSTER	1979	5.00	1293085.	0.2544D+08	19.06
LYSTER	1979	6.00	1243361.	0.2418D+08	18.10
LYSTER	1979	7.00	1205098.	0.2295D+08	17.37
LYSTER	1979	8.00	1174554.	0.2176D+08	15.07
LYSTER	1979	9.00	1147987.	0.2060D+08	12.57
LYSTER	1979	10.00	1121654.	0.1947D+08	10.52
LYSTER	1979	11.00	1092543.	0.1836D+08	9.11
LYSTER	1979	12.00	1061131.	0.1728D+08	8.09
LYSTER	1979	13.00	1028945.	0.1624D+08	7.51
LYSTER	1979	14.00	997507.	0.1523D+08	6.99
LYSTER	1979	15.00	968342.	0.1424D+08	6.60
LYSTER	1979	16.00	942278.	0.1329D+08	6.33
LYSTER	1979	17.00	917815.	0.1236D+08	5.97
LYSTER	1979	18.00	892967.	0.1145D+08	5.89
LYSTER	1979	19.00	865749.	0.1057D+08	5.76
LYSTER	1979	20.00	834176.	0.9722D+07	5.59
LYSTER	1979	22.00	755060.	0.8130D+07	5.36
LYSTER	1979	24.00	668921.	0.6706D+07	5.17
LYSTER	1979	26.00	595483.	0.5445D+07	5.15
LYSTER	1979	28.00	536435.	0.4314D+07	4.92
LYSTER	1979	30.00	475669.	0.3301D+07	4.80
LYSTER	1979	32.50	381888.	0.2225D+07	4.72
LYSTER	1979	35.00	281924.	0.1396D+07	4.69
LYSTER	1979	37.50	192791.	0.8057D+06	4.65
LYSTER	1979	40.00	118390.	0.4206D+06	4.63

LYSTER	1980	0.0	1710000.	0.3287D+08	18.78	17.29	10.24
LYSTER	1980	1.00	1613787.	0.3121D+08	18.80	17.12	9.87
LYSTER	1980	2.00	1520782.	0.2964D+08	18.79	17.14	9.48
LYSTER	1980	3.00	1434192.	0.2816D+08	18.79	17.20	9.08
LYSTER	1980	4.00	1357224.	0.2677D+08	18.64	17.07	8.66
LYSTER	1980	5.00	1293085.	0.2544D+08	18.27	16.78	8.23
LYSTER	1980	6.00	1243361.	0.2418D+08	17.90	16.45	7.79
LYSTER	1980	7.00	1205098.	0.2295D+08	17.42	16.09	7.33
LYSTER	1980	8.00	1174554.	0.2176D+08	16.13	14.93	6.88
LYSTER	1980	9.00	1147987.	0.2060D+08	13.38	12.48	6.50
LYSTER	1980	10.00	1121654.	0.1947D+08	11.43	10.83	6.20
LYSTER	1980	11.00	1092543.	0.1836D+08	9.80	9.17	5.97
LYSTER	1980	12.00	1061131.	0.1728D+08	8.74	8.99	5.78
LYSTER	1980	13.00	1028945.	0.1624D+08	7.90	7.75	5.61
LYSTER	1980	14.00	997507.	0.1523D+08	7.28	6.99	5.50
LYSTER	1980	15.00	968342.	0.1424D+08	6.89	6.76	5.40
LYSTER	1980	16.00	942278.	0.1329D+08	6.57	6.32	5.32
LYSTER	1980	17.00	917815.	0.1236D+08	6.19	5.98	5.26
LYSTER	1980	18.00	892967.	0.1145D+08	5.98	5.80	5.21
LYSTER	1980	19.00	865749.	0.1057D+08	5.78	5.56	5.17
LYSTER	1980	20.00	834176.	0.9722D+07	5.70	5.58	5.14
LYSTER	1980	22.00	755060.	0.8130D+07	5.49	5.34	5.07
LYSTER	1980	24.00	668921.	0.6706D+07	5.36	5.17	5.03
LYSTER	1980	26.00	595483.	0.5445D+07	5.25	5.09	5.01
LYSTER	1980	28.00	536435.	0.4314D+07	5.18	5.11	4.99
LYSTER	1980	30.00	475669.	0.3301D+07	5.09	5.06	4.95
LYSTER	1980	32.50	381888.	0.2225D+07	5.02	5.03	4.91
LYSTER	1980	35.00	281924.	0.1396D+07	4.97	4.96	4.86
LYSTER	1980	37.50	192791.	0.8057D+06	4.93	4.90	4.81
LYSTER	1980	40.00	118390.	0.4206D+06	4.91	4.84	4.74

MASSAWIPPI	1979	0.0	21000000.	0.7816D+09	20.85	20.68	7.98
MASSAWIPPI	1979	1.00	20627909.	0.7608D+09	20.48	20.33	7.64
MASSAWIPPI	1979	2.00	20253911.	0.7404D+09	20.33	20.20	7.29
MASSAWIPPI	1979	3.00	19876095.	0.7203D+09	20.20	20.07	6.93
MASSAWIPPI	1979	4.00	19492556.	0.7006D+09	20.08	19.96	6.56
MASSAWIPPI	1979	5.00	19101383.	0.6813D+09	19.05	19.01	6.19
MASSAWIPPI	1979	6.00	18700670.	0.6624D+09	17.40	17.39	5.85
MASSAWIPPI	1979	7.00	18288035.	0.6439D+09	15.65	15.79	5.54
MASSAWIPPI	1979	8.00	17858549.	0.6259D+09	13.01	13.27	5.28
MASSAWIPPI	1979	9.00	17406420.	0.6082D+09	10.70	10.71	5.09
MASSAWIPPI	1979	10.00	16925857.	0.5911D+09	9.59	9.48	4.94
MASSAWIPPI	1979	11.00	16411072.	0.5744D+09	8.71	8.54	4.83
MASSAWIPPI	1979	12.00	15856271.	0.5583D+09	7.82	7.75	4.73
MASSAWIPPI	1979	13.00	15258404.	0.5427D+09	7.20	7.18	4.65
MASSAWIPPI	1979	14.00	14634648.	0.5277D+09	6.85	6.84	4.59
MASSAWIPPI	1979	15.00	14011254.	0.5134D+09	6.62	6.61	4.53
MASSAWIPPI	1979	16.00	13414511.	0.4997D+09	6.39	6.39	4.47
MASSAWIPPI	1979	17.00	12870713.	0.4866D+09	6.09	6.05	4.42
MASSAWIPPI	1979	18.00	12406149.	0.4739D+09	5.89	5.87	4.38
MASSAWIPPI	1979	19.00	12043997.	0.4617D+09	5.75	5.73	4.35
MASSAWIPPI	1979	20.00	11776394.	0.4498D+09	5.49	5.49	4.31
MASSAWIPPI	1979	22.50	11351981.	0.4210D+09	5.27	5.25	4.24
MASSAWIPPI	1979	25.00	10954675.	0.3931D+09	5.02	5.02	4.18
MASSAWIPPI	1979	27.50	10368440.	0.3664D+09	4.80	4.80	4.12
MASSAWIPPI	1979	30.00	9746906.	0.3412D+09	4.65	4.65	4.08
MASSAWIPPI	1979	32.50	9263216.	0.3175D+09	4.54	4.53	4.04
MASSAWIPPI	1979	35.00	8918952.	0.2948D+09	4.43	4.42	4.01
MASSAWIPPI	1979	37.50	8641010.	0.2729D+09	4.33	4.33	3.98
MASSAWIPPI	1979	40.00	8379561.	0.2516D+09	4.26	4.26	3.95
MASSAWIPPI	1979	42.50	8118126.	0.2310D+09	4.19	4.20	3.93
MASSAWIPPI	1979	45.00	7844408.	0.2110D+09	4.14	4.14	3.91
MASSAWIPPI	1979	47.50	7554241.	0.1918D+09	4.09	4.09	3.89
MASSAWIPPI	1979	50.00	7246624.	0.1732D+09	4.02	4.02	3.87
MASSAWIPPI	1979	55.00	6655579.	0.1385D+09	3.96	3.96	3.84
MASSAWIPPI	1979	60.00	6230112.	0.1064D+09	3.88	3.88	3.81
MASSAWIPPI	1979	70.00	5319786.	0.4776D+08	3.80	3.80	3.79
MASSAWIPPI	1979	80.00	2422441.	0.7323D+07	3.78	3.78	3.78

MASSAWIPPI	1980	0.0	21000000.	0.7816D+09	20.02	19.44	7.71
MASSAWIPPI	1980	1.00	20627909.	0.7608D+09	19.93	19.36	7.39
MASSAWIPPI	1980	2.00	20253911.	0.7404D+09	19.88	19.28	7.06
MASSAWIPPI	1980	3.00	19876095.	0.7203D+09	19.71	19.09	6.72
MASSAWIPPI	1980	4.00	19492556.	0.7006D+09	19.57	18.96	6.37
MASSAWIPPI	1980	5.00	19101383.	0.6813D+09	18.73	17.93	6.03
MASSAWIPPI	1980	6.00	18700670.	0.6624D+09	17.13	16.77	5.70
MASSAWIPPI	1980	7.00	18288035.	0.6439D+09	14.95	13.84	5.43
MASSAWIPPI	1980	8.00	17858549.	0.6259D+09	12.47	11.80	5.21
MASSAWIPPI	1980	9.00	17406420.	0.6082D+09	10.71	9.84	5.05
MASSAWIPPI	1980	10.00	16925857.	0.5911D+09	9.25	7.98	4.94
MASSAWIPPI	1980	11.00	16411072.	0.5744D+09	8.26	7.97	4.86
MASSAWIPPI	1980	12.00	15856271.	0.5583D+09	7.78	7.52	4.77
MASSAWIPPI	1980	13.00	15258404.	0.5427D+09	7.27	7.01	4.70
MASSAWIPPI	1980	14.00	14634648.	0.5277D+09	6.96	6.76	4.64
MASSAWIPPI	1980	15.00	14011254.	0.5134D+09	6.73	6.32	4.58
MASSAWIPPI	1980	16.00	13414511.	0.4997D+09	6.44	6.24	4.54
MASSAWIPPI	1980	17.00	12870713.	0.4866D+09	6.25	6.03	4.50
MASSAWIPPI	1980	18.00	12406149.	0.4739D+09	6.12	5.91	4.46
MASSAWIPPI	1980	19.00	12043997.	0.4617D+09	5.95	5.83	4.42
MASSAWIPPI	1980	20.00	11776394.	0.4498D+09	5.64	5.62	4.38
MASSAWIPPI	1980	22.50	11351981.	0.4210D+09	5.39	5.39	4.31
MASSAWIPPI	1980	25.00	10954675.	0.3931D+09	5.18	5.18	4.24
MASSAWIPPI	1980	27.50	10368440.	0.3664D+09	4.97	4.98	4.18
MASSAWIPPI	1980	30.00	9746906.	0.3412D+09	4.82	4.82	4.13
MASSAWIPPI	1980	32.50	9263216.	0.3175D+09	4.70	4.69	4.08
MASSAWIPPI	1980	35.00	8918952.	0.2948D+09	4.59	4.56	4.04
MASSAWIPPI	1980	37.50	8641010.	0.2729D+09	4.43	4.39	4.00
MASSAWIPPI	1980	40.00	8379561.	0.2516D+09	4.34	4.32	3.97
MASSAWIPPI	1980	42.50	8118126.	0.2310D+09	4.29	4.28	3.94
MASSAWIPPI	1980	45.00	7844408.	0.2110D+09	4.22	4.21	3.91
MASSAWIPPI	1980	47.50	7554241.	0.1918D+09	4.16	4.14	3.89
MASSAWIPPI	1980	50.00	7246624.	0.1732D+09	4.06	4.05	3.86
MASSAWIPPI	1980	55.00	6655579.	0.1385D+09	3.99	3.98	3.83
MASSAWIPPI	1980	60.00	6230112.	0.1064D+09	3.87	3.87	3.80
MASSAWIPPI	1980	70.00	5319786.	0.4776D+08	3.80	3.79	3.78
MASSAWIPPI	1980	80.00	2422441.	0.7323D+07	3.79	3.77	3.77

MAGOG	1979	0.0	10440000.	0.8553D+08	20.40
MAGOG	1979	1.00	9834378.	0.7540D+08	20.08
MAGOG	1979	2.00	9221373.	0.6587D+08	19.96
MAGOG	1979	3.00	8593598.	0.5696D+08	19.84
MAGOG	1979	4.00	7943669.	0.4869D+08	19.69
MAGOG	1979	5.00	7264203.	0.4108D+08	19.41
MAGOG	1979	6.00	6547815.	0.3417D+08	18.71
MAGOG	1979	7.00	5787120.	0.2800D+08	18.26
MAGOG	1979	8.00	4977764.	0.2262D+08	17.49
MAGOG	1979	9.00	4248353.	0.1802D+08	16.40
MAGOG	1979	10.00	3825684.	0.1401D+08	14.61
MAGOG	1979	11.00	3440565.	0.1036D+08	13.16
MAGOG	1979	12.00	2875170.	0.7193D+07	12.00
MAGOG	1979	13.00	2272749.	0.4618D+07	11.24
MAGOG	1979	14.00	1651765.	0.2654D+07	11.06
MAGOG	1979	15.00	1032506.	0.1317D+07	10.85
MAGOG	1979	16.00	548059.	0.5407D+06	10.68
MAGOG	1979	17.00	225795.	0.1678D+06	10.44

MAGOG	1980	0.0	10440000.	0.8553D+08	17.26	18.43	16.55
MAGOG	1980	1.00	9834378.	0.7540D+08	17.25	18.45	16.30
MAGOG	1980	2.00	9221373.	0.6587D+08	17.22	18.41	15.99
MAGOG	1980	3.00	8593598.	0.5696D+08	17.17	18.37	15.62
MAGOG	1980	4.00	7943669.	0.4869D+08	17.01	18.29	15.15
MAGOG	1980	5.00	7264203.	0.4108D+08	16.10	17.51	14.64
MAGOG	1980	6.00	6547815.	0.3417D+08	15.51	17.08	14.09
MAGOG	1980	7.00	5787120.	0.2800D+08	14.76	15.68	13.58
MAGOG	1980	8.00	4977764.	0.2262D+08	13.89	14.93	13.18
MAGOG	1980	9.00	4248353.	0.1802D+08	13.33	14.55	12.79
MAGOG	1980	10.00	3825684.	0.1401D+08	12.75	14.07	12.34
MAGOG	1980	11.00	3440565.	0.1036D+08	12.34	12.81	11.94
MAGOG	1980	12.00	2875170.	0.7193D+07	11.80	12.22	11.71
MAGOG	1980	13.00	2272749.	0.4618D+07	11.32	11.85	11.53
MAGOG	1980	14.00	1651765.	0.2654D+07	11.04	11.56	11.40
MAGOG	1980	15.00	1032506.	0.1317D+07	10.84	11.39	11.32
MAGOG	1980	16.00	548059.	0.5407D+06	10.77	11.29	11.29
MAGOG	1980	17.00	225795.	0.1678D+06	10.76	11.28	11.31

NORTH	1979	0.0	18810000.	0.2895D+09	18.43	18.57	14.89
NORTH	1979	1.00	18176781.	0.2710D+09	18.20	18.20	14.66
NORTH	1979	2.00	17549367.	0.2531D+09	18.12	18.09	14.41
NORTH	1979	3.00	16933562.	0.2359D+09	18.06	18.01	14.15
NORTH	1979	4.00	16335172.	0.2193D+09	18.01	18.00	13.85
NORTH	1979	5.00	15760000.	0.2032D+09	17.99	17.98	13.53
NORTH	1979	6.00	15214127.	0.1877D+09	17.96	17.97	13.16
NORTH	1979	7.00	14704734.	0.1728D+09	17.93	18.05	12.74
NORTH	1979	8.00	14239277.	0.1583D+09	17.79	18.03	12.25
NORTH	1979	9.00	13825214.	0.1443D+09	17.63	17.66	11.71
NORTH	1979	10.00	13470000.	0.1306D+09	17.39	17.52	11.09
NORTH	1979	11.00	13170791.	0.1173D+09	16.44	16.04	10.43
NORTH	1979	12.00	12883538.	0.1043D+09	13.29	13.35	9.89
NORTH	1979	13.00	12553888.	0.9156D+08	11.20	11.39	9.56
NORTH	1979	14.00	12127493.	0.7921D+08	10.41	10.47	9.36
NORTH	1979	15.00	11550000.	0.6736D+08	10.07	9.94	9.21
NORTH	1979	16.00	10782948.	0.5618D+08	9.71	9.72	9.09
NORTH	1979	17.00	9851436.	0.4585D+08	9.45	9.36	8.99
NORTH	1979	18.00	8796449.	0.3651D+08	9.28	9.29	8.91
NORTH	1979	19.00	7658975.	0.2828D+08	9.15	9.09	8.82
NORTH	1979	20.00	6480000.	0.2121D+08	8.98	8.96	8.76
NORTH	1979	22.00	4164239.	0.1059D+08	8.82	8.84	8.61
NORTH	1979	24.00	2190769.	0.4327D+07	8.64	8.58	8.44
NORTH	1979	26.00	890432.	0.1372D+07	8.47	8.45	8.29
NORTH	1979	28.00	283565.	0.2885D+06	8.29	8.31	7.87

NORTH	1980	0.0	18810000.	0.2895D+09	19.84	19.38	14.77
NORTH	1980	1.00	18176781.	0.2710D+09	19.68	19.09	14.47
NORTH	1980	2.00	17549367.	0.2531D+09	19.58	19.06	14.14
NORTH	1980	3.00	16933562.	0.2359D+09	19.47	18.92	13.79
NORTH	1980	4.00	16335172.	0.2193D+09	19.40	18.85	13.40
NORTH	1980	5.00	15760000.	0.2032D+09	19.32	18.77	12.98
NORTH	1980	6.00	15214127.	0.1877D+09	19.14	18.59	12.50
NORTH	1980	7.00	14704734.	0.1728D+09	18.63	18.15	11.99
NORTH	1980	8.00	14239277.	0.1583D+09	17.64	17.30	11.47
NORTH	1980	9.00	13825214.	0.1443D+09	16.44	16.13	10.95
NORTH	1980	10.00	13470000.	0.1306D+09	14.85	14.65	10.49
NORTH	1980	11.00	13170791.	0.1173D+09	13.07	12.98	10.11
NORTH	1980	12.00	12883538.	0.1043D+09	11.86	11.72	9.84
NORTH	1980	13.00	12553888.	0.9156D+08	11.24	11.15	9.62
NORTH	1980	14.00	12127493.	0.7921D+08	10.57	10.51	9.43
NORTH	1980	15.00	11550000.	0.6736D+08	10.09	10.03	9.28
NORTH	1980	16.00	10782948.	0.5618D+08	9.80	9.74	9.17
NORTH	1980	17.00	9851436.	0.4585D+08	9.62	9.58	9.06
NORTH	1980	18.00	8796449.	0.3651D+08	9.47	9.42	8.94
NORTH	1980	19.00	7658975.	0.2828D+08	9.24	9.19	8.84
NORTH	1980	20.00	6480000.	0.2121D+08	9.04	9.01	8.75
NORTH	1980	22.00	4164239.	0.1059D+08	8.84	8.79	8.60
NORTH	1980	24.00	2190769.	0.4327D+07	8.65	8.60	8.46
NORTH	1980	26.00	890432.	0.1372D+07	8.45	8.41	8.33
NORTH	1980	28.00	283565.	0.2885D+06	8.35	8.31	8.25

ORFORD	1979	0.0	1278000.	0.2293D+08	22.05
ORFORD	1979	1.00	1197117.	0.2169D+08	21.95
ORFORD	1979	2.00	1117765.	0.2054D+08	21.84
ORFORD	1979	3.00	1041477.	0.1946D+08	21.34
ORFORD	1979	4.00	969784.	0.1845D+08	20.95
ORFORD	1979	5.00	904218.	0.1751D+08	20.12
ORFORD	1979	6.00	846311.	0.1664D+08	19.41
ORFORD	1979	7.00	797240.	0.1582D+08	16.92
ORFORD	1979	8.00	756277.	0.1504D+08	13.88
ORFORD	1979	9.00	722049.	0.1430D+08	10.41
ORFORD	1979	10.00	693183.	0.1360D+08	8.68
ORFORD	1979	11.00	668307.	0.1292D+08	7.59
ORFORD	1979	12.00	646047.	0.1226D+08	6.79
ORFORD	1979	13.00	625150.	0.1162D+08	6.05
ORFORD	1979	14.00	605216.	0.1101D+08	5.75
ORFORD	1979	15.00	586218.	0.1041D+08	5.54
ORFORD	1979	16.00	568131.	0.9836D+07	5.35
ORFORD	1979	17.00	550928.	0.9277D+07	5.20
ORFORD	1979	18.00	534583.	0.8734D+07	5.09
ORFORD	1979	19.00	519052.	0.8207D+07	4.97
ORFORD	1979	20.00	504104.	0.7696D+07	4.87
ORFORD	1979	22.00	474601.	0.6717D+07	4.74
ORFORD	1979	24.00	443357.	0.5799D+07	4.65
ORFORD	1979	26.00	408375.	0.4946D+07	4.57
ORFORD	1979	28.00	372810.	0.4166D+07	4.51
ORFORD	1979	30.00	342062.	0.3452D+07	4.46
ORFORD	1979	32.50	315438.	0.2632D+07	4.42
ORFORD	1979	35.00	285878.	0.1876D+07	4.36
ORFORD	1979	37.50	228334.	0.1230D+07	4.77

ORFORD	1980	0.0	1278000.	0.2293D+08	20.89	14.19	8.29
ORFORD	1980	1.00	1197117.	0.2169D+08	20.84	14.30	7.95
ORFORD	1980	2.00	1117765.	0.2054D+08	20.81	14.46	7.58
ORFORD	1980	3.00	1041477.	0.1946D+08	20.76	14.50	7.20
ORFORD	1980	4.00	969784.	0.1845D+08	20.74	14.74	6.80
ORFORD	1980	5.00	904218.	0.1751D+08	20.05	14.48	6.38
ORFORD	1980	6.00	846311.	0.1664D+08	19.26	15.98	5.91
ORFORD	1980	7.00	797240.	0.1582D+08	16.74	13.38	5.45
ORFORD	1980	8.00	756277.	0.1504D+08	13.77	11.72	5.09
ORFORD	1980	9.00	722049.	0.1430D+08	11.20	10.01	4.78
ORFORD	1980	10.00	693183.	0.1360D+08	9.13	7.79	4.57
ORFORD	1980	11.00	668307.	0.1292D+08	7.84	6.20	4.45
ORFORD	1980	12.00	646047.	0.1226D+08	6.86	6.06	4.36
ORFORD	1980	13.00	625150.	0.1162D+08	6.35	5.01	4.29
ORFORD	1980	14.00	605216.	0.1101D+08	5.88	4.89	4.26
ORFORD	1980	15.00	586218.	0.1041D+08	5.61	4.88	4.22
ORFORD	1980	16.00	568131.	0.9836D+07	5.37	4.67	4.19
ORFORD	1980	17.00	550928.	0.9277D+07	5.15	4.47	4.17
ORFORD	1980	18.00	534583.	0.8734D+07	4.98	4.29	4.15
ORFORD	1980	19.00	519052.	0.8207D+07	4.85	4.33	4.15
ORFORD	1980	20.00	504104.	0.7696D+07	4.76	4.28	4.13
ORFORD	1980	22.00	474601.	0.6717D+07	4.57	4.33	4.11
ORFORD	1980	24.00	443357.	0.5799D+07	4.48	4.23	4.08
ORFORD	1980	26.00	408375.	0.4946D+07	4.41	4.15	4.06
ORFORD	1980	28.00	372810.	0.4166D+07	4.35	4.13	4.05
ORFORD	1980	30.00	342062.	0.3452D+07	4.31	4.10	4.04
ORFORD	1980	32.50	315438.	0.2632D+07	4.26	4.05	4.02
ORFORD	1980	35.00	285878.	0.1876D+07	4.22	4.08	4.01
ORFORD	1980	37.50	228334.	0.1230D+07	4.20	4.05	3.98

STOKELY	1979	0.0	3660000.	0.4232D+08	21.86	20.81	13.64
STOKELY	1979	1.00	3386349.	0.3880D+08	21.68	20.83	12.99
STOKELY	1979	2.00	3118927.	0.3554D+08	21.38	20.29	12.30
STOKELY	1979	3.00	2863960.	0.3255D+08	20.94	20.08	11.57
STOKELY	1979	4.00	2627676.	0.2981D+08	20.54	19.74	10.80
STOKELY	1979	5.00	2416304.	0.2729D+08	19.91	19.12	10.00
STOKELY	1979	6.00	2236071.	0.2497D+08	19.02	18.46	9.19
STOKELY	1979	7.00	2091327.	0.2281D+08	17.22	16.86	8.36
STOKELY	1979	8.00	1976268.	0.2077D+08	14.74	13.19	7.71
STOKELY	1979	9.00	1881672.	0.1885D+08	11.94	11.36	7.26
STOKELY	1979	10.00	1798312.	0.1701D+08	10.33	9.83	6.89
STOKELY	1979	11.00	1716964.	0.1525D+08	9.09	8.48	6.64
STOKELY	1979	12.00	1628403.	0.1358D+08	8.19	7.59	6.47
STOKELY	1979	13.00	1524712.	0.1200D+08	7.50	7.08	6.36
STOKELY	1979	14.00	1407332.	0.1053D+08	7.00	6.88	6.27
STOKELY	1979	15.00	1281784.	0.9186D+07	6.71	6.56	6.20
STOKELY	1979	16.00	1153606.	0.7968D+07	6.56	6.42	6.16
STOKELY	1979	17.00	1028335.	0.6878D+07	6.44	6.37	6.13
STOKELY	1979	18.00	911509.	0.5909D+07	6.30	6.25	6.10
STOKELY	1979	19.00	808192.	0.5050D+07	6.29	6.25	6.07
STOKELY	1979	20.00	718721.	0.4288D+07	6.24	6.19	6.05
STOKELY	1979	22.00	571779.	0.3003D+07	6.14	6.09	6.01
STOKELY	1979	24.00	451445.	0.1983D+07	6.08	6.02	5.98
STOKELY	1979	26.00	340453.	0.1192D+07	6.04	6.01	5.96
STOKELY	1979	28.00	235858.	0.6169D+06	6.01	5.96	5.94
STOKELY	1979	30.00	140962.	0.2421D+06	5.98	5.93	5.93

STOKELY	1980	0.0	3660000.	0.4232D+08	19.91	20.03	13.69
STOKELY	1980	1.00	3386349.	0.3880D+08	19.89	19.99	13.12
STOKELY	1980	2.00	3118927.	0.3554D+08	19.83	19.94	12.49
STOKELY	1980	3.00	2863960.	0.3255D+08	19.72	19.84	11.81
STOKELY	1980	4.00	2627676.	0.2981D+08	19.24	19.34	11.09
STOKELY	1980	5.00	2416304.	0.2729D+08	18.54	18.57	10.36
STOKELY	1980	6.00	2236071.	0.2497D+08	17.50	17.58	9.64
STOKELY	1980	7.00	2091327.	0.2281D+08	15.59	15.73	8.97
STOKELY	1980	8.00	1976268.	0.2077D+08	13.94	14.11	8.38
STOKELY	1980	9.00	1881672.	0.1885D+08	11.72	11.78	7.92
STOKELY	1980	10.00	1798312.	0.1701D+08	10.60	10.71	7.57
STOKELY	1980	11.00	1716964.	0.1525D+08	9.52	9.69	7.26
STOKELY	1980	12.00	1628403.	0.1358D+08	8.69	8.81	7.02
STOKELY	1980	13.00	1524712.	0.1200D+08	7.97	8.09	6.83
STOKELY	1980	14.00	1407332.	0.1053D+08	7.36	7.39	6.71
STOKELY	1980	15.00	1281784.	0.9186D+07	7.05	7.10	6.63
STOKELY	1980	16.00	1153606.	0.7968D+07	6.89	6.92	6.57
STOKELY	1980	17.00	1028335.	0.6878D+07	6.75	6.77	6.53
STOKELY	1980	18.00	911509.	0.5909D+07	6.66	6.71	6.50
STOKELY	1980	19.00	808192.	0.5050D+07	6.59	6.63	6.47
STOKELY	1980	20.00	718721.	0.4288D+07	6.53	6.57	6.44
STOKELY	1980	22.00	571779.	0.3003D+07	6.47	6.49	6.41
STOKELY	1980	24.00	451445.	0.1983D+07	6.41	6.43	6.38
STOKELY	1980	26.00	340453.	0.1192D+07	6.38	6.40	6.36
STOKELY	1980	28.00	235858.	0.6169D+06	6.35	6.37	6.34
STOKELY	1980	30.00	140962.	0.2421D+06	6.31	6.34	6.33

TROITE	1979	0.0	394600.	0.2066D+07	16.80	19.63	14.21
TROITE	1979	1.00	322582.	0.1708D+07	21.39	19.11	13.14
TROITE	1979	2.00	258894.	0.1418D+07	20.89	19.14	11.92
TROITE	1979	3.00	211865.	0.1184D+07	20.28	18.73	10.52
TROITE	1979	4.00	186834.	0.9866D+06	18.66	17.62	8.97
TROITE	1979	5.00	175247.	0.8062D+06	14.31	14.38	7.33
TROITE	1979	5.50	170560.	0.7197D+06	11.08	11.33	6.66
TROITE	1979	6.00	164511.	0.6359D+06	9.10	8.75	6.22
TROITE	1979	6.50	155733.	0.5557D+06	7.89	7.25	5.98
TROITE	1979	7.00	144364.	0.4806D+06	6.99	6.78	5.82
TROITE	1979	7.50	131222.	0.4116D+06	6.36	6.60	5.68
TROITE	1979	8.00	117127.	0.3495D+06	6.00	6.25	5.54
TROITE	1979	8.50	102898.	0.2945D+06	5.83	6.07	5.43
TROITE	1979	9.00	89357.	0.2465D+06	5.64	5.71	5.33
TROITE	1979	10.00	66769.	0.1689D+06	5.35	5.42	5.25
TROITE	1979	11.00	49898.	0.1110D+06	5.21	5.30	5.19
TROITE	1979	12.00	37322.	0.6773D+05	5.13	5.18	5.16
TROITE	1979	13.00	27517.	0.3539D+05	5.08	5.16	5.17

TROITE	1980	0.0	394600.	0.2066D+07	19.25
TROITE	1980	1.00	322582.	0.1708D+07	19.10
TROITE	1980	2.00	258894.	0.1418D+07	18.85
TROITE	1980	3.00	211865.	0.1184D+07	17.75
TROITE	1980	4.00	186834.	0.9866D+06	16.06
TROITE	1980	5.00	175247.	0.8062D+06	12.25
TROITE	1980	5.50	170560.	0.7197D+06	10.02
TROITE	1980	6.00	164511.	0.6359D+06	8.17
TROITE	1980	6.50	155733.	0.5557D+06	6.98
TROITE	1980	7.00	144364.	0.4806D+06	5.96
TROITE	1980	7.50	131222.	0.4116D+06	5.44
TROITE	1980	8.00	117127.	0.3495D+06	5.15
TROITE	1980	8.50	102898.	0.2945D+06	4.92
TROITE	1980	9.00	89357.	0.2465D+06	4.76
TROITE	1980	10.00	66769.	0.1689D+06	4.57
TROITE	1980	11.00	49898.	0.1110D+06	4.48
TROITE	1980	12.00	37322.	0.6773D+05	4.44
TROITE	1980	13.00	27517.	0.3539D+05	4.43

APPENDIX THREE

Summary of the temperatures measured on each sampling day. The data are arranged in the following groups:

1. Lake name, number of depths sampled.
2. Depths sampled below lake surface.
3. Area at each depth (square meter).
4. Number of temperature profiles.
5. Julian day on which profiles were collected.
6. Year lake was sampled.
7. Measured temperatures (celsius) at the depths mentioned earlier. Each new profile is started on a new line.

Note: As in Appendix Two, temperatures reported for 1980 only are 0.16 C low. Only temperatures measured between Julian day 121 and 272 are presented in this table. Duplicate temperature profiles were measured on most days. However in these tables the dates were adjusted by subtracting 1 day from the true date of the first profile and adding 1 day to the true date of the second (eg. 173, 173 is listed as 172, 174). This was done in order to use the cubic spline interpolations.

```
BIGBROMPTON  30
  0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.00 24.00 26.00
28.00 30.00 32.50 35.00 37.50 42.67
 9950000.  8859396.  7843019.  6975096.  6327048.  5905801.  5653782.  5510612.
 5415914.  5309311.  5138695.  4902536.  4618426.  4303989.  3976852.  3654640.
 3353361.  3075402.  2816327.  2571650.  2336883.  1879588.  1437074.  1045867.
  746016.   551198.   404735.   299852.   201890.        0.
 12
  172  174  197  199  211  213  226  228  240  242  254  256
1979
20.62 20.58 20.48 19.69 19.28 18.95 18.56 17.92 17.24 14.42 10.85  9.75
 8.54  7.54  7.34  7.21  7.14  7.07  7.01  6.92  6.84  6.69  6.62  6.53
 6.46  6.42  6.41  6.39  6.37  6.34
20.61 20.57 20.55 19.85 19.32 19.04 18.50 17.92 17.26 14.31 10.94  9.65
 8.30  7.59  7.32  7.21  7.11  7.05  6.99  6.90  6.83  6.70  6.63  6.55
 6.49  6.43  6.41  6.39  6.36  6.34
23.22 23.07 22.80 22.52 22.52 22.46 22.16 20.97 19.45 16.20 12.91 10.23
 9.20  8.52  7.95  7.81  7.55  7.33  7.15  6.83  6.72  6.69  6.65  6.61
 6.58  6.54  6.52  6.49  6.43  6.41
23.15 23.15 22.93 22.58 22.56 22.43 21.77 20.94 19.21 16.20 12.69 10.67
 8.98  8.59  8.10  7.85  7.67  7.38  7.23  7.09  6.82  6.71  6.65  6.64
 6.57  6.54  6.53  6.49  6.44  6.41
23.66 23.66 23.64 23.61 23.59 23.59 20.83 18.93 17.57 14.52 11.84  9.89
 8.80  8.37  7.58  7.33  7.15  7.10  7.00  6.87  6.80  6.72  6.68  6.61
 6.59  6.59  6.55  6.53  6.51  6.46
23.75 23.77 23.77 23.68 23.66 22.45 21.15 18.85 18.18 14.90 11.60  9.67
 8.78  8.41  7.97  7.43  7.15  7.09  6.96  6.90  6.85  6.72  6.68  6.60
 6.59  6.59  6.56  6.53  6.51  6.46
19.50 19.50 19.50 19.49 19.48 19.44 19.44 19.38 19.32 19.30 16.38 11.75
 9.93  8.16  7.81  7.51  7.35  7.32  7.08  6.94  6.92  6.86  6.79  6.73
 6.64  6.64  6.63  6.62  6.61  6.57
19.52 19.52 19.50 19.50 19.49 19.46 19.43 19.38 19.32 19.31 16.36 12.01
10.05  8.40  7.82  7.45  7.31  7.23  7.09  6.94  6.92  6.84  6.78  6.74
 6.65  6.64  6.64  6.63  6.61  6.57
19.13 19.14 19.13 19.11 19.11 19.10 19.09 19.06 18.37 17.06 14.13  9.84
 8.29  7.90  7.62  7.33  7.23  7.09  6.97  6.90  6.86  6.79  6.75  6.69
 6.67  6.64  6.61  6.60  6.58  6.55
19.13 19.14 19.13 19.11 19.11 19.10 19.06 18.83 18.48 17.49 16.63 10.72
 9.02  8.00  7.65  7.37  7.27  7.11  7.03  6.93  6.88  6.82  6.77  6.71
 6.67  6.64  6.61  6.61  6.58  6.55
18.01 17.33 17.25 17.22 17.22 17.21 17.21 17.20 17.19 17.17 17.11 16.96
15.93 11.27  9.12  7.92  7.64  7.47  7.33  7.22  7.11  6.98  6.90  6.86
 6.75  6.72  6.70  6.69  6.68  6.65
18.07 17.33 17.25 17.22 17.22 17.21 17.20 17.19 17.18 17.13 17.07 16.96
15.70 11.32  9.00  7.91  7.66  7.49  7.35  7.22  7.11  6.97  6.89  6.82
 6.75  6.71  6.70  6.69  6.68  6.66
```

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BIGBROMPTON  30
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.00 24.00 26.00
28.00 30.00 32.50 35.00 37.50 42.67
 9950000.  8859396.  7843019.  6975096.  6327048.  5905801.  5653782.  5510612.
 5415914.  5309311.  5138695.  4902536.  4618426.  4303989.  3976852.  3654640.
 3353361.  3075402.  2816327.  2571650.  2336883.  1879588.  1437074.  1045867.
  746016.   551198.   404735.   299852.   201890.        0.
21
  113  113  122  122  148  148  167  167  188  188  197  197  211  211  223  223
  230  263  263  285  298
1980
 9.43  7.58  6.81  6.27  6.03  5.95  5.92  5.71  5.28  5.21  5.10  4.93
 4.75  4.63  4.54  4.47  4.45  4.49  4.52  4.42  4.27  4.09  4.05  4.10
 4.15  4.17  4.13  4.09  4.07  4.09
 9.40  7.58  6.81  6.27  6.03  5.91  5.92  5.71  5.28  5.21  4.98  4.83
 4.75  4.64  4.54  4.49  4.45  4.36  4.28  4.25  4.25  4.25  4.22  4.19
 4.16  4.13  4.10  4.09  4.08  4.09
13.09 13.06 13.04 12.84 12.69 12.61 12.50 12.31 12.26 12.19 11.50 11.26
10.28  9.38  8.67  8.24  7.75  7.62  7.53  7.43  7.38  7.15  6.98  6.70
 6.54  6.27  6.21  6.17  6.13  6.12
13.02 13.06 13.04 12.84 12.69 12.61 12.50 12.31 12.26 12.19 11.50 11.12
10.34  8.90  8.65  8.19  7.92  7.63  7.58  7.47  7.36  7.07  7.00  6.68
 6.53  6.26  6.20  6.17  6.10  6.09
15.43 15.41 15.39 15.37 15.36 15.34 15.28 15.25 15.21 14.69 12.69 12.11
11.37  9.84  9.28  8.90  8.66  8.23  8.07  7.73  7.54  7.27  7.14  7.02
 6.93  6.90  6.83  6.78  6.70  6.70
15.42 15.41 15.39 15.37 15.36 15.34 15.28 15.25 15.19 14.31 12.59 12.13
11.34 10.53  9.36  8.90  8.74  8.21  8.05  7.76  7.54  7.28  7.14  7.00
 6.92  6.90  6.83  6.78  6.70  6.70
18.71 18.63 18.50 18.46 18.44 18.39 18.32 18.24 17.00 14.85 13.20 12.34
11.43 10.39  9.48  8.97  8.80  8.33  8.22  8.12  8.06  7.75  7.30  7.21
 7.21  7.19  7.15  7.07  7.07  7.06
18.71 18.63 18.50 18.46 18.44 18.39 18.32 18.24 16.96 14.73 13.22 12.15
10.82 10.31  9.18  8.92  8.63  8.25  8.21  8.15  7.99  7.77  7.29  7.22
 7.21  7.19  7.15  7.07  7.07  7.06
20.48 20.28 19.84 19.34 19.14 18.52 18.38 18.14 17.83 17.43 11.88 10.79
 9.58  8.74  8.38  8.06  7.92  7.56  7.48  7.41  7.38  7.23  7.17  7.16
 7.11  7.09  7.05  7.04  7.04  7.04
20.48 20.28 19.84 19.34 19.14 18.52 18.38 18.14 17.83 17.43 11.88 10.79
 9.58  8.72  8.38  8.06  7.92  7.57  7.49  7.41  7.38  7.24  7.18  7.18
 7.12  7.10  7.06  7.04  7.04  7.03
21.22 21.20 21.16 21.14 21.05 20.66 20.13 19.69 18.29 17.69 14.09 12.49
11.19  9.60  8.97  8.45  8.26  7.99  7.88  7.70  7.68  7.63  7.59  7.48
 7.47  7.46  7.45  7.44  7.43  7.42
21.74 21.20 21.16 21.14 21.05 20.66 20.13 19.69 18.29 17.76 13.90 12.53
11.06  9.66  9.11  8.57  8.32  8.07  7.96  7.80  7.76  7.68  7.62  7.53
 7.52  7.48  7.47  7.45  7.42  7.42
22.66 22.58 22.36 22.25 22.21 22.20 22.18 20.66 18.21 17.13 15.46 13.78
11.93 10.80  9.99  9.40  9.05  8.60  8.32  8.08  7.96  7.83  7.72  7.66
 7.64  7.60  7.57  7.54  7.52  7.52
22.66 22.58 22.36 22.25 22.21 22.20 22.18 20.61 18.04 16.75 15.44 13.78
11.80 10.82 10.06  9.39  9.08  8.63  8.35  8.14  7.91  7.79  7.71  7.69
 7.64  7.60  7.56  7.53  7.52  7.51
20.53 20.53 20.53 20.53 20.53 20.53 20.05 19.96 19.71 16.79 15.03 13.55
12.41 10.99  9.68  9.31  9.00  8.49  8.24  8.09  7.87  7.64  7.58  7.50
 7.42  7.39  7.35  7.33  7.32  7.32
```

15.39	15.34	15.28	15.21	15.15	15.13	15.11	15.08	15.01	14.91	14.83	14.49
13.97	12.71	11.62	9.83	9.26	9.00	8.30	8.26	8.10	7.87	7.77	7.68
7.63	7.59	7.52	7.49	7.48	7.47						
15.36	15.34	15.28	15.21	15.15	15.13	15.11	15.08	15.01	14.86	14.82	14.48
13.55	12.59	11.65	9.76	9.23	8.90	8.29	8.27	8.19	7.85	7.75	7.67
7.61	7.56	7.51	7.49	7.47	7.47						

```
CENTRAL       38
 0.0    1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00
12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.50  25.00  27.50
30.00  32.50  35.00  37.50  40.00  42.50  45.00  50.00  55.00  60.00  70.00  80.00
90.00 106.
21740000. 21477266. 21194716. 20872532. 20490899. 20030000. 19480795. 18877350.
18264507. 17687110. 17190000. 16804994. 16511805. 16277119. 16067621. 15850000.
15599068. 15322150. 15034698. 14752164. 14490000. 13958168. 13490000. 12981053.
12550000. 12315139. 12170160. 11952601. 11500000. 10708958.  9712332.  7870000.
 7123013.  7080000.  6840000.  5660000.  4610000.        0.
 16
  167   169   188   190   198   200   212   214   233   235   239   241   255   257   269   271
1979
17.47  17.32  17.23  17.16  17.11  17.01  16.71  16.64  16.32  15.95  15.42  14.83
13.66  12.73  11.79  10.57   9.39   8.63   8.18   7.70   7.30   6.02   5.58   5.01
 4.89   4.76   4.55   4.41   4.26   4.21   4.22   4.14   4.04   3.98   3.94   3.92
 3.93   3.92
17.95  17.60  17.33  17.23  17.17  17.07  16.87  16.77  16.61  16.31  15.41  14.55
13.46  12.91  12.53  11.30  10.18   9.06   8.42   7.86   7.50   6.31   5.71   5.07
 4.87   4.67   4.55   4.40   4.27   4.22   4.21   4.16   4.07   3.99   3.96   3.96
 3.94   3.90
18.48  18.47  18.34  18.14  17.98  17.83  17.75  17.72  17.70  17.66  17.52  16.60
15.41  14.57  13.55  12.17  10.84   9.20   8.11   7.88   7.45   6.55   6.07   5.75
 5.41   5.18   4.99   4.86   4.59   4.43   4.37   4.25   4.16   4.11   4.04   4.00
 3.93   3.90
18.58  18.52  18.29  18.08  17.97  17.86  17.84  17.77  17.71  17.65  17.37  16.25
15.05  14.26  13.31  12.08  10.91   9.10   7.95   7.62   7.21   6.62   6.17   5.77
 5.50   5.20   5.03   4.87   4.67   4.52   4.41   4.27   4.17   4.10   4.03   4.00
 3.93   3.90
23.56  22.87  22.33  22.19  22.07  21.53  21.47  21.39  20.63  20.13  19.74  18.84
15.79  13.74  13.06  11.94  11.21   9.27   8.38   7.75   7.36   6.70   6.22   5.78
 5.37   5.12   4.86   4.57   4.45   4.42   4.39   4.22   4.13   4.12   4.07   4.02
 3.98   3.96
23.54  23.14  22.41  22.23  22.06  21.53  21.43  20.94  20.58  20.05  19.61  18.69
15.35  13.90  13.19  11.94  10.87   9.52   8.35   7.70   7.28   6.70   6.22   5.78
 5.38   5.09   4.87   4.56   4.44   4.39   4.34   4.23   4.16   4.13   4.07   4.03
 3.99   3.96
24.01  23.92  23.67  23.42  23.38  23.35  23.13  22.35  21.06  20.52  19.58  18.34
17.13  13.27  12.23  11.13  10.22   7.97   7.15   6.86   6.30   5.79   5.57   5.37
 5.18   4.73   4.59   4.48   4.41   4.37   4.28   4.20   4.14   4.07   4.01   3.99
 3.94   3.96
24.20  24.13  23.95  23.64  23.50  23.43  23.40  22.75  21.28  21.04  20.21  18.95
17.53  14.11  12.87  11.33  10.12   8.21   7.58   7.07   6.51   6.05   5.56   5.36
 5.17   4.83   4.54   4.50   4.47   4.39   4.27   4.20   4.17   4.09   4.06   4.01
 3.94   3.96
19.34  19.26  19.21  19.17  19.06  18.86  18.80  18.75  18.88  18.55  18.45  18.38
18.04  14.67  13.09  11.78   9.63   8.68   8.19   7.84   7.18   6.72   6.32   5.28
 4.97   4.74   4.62   4.47   4.37   4.32   4.24   4.16   4.09   4.07   4.01   3.99
 3.95   3.96
19.58  19.39  19.33  19.27  19.23  19.04  18.92  18.87  18.79  18.63  18.63  18.45
18.16  14.25  13.10  11.67  10.78   9.18   8.25   7.87   7.22   6.62   5.86   5.27
 4.98   4.80   4.63   4.54   4.46   4.38   4.30   4.22   4.14   4.09   4.02   3.98
 3.94   3.96
19.87  19.86  19.62  19.37  19.35  19.17  19.10  19.07  18.99  18.92  18.91  18.14
16.34  15.32  12.94  12.17  10.61   9.51   8.78   8.13   7.22   6.38   5.84   5.40
 5.01   4.77   4.66   4.56   4.44   4.34   4.23   4.19   4.16   4.08   4.05   4.01
 3.97   3.96
```

20.08 19.87 19.61 19.41 19.39 19.23 19.10 19.08 19.00 18.94 18.88 18.59
16.98 15.87 13.58 12.31 10.85 10.72 8.96 8.20 7.23 6.41 5.96 5.49
5.07 4.83 4.71 4.60 4.48 4.36 4.24 4.18 4.14 4.07 4.05 4.01
3.98 3.96
19.37 18.74 18.60 18.29 18.24 18.18 18.16 18.16 18.14 18.13 18.13 18.12
18.10 18.10 17.98 15.45 12.20 10.09 9.90 8.46 8.14 7.43 6.93 6.27
5.77 5.32 4.92 4.84 4.67 4.58 4.53 4.36 4.26 4.23 4.11 4.06
4.04 4.00
18.75 18.75 18.60 18.29 18.24 18.18 18.16 18.16 18.14 18.13 18.13 18.12
18.10 18.09 18.07 16.71 13.12 10.20 9.77 8.20 8.01 7.28 6.89 6.19
5.53 5.25 4.85 4.63 4.57 4.51 4.45 4.36 4.28 4.20 4.09 4.05
4.05 4.00
15.94 15.87 15.88 15.71 15.69 15.61 15.60 15.58 15.58 15.56 15.57 15.56
15.55 15.54 15.60 14.79 13.23 10.40 9.02 8.57 7.73 7.12 6.73 6.12
5.39 4.98 4.80 4.59 4.47 4.42 4.35 4.31 4.29 4.15 4.09 4.05
4.03 4.00
15.95 15.87 15.88 15.70 15.69 15.61 15.60 15.58 15.58 15.56 15.57 15.56
15.54 15.57 15.23 15.05 12.62 9.97 8.79 8.44 7.81 7.10 6.88 6.19
5.49 4.92 4.79 4.61 4.50 4.47 4.37 4.29 4.23 4.14 4.08 4.04
4.03 4.00

```
CENTRAL      38
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.50 25.00 27.50
30.00 32.50 35.00 37.50 40.00 42.50 45.00 50.00 55.00 60.00 70.00 80.00
90.00
21740000. 21477266. 21194716. 20872532. 20490899. 20030000. 19480795. 18877350.
18264507. 17687110. 17190000. 16804994. 16511805. 16277119. 16067621. 15850000.
15599068. 15322150. 15034698. 14752164. 14490000. 13958168. 13490000. 12981053.
12550000. 12315139. 12170160. 11952601. 11500000. 10708958.  9712332.  7870000.
 7123013.  7080000.  6840000.  5660000.  4610000.        0.
25
  114  121  121  128  133  133  143  143  157  157  174  174  183  183  199  199
  213  213  235  235  263  263  271  285  299
1980
 3.42  3.40  3.38  3.38  3.36  3.37  3.35  3.33  3.34  3.34  3.33  3.32
 3.33  3.33  3.33  3.33  3.33  3.33  3.34  3.34  3.33  3.33  3.33  3.33
 3.33  3.34  3.34  3.34  3.34  3.35  3.35  3.35  3.36  3.36  3.36  3.37
 3.37  3.36
 3.40  3.40  3.40  3.40  3.40  3.40  3.40  3.40  3.40  3.40  3.40  3.40
 3.39  3.39  3.39  3.39  3.39  3.38  3.38  3.37  3.37  3.36  3.37  3.37
 3.38  3.39  3.39  3.39  3.39  3.39  3.39  3.38  3.38  3.38  3.39  3.37
 3.36  3.37
 4.91  4.86  4.81  4.77  4.72  4.72  4.73  4.72  4.65  4.41  4.32  4.28
 4.25  4.32  4.26  4.24  4.27  4.30  4.30  4.30  4.30  4.27  4.22  4.17
 4.15  4.12  4.10  4.08  4.07  4.06  4.05  4.03  4.01  3.99  3.99  3.93
 3.88  3.88
 6.50  6.44  6.40  6.34  6.13  6.06  5.76  5.62  5.57  5.54  5.50  5.44
 5.41  5.33  5.29  5.26  5.16  5.12  4.99  4.98  4.92  4.84  4.64  4.53
 4.48  4.44  4.43  4.29  4.23  4.17  4.13  4.01  3.99  4.01  3.81  3.74
 3.73  3.73
 6.35  6.35  6.31  6.26  6.28  6.21  6.15  6.04  5.80  5.56  5.52  5.50
 5.46  5.41  5.37  5.31  5.20  5.15  5.02  4.96  4.93  4.77  4.60  4.52
 4.48  4.43  4.40  4.29  4.27  4.17  4.09  4.01  3.95  3.90  3.80  3.74
 3.72  3.73
11.63 10.97 10.62 10.26 10.05  9.38  8.64  8.58  8.55  8.55  8.43  8.07
 7.43  6.83  6.56  6.48  6.08  5.92  5.76  5.71  5.69  5.48  5.29  5.20
 5.10  4.88  4.82  4.66  4.52  4.42  4.33  4.18  4.07  4.00  3.89  3.86
 3.83  3.82
13.33 10.97 10.62 10.26 10.05  9.38  8.64  8.58  8.55  8.59  8.58  6.95
 6.84  6.82  6.55  6.26  6.09  5.89  5.72  5.68  5.59  5.28  5.25  5.10
 4.95  4.83  4.67  4.57  4.53  4.43  4.29  4.13  4.05  4.01  3.91  3.86
 3.83  3.83
13.13 12.99 12.86 12.76 12.68 12.66 12.57 12.47 12.29 12.25 12.13 12.05
11.64 11.38 10.49 10.30  8.95  8.54  7.99  7.52  7.24  6.71  6.54  5.55
 5.15  4.90  4.70  4.52  4.45  4.33  4.22  4.17  4.10  4.02  3.95  4.14
 3.89  3.88
13.66 12.99 12.86 12.76 12.68 12.66 12.57 12.47 12.32 12.28 12.21 11.74
11.14 10.80 10.50  9.90  8.81  8.66  7.94  7.64  7.20  6.85  6.62  5.69
 5.16  4.86  4.68  4.54  4.45  4.34  4.23  4.17  4.11  4.02  3.96  3.91
 3.88  3.88
16.05 15.61 14.98 14.71 14.61 14.55 14.49 14.18 14.02 13.97 13.72 13.39
12.78 11.63 11.02 10.24  9.96  9.49  8.91  7.98  7.61  6.94  6.29  5.58
 5.30  4.97  4.80  4.60  4.48  4.36  4.33  4.27  4.22  4.17  4.02  3.99
 3.93  3.93
16.04 15.61 14.98 14.71 14.61 14.55 14.49 14.18 14.02 13.97 13.72 13.39
12.84 11.99 10.79 10.11  9.73  9.48  8.49  7.79  7.73  7.00  6.56  5.88
 5.51  5.15  4.80  4.66  4.50  4.37  4.33  4.30  4.25  4.17  4.02  3.98
```

3.94 3.93
17.92 17.93 17.92 17.93 17.73 17.19 16.93 16.68 16.03 14.97 14.51 12.90
12.61 12.33 11.76 10.59 9.90 8.62 8.01 7.57 7.32 6.96 6.41 6.05
5.38 5.12 5.00 4.72 4.49 4.38 4.34 4.26 4.19 4.13 4.06 4.00
3.98 4.00
17.95 17.92 17.89 17.86 17.55 17.26 17.01 16.72 15.99 15.01 14.40 12.86
12.62 12.25 11.68 10.42 9.73 8.50 8.03 7.56 7.31 6.94 6.41 6.05
5.57 5.08 4.93 4.72 4.50 4.39 4.35 4.26 4.19 4.13 4.06 4.00
3.98 4.00
19.85 19.81 19.72 19.68 19.65 19.58 18.79 18.26 17.72 16.85 16.27 16.35
15.48 12.63 11.76 10.58 10.03 9.36 8.94 8.22 7.95 7.03 6.51 5.81
5.50 5.02 4.94 4.79 4.55 4.45 4.34 4.19 4.12 4.10 4.06 4.02
3.97 3.95
19.85 19.81 19.72 19.68 19.65 19.58 18.79 18.26 17.72 16.85 16.27 16.35
15.48 12.63 11.76 10.58 10.02 9.39 9.08 8.46 8.07 7.15 6.58 6.01
5.61 5.12 4.95 4.71 4.53 4.44 4.32 4.19 4.14 4.12 4.06 4.03
3.97 3.95
21.87 21.85 21.63 21.32 21.17 21.14 21.09 20.89 20.56 19.41 17.46 16.16
15.02 12.62 11.58 10.59 9.52 9.02 8.52 8.21 7.81 7.16 6.56 6.07
5.52 5.15 4.72 4.54 4.43 4.34 4.29 4.18 4.12 4.08 4.01 3.98
3.95 3.95
22.00 21.96 21.85 21.49 21.37 21.29 21.16 20.88 20.63 20.25 17.64 16.31
15.18 13.76 12.83 11.13 9.74 9.11 8.79 8.44 8.14 7.34 6.78 6.20
5.42 4.97 4.65 4.50 4.41 4.31 4.28 4.18 4.11 4.08 4.01 3.98
3.95 3.95
21.95 20.86 20.57 20.45 20.38 20.24 20.16 20.02 19.88 19.86 19.70 19.58
15.28 13.61 12.49 11.54 10.80 9.33 8.64 8.29 7.96 7.35 6.82 6.33
5.87 5.49 4.90 4.66 4.48 4.44 4.35 4.28 4.24 4.18 4.10 4.05
3.99 3.98
21.89 20.87 20.57 20.45 20.38 20.24 20.17 20.02 19.88 19.86 19.65 19.50
15.53 13.65 12.42 11.74 10.77 9.34 8.98 8.49 8.08 7.29 6.70 6.20
5.69 5.19 4.77 4.61 4.48 4.42 4.35 4.28 4.24 4.17 4.10 4.05
3.98 3.98
16.42 16.42 16.40 16.27 16.21 16.08 16.05 16.00 15.97 15.89 15.87 15.82
15.79 15.70 15.61 15.21 14.40 12.77 9.89 8.97 8.69 7.73 7.52 7.31
6.89 6.29 5.71 5.28 4.74 4.45 4.38 4.32 4.23 4.18 4.14 4.09
4.06 4.05
16.35 16.34 16.29 16.21 16.21 16.08 16.05 16.00 15.97 15.89 15.87 15.82
15.79 15.66 15.57 15.23 14.46 12.98 9.84 8.96 8.28 7.63 7.27 7.11
6.51 6.12 5.59 5.00 4.83 4.61 4.39 4.34 4.25 4.16 4.15 4.14
4.06 4.05
14.28 14.28 14.29 14.29 14.29 14.29 14.29 14.29 14.29 14.28 14.28 14.27
14.27 14.25 14.20 14.16 14.15 13.91 13.58 12.77 10.69 8.53 7.44 6.43
5.53 4.72 4.00 3.36 2.81 2.35 1.96 1.40 1.12 1.09 1.69 3.00
4.82 8.31

FITCH BAY 19
0.0 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00
2803000. 2675483. 2546046. 2412766. 2273725. 2127000. 1972176. 1814856.
1662148. 1521160. 1399000. 1298621. 1206354. 1104378. 974867. 800000.
568433. 294747. 0.
12
135 137 154 156 202 204 208 210 224 226 239 241
1979
16.06 15.70 14.92 13.99 12.22 11.58 11.34 10.98 10.43 10.15 9.54 8.55
7.50 6.77 6.23 6.09 5.93 5.91 5.96
15.79 15.50 14.96 14.01 12.40 11.40 11.21 10.82 10.36 10.06 9.46 8.31
7.53 6.89 6.18 6.17 5.98 5.95 6.02
17.88 17.28 16.56 16.42 16.29 16.13 16.09 15.55 13.57 11.58 11.17 10.78
9.64 8.63 7.97 7.38 6.80 6.68 6.86
17.77 17.31 16.52 16.42 16.31 16.21 16.09 15.52 13.61 11.65 11.16 10.65
9.38 8.58 7.93 7.38 6.80 6.69 6.87
24.36 24.38 24.31 23.96 23.87 23.40 22.76 22.25 20.88 18.92 17.46 13.39
10.98 9.51 8.30 7.86 7.55 7.46 7.54
24.31 24.32 24.32 24.02 23.96 23.27 22.69 22.19 21.04 19.16 17.47 13.66
11.16 9.55 8.27 7.81 7.52 7.43 7.51
18.92 23.31 22.56 22.34 22.02 20.91 20.40 19.92 19.18 18.11 14.09 10.68
9.31 8.59 7.89 7.61 7.57 7.60 7.51
24.22 23.35 22.56 22.34 22.04 20.93 20.40 19.97 19.30 18.35 13.77 10.60
9.27 8.57 7.89 7.61 7.57 7.60 7.51
20.79 20.79 20.78 20.78 20.75 20.74 20.71 21.04 20.68 20.31 14.53 12.13
9.61 8.55 7.89 7.70 7.71 7.70 7.51
20.79 20.79 20.78 20.78 20.75 20.74 20.73 20.73 20.69 20.27 14.61 11.63
9.64 8.54 7.87 7.71 7.71 7.71 7.51
20.94 18.97 19.47 19.53 19.44 19.42 19.36 19.27 19.20 18.84 17.23 12.96
10.65 8.97 7.90 7.72 7.73 7.72 7.51
20.94 18.97 19.47 19.53 19.44 19.43 19.37 19.27 19.21 18.86 17.22 12.43
10.61 8.93 8.00 7.73 7.66 7.71 7.51

```
FITCH BAY    19
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00
 2803000.  2675483.  2546046.  2412766.  2273725.  2127000.  1972176.  1814856.
 1662148.  1521160.  1399000.  1298621.  1206354.  1104378.   974867.   800000.
  568433.   294747.        0.
 31
  114   114   121   121   128   128   133   133   136   136   143   143   152   152   157   157
  164   164   171   171   179   179   192   192   205   205   234   234   255   255   263
1980
 8.30  7.62  7.29  6.86  6.52  6.62  6.43  6.50  6.00  4.79  4.69  4.51
 4.32  4.25  4.23  4.21  4.20  4.20  4.20
 8.20  7.90  7.24  7.10  6.78  6.60  6.53  6.45  6.37  5.75  4.77  4.53
 4.53  4.37  4.21  4.18  4.20  4.21  4.19
 8.85  8.55  8.36  8.22  8.18  8.14  8.10  8.05  7.99  7.97  7.92  7.75
 7.58  6.75  5.36  4.71  4.75  4.74  4.74
 8.91  8.47  8.41  8.32  8.23  8.15  8.13  8.12  8.11  8.04  7.94  7.87
 7.72  6.79  5.09  4.78  4.74  4.74  4.74
10.98 10.77 10.32 10.23  9.99  9.80  9.51  9.48  9.32  9.07  8.54  7.91
 7.38  7.06  6.60  6.30  6.12  5.95  5.97
11.09 10.82 10.28 10.23  9.98  9.80  9.53  9.49  9.37  9.34  9.07  8.31
 7.34  7.00  6.61  6.28  6.17  5.96  5.99
11.51 11.25 10.81 10.72 10.52 10.18  9.99  9.66  9.53  9.31  9.19  8.87
 8.17  7.78  6.59  5.82  5.71  5.59  5.60
11.51 11.25 10.81 10.72 10.52 10.18  9.99  9.68  9.59  9.28  9.09  8.76
 8.46  7.91  7.25  6.11  5.76  5.57  5.59
16.52 15.71 13.61 12.79 12.55 12.19 11.53 10.30 10.05  9.69  9.32  8.95
 8.42  8.11  7.55  6.60  6.50  6.43  6.44
17.27 15.65 13.63 12.78 12.55 12.19 11.52 10.22  9.96  9.67  9.45  8.92
 8.46  8.12  7.47  6.65  6.48  6.46  6.46
14.71 14.62 14.56 14.49 14.49 14.47 14.39 14.37 14.33 14.44 13.54  9.99
 8.80  8.18  7.66  7.45  7.33  7.31  7.34
14.65 14.62 14.55 14.49 14.49 14.47 14.39 14.36 14.37 14.26 12.73  9.91
 8.94  8.33  7.77  7.46  7.33  7.31  7.34
15.59 15.06 14.09 13.46 13.07 12.96 12.65 12.10 11.71 10.26  9.79  9.18
 8.83  8.22  7.84  7.33  7.31  7.24  7.24
15.53 15.07 14.09 13.46 13.07 12.96 12.64 12.11 11.84 10.40  9.82  9.31
 8.90  8.21  7.85  7.34  7.31  7.24  7.24
15.36 15.30 15.02 14.46 14.19 14.18 14.09 13.49 12.94 12.53 11.74 10.81
 9.02  8.54  8.26  7.94  7.45  7.36  7.36
15.23 15.31 15.02 14.46 14.19 14.18 14.09 13.49 12.95 12.59 11.73 10.82
 8.98  8.50  8.20  7.86  7.44  7.39  7.38
16.01 16.00 16.00 15.98 15.59 14.96 14.78 14.49 13.95 13.61 12.17  9.66
 8.92  8.41  8.04  7.77  7.61  7.58  7.62
16.01 16.00 16.00 15.98 15.62 14.93 14.68 14.63 14.21 13.72 12.32  9.49
 8.80  8.29  7.95  7.76  7.60  7.57  7.61
19.05 18.95 18.44 16.10 15.68 15.26 14.72 14.07 13.81 13.57 12.42 10.94
 9.19  8.42  8.14  7.86  7.70  7.63  7.63
19.05 18.85 18.32 16.45 15.75 15.32 14.73 14.12 13.79 13.54 12.08 10.71
 9.13  8.36  8.12  7.85  7.69  7.64  7.64
19.60 19.60 19.60 19.48 19.34 19.29 19.20 18.63 17.34 17.24 13.43 12.24
 9.77  9.08  8.33  7.93  7.91  7.91  7.90
19.64 19.65 19.59 19.49 19.33 19.30 19.20 19.09 17.14 16.25 13.34 12.17
 9.50  9.05  8.46  7.93  7.90  7.91  7.89
21.87 21.50 21.42 21.36 21.21 21.14 20.90 18.13 17.25 16.01 14.07 11.42
 9.74  8.66  8.22  7.98  7.76  7.70  7.76
22.00 21.50 21.42 21.36 21.21 21.14 20.90 18.13 17.21 16.00 14.11 11.50
```

9.63	8.59	8.19	7.94	7.75	7.70	7.75						
20.65	20.56	20.50	20.47	20.45	20.43	20.31	20.06	19.38	17.86	13.35	10.88	
9.57	8.74	8.17	7.98	7.98	7.98	7.75						
20.70	20.56	20.50	20.47	20.45	20.42	20.29	19.98	19.31	17.70	13.50	10.88	
9.31	8.63	8.14	7.98	7.99	7.98	7.75						
18.69	18.58	18.54	18.51	18.45	18.41	18.37	18.36	18.17	17.68	17.30	13.21	
10.30	9.17	8.56	8.34	8.31	8.33	7.75						
18.68	18.58	18.54	18.51	18.45	18.41	18.37	18.35	18.17	17.66	17.38	13.11	
10.10	9.06	8.51	8.33	8.31	8.32	7.75						
16.68	16.63	16.50	16.48	16.47	16.45	16.44	16.40	16.37	16.34	16.03	15.83	
15.62	13.91	9.03	8.42	8.24	8.13	8.24						

LITTLEBROMPT 19

0.0 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.50
71430000. 64565481. 57415869. 49696071. 41324631. 33166666. 26362126. 21832557.
19318051. 18161089. 17678799. 17035088. 15335943. 11978622. 8446014. 7129899.
9732809. 2122620. 0.
22
122 122 125 125 162 162 178 178 197 197 211 211 223 231 231 238
238 256 256 271 285 298
1980
9.51 8.79 7.96 7.25 6.78 6.45 6.15 5.98 5.79 5.77 5.69 5.60
5.54 5.48 5.44 5.42 5.35 5.20 5.19
9.81 8.90 7.86 7.21 6.91 6.45 6.16 5.96 5.79 5.75 5.63 5.56
5.53 5.48 5.44 5.41 5.34 5.20 5.19
10.26 10.09 9.64 10.23 8.59 7.86 6.64 6.13 6.06 5.84 5.71 5.65
5.60 5.56 5.55 5.46 5.41 5.41 5.46
10.10 12.90 9.54 9.35 8.88 8.02 6.73 6.15 6.06 5.85 5.80 5.67
5.59 5.56 5.54 5.47 5.42 5.42 5.46
14.24 14.24 14.23 14.23 14.23 14.21 14.21 10.01 7.57 6.93 6.45 6.17
5.97 5.77 5.63 5.48 5.43 5.42 5.42
14.25 14.24 14.23 14.23 14.23 14.20 14.15 9.74 7.75 7.01 6.47 6.17
5.97 5.78 5.62 5.48 5.43 5.42 5.42
20.72 20.74 20.73 20.60 17.37 15.51 13.60 11.48 8.71 7.04 6.59 6.23
6.00 5.86 5.70 5.58 5.52 5.50 5.52
20.70 20.74 20.68 20.60 17.37 15.51 13.75 11.56 8.42 7.22 6.65 6.23
5.97 5.89 5.71 5.56 5.52 5.52 5.52
18.16 18.39 18.42 17.71 17.61 17.05 13.43 10.15 7.88 6.66 6.06 5.69
5.28 5.18 4.93 4.79 4.66 4.61 4.66
20.37 18.39 18.42 17.71 19.00 18.25 15.07 11.15 8.66 7.24 6.60 6.17
5.74 5.64 5.39 5.32 5.19 5.13 5.19
23.17 23.16 22.98 22.70 22.52 19.92 16.39 12.98 10.27 8.74 7.60 6.98
6.55 6.17 6.03 5.92 5.87 5.85 5.86
23.05 23.16 22.98 22.70 22.33 19.83 15.97 12.87 9.71 8.52 7.48 7.00
6.56 6.19 6.03 5.91 5.87 5.86 5.86
23.34 23.32 22.61 22.59 22.51 22.41 17.52 13.18 10.18 8.39 7.57 7.16
6.88 6.41 6.18 6.10 5.98 5.93 5.98
20.66 20.62 20.60 20.58 20.27 19.96 19.15 13.76 10.71 8.32 7.35 6.77
6.38 6.12 5.93 5.82 5.65 5.58 5.64
20.66 20.61 20.60 20.58 20.29 19.83 19.23 13.73 10.40 8.43 7.43 6.81
6.45 6.15 5.92 5.80 5.64 5.57 5.64
21.41 21.38 21.28 21.11 20.34 19.98 19.32 14.65 10.25 8.31 7.39 6.81
6.39 6.06 5.85 5.75 5.66 5.62 5.65
21.70 21.38 21.21 21.11 20.34 19.93 18.91 14.00 10.28 8.24 7.51 6.88
6.48 6.05 5.84 5.75 5.66 5.62 5.65
17.73 17.74 17.74 17.71 17.69 17.51 17.38 17.12 11.61 9.18 7.94 7.31
6.85 6.45 6.11 5.93 5.87 5.86 5.93
16.86 17.74 17.74 17.71 17.69 17.51 17.34 17.08 11.85 9.17 7.94 7.27
6.80 6.43 6.08 5.92 5.87 5.87 5.92
13.11 13.08 13.07 13.06 13.06 13.06 11.99 12.97 12.94 12.88 11.14 7.44
6.81 6.27 6.10 5.79 5.61 5.61 5.79

LOVERING 24

0.0	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00	10.00	11.00
12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	24.00

5210000.	4846097.	4496388.	4175066.	3890805.	3626611.	3358039.	3063653.	
2738292.	2382271.	1999377.	1614602.	1260950.	968352.	744604.	587859.	
493729.	436788.	381074.	294594.	185744.	86113.	25103.	0.	

12

141	143	163	165	204	206	219	221	247	249	260	262

1979

16.42	16.24	15.95	15.50	15.09	14.88	14.07	11.15	9.86	9.63	9.26	9.20
9.18	9.14	9.12	8.90	8.81	8.81	8.79	8.63	8.63	8.61	8.59	8.59
16.43	16.28	15.95	15.51	15.10	14.92	14.07	11.12	9.83	9.47	9.34	9.25
9.16	9.12	8.82	8.83	8.80	8.79	8.71	8.64	8.69	8.62	8.59	8.59
18.07	18.07	18.08	18.08	18.07	18.03	17.60	15.77	12.76	10.67	10.22	9.99
9.94	9.83	9.62	9.22	9.17	9.09	9.02	8.98	8.95	8.92	8.84	8.84
18.07	18.07	18.07	18.07	18.08	18.04	17.66	15.96	12.47	10.62	10.19	9.99
9.94	9.81	9.48	9.22	9.15	9.09	9.01	8.98	8.95	8.93	8.91	8.91
25.28	24.76	24.58	23.87	20.11	18.38	18.12	15.90	13.27	11.38	11.00	10.75
10.33	10.19	9.88	9.72	9.59	9.45	9.32	9.24	9.18	9.13	9.12	8.91
25.30	24.70	24.56	24.16	19.93	18.30	17.90	15.85	13.21	11.47	10.98	10.76
10.45	10.16	9.90	9.73	9.59	9.45	9.32	9.24	9.18	9.13	9.12	8.91
23.35	23.35	23.26	23.21	23.16	23.09	22.71	18.73	15.78	13.63	12.38	11.62
11.19	10.79	10.40	10.05	9.74	9.73	9.61	9.53	9.48	9.42	9.37	9.37
23.39	23.37	23.29	23.24	23.15	23.05	22.74	19.58	16.05	13.52	12.34	11.60
11.14	10.88	10.49	10.06	9.91	9.72	9.61	9.51	9.47	9.41	9.37	9.37
21.57	21.54	20.96	20.34	20.17	19.19	19.10	19.48	19.11	17.26	13.70	12.07
11.47	11.22	10.90	10.58	10.19	9.86	9.72	9.59	9.51	9.48	9.44	9.44
21.57	21.54	20.96	20.34	20.17	19.19	19.10	19.42	19.11	17.26	13.47	12.06
11.50	11.21	10.89	10.57	10.20	9.86	9.74	9.58	9.51	9.48	9.46	9.45
17.42	17.40	17.33	17.28	17.14	17.05	17.03	17.03	16.98	16.98	16.41	15.22
12.33	11.58	11.15	10.72	10.20	10.05	9.96	9.85	9.72	9.66	9.66	9.45
17.50	17.40	17.32	17.26	17.10	17.05	17.03	17.03	16.98	16.97	16.35	15.65
12.32	11.61	10.59	10.71	10.28	10.05	9.97	9.83	9.72	9.66	9.66	9.45

LOVERING 24

Q.0 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 21.00 22.00 24.00
5210000. 4846097. 4496388. 4175066. 3890805. 3626611. 3358039. 3063653.
2738292. 2382271. 1999377. 1614602. 1260950. 968352. 744604. 587859.
493729. 436788. 381074. 294594. 185744. 86113. 25103. 0.

23

114 116 119 119 125 127 133 135 145 147 180 182 194 196 208 210
237 239 254 256 271 285 298

1980

9.74 9.36 9.07 8.90 8.39 7.94 7.60 7.45 7.29 7.20 6.80 6.18
6.08 5.95 5.68 5.68 5.64 5.58 5.53 5.50 5.45 5.41 5.43 5.27
10.21 8.97 6.58 9.00 7.99 7.79 7.59 7.37 7.28 7.21 6.97 6.23
6.05 5.81 5.79 5.73 5.68 5.64 5.61 5.52 5.49 5.46 5.42 5.24
10.62 10.60 10.60 10.59 10.60 10.34 9.34 9.12 8.60 8.13 7.52 7.47
7.29 7.13 7.05 6.95 6.89 6.79 6.74 6.67 6.58 6.54 6.52 6.48
10.62 10.60 10.60 10.59 10.61 10.34 9.35 9.37 8.98 8.25 7.64 7.52
7.33 7.16 7.06 6.98 6.87 6.81 6.78 6.69 6.58 6.54 6.51 6.48
13.69 13.62 13.19 12.84 12.67 12.65 12.63 12.54 12.49 12.20 10.52 10.05
8.98 8.89 8.64 8.41 8.47 8.42 8.22 8.08 8.05 8.00 7.84 7.55
13.61 13.55 13.20 12.83 12.67 12.65 12.63 12.54 12.50 12.20 10.35 9.94
9.11 8.85 8.72 8.48 8.45 8.36 8.25 8.09 8.09 8.05 7.85 7.49
20.01 19.90 19.56 19.48 19.13 17.42 14.89 14.08 13.49 12.30 12.11 11.88
11.30 10.64 10.24 9.67 9.47 9.28 9.18 9.11 9.02 8.92 8.86 8.80
20.11 19.90 19.55 19.48 19.13 17.46 14.86 14.06 13.61 12.35 12.22 11.86
11.36 10.71 10.36 9.67 9.47 9.30 9.23 9.13 9.04 8.93 8.85 8.81
19.50 19.24 19.05 18.84 18.81 18.78 17.96 16.54 15.56 14.47 12.57 11.74
11.53 11.36 10.90 10.03 9.89 9.69 9.53 9.43 9.38 9.37 9.33 9.29
19.52 19.24 19.05 18.84 18.81 18.78 17.95 16.54 15.66 14.37 12.56 11.78
11.53 11.31 10.90 10.18 9.88 9.73 9.55 9.43 9.38 9.37 9.32 9.28
22.38 22.36 22.36 22.34 22.32 22.30 21.82 17.09 15.55 13.28 12.58 11.99
11.64 11.26 11.08 10.85 10.42 9.92 9.76 9.64 9.56 9.53 9.52 9.44
22.37 22.36 22.36 22.34 22.32 22.29 19.32 17.05 15.01 13.25 11.84 11.76
11.56 11.29 11.06 10.80 10.41 9.98 9.73 9.62 9.55 9.52 9.52 9.44
22.18 22.18 21.96 21.27 20.84 19.96 19.75 19.06 17.73 14.38 13.52 12.18
11.80 11.48 11.47 10.92 10.82 10.49 10.20 9.73 9.66 9.63 9.54 9.54
22.27 22.18 21.96 21.27 20.84 19.96 19.75 19.06 17.24 14.72 12.97 12.42
12.05 11.76 11.13 10.85 10.77 10.08 9.88 9.84 9.68 9.60 9.54 9.54
18.07 18.07 18.05 17.99 17.77 17.72 17.69 17.51 17.38 17.22 15.75 13.54
12.77 12.40 11.75 11.22 11.03 10.67 10.25 10.13 10.02 9.99 9.90 9.86
17.97 18.07 18.05 17.99 17.77 17.72 17.69 17.51 17.46 17.12 15.48 13.15
12.64 12.25 11.71 11.31 10.96 10.47 10.19 10.07 10.01 9.99 9.90 9.86
14.04 14.04 14.02 14.02 14.02 14.03 14.04 14.04 14.04 14.03 14.01 13.98
13.97 13.66 13.27 12.79 11.03 10.53 10.27 10.09 10.02 9.75 9.72 9.86

```
LYSTER        31
  0.0    1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00
 12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.00  24.00  26.00
 28.00  30.00  32.50  35.00  37.50  40.00  49.99
  1710000.   1613787.   1520782.   1434192.   1357224.   1293085.   1243361.   1205098.
  1174554.   1147987.   1121654.   1092543.   1061131.   1028945.    997507.    968342.
   942278.    917815.    892967.    865749.    834176.    755060.    668921.    595483.
   536435.    475669.    381888.    281924.    192791.    118390.         0.
 10
   204    206    225    227    247    249    260    262    274    276
 1979
 23.46  23.46  23.41  23.43  23.06  19.87  18.02  17.11  15.73  13.32  10.96   9.52
  8.28   7.51   6.88   6.55   6.26   6.03   5.86   5.76   5.67   5.43   5.24   5.09
  4.94   4.84   4.75   4.72   4.68   4.64   4.63
 23.54  23.53  23.49  23.45  23.35  20.27  18.31  17.20  15.87  13.36  11.15   9.77
  8.56   7.84   7.10   6.67   6.43   5.64   5.93   5.82   5.72   5.50   5.26   5.11
  4.97   4.85   4.76   4.73   4.68   4.64   4.63
 18.13  18.12  18.08  18.06  18.05  18.05  18.04  17.45  14.21  11.77   9.96   8.51
  7.75   7.34   7.01   6.62   6.31   6.11   5.89   5.73   5.48   5.26   5.08   5.43
  4.89   4.76   4.69   4.65   4.62   4.61   4.63
 18.15  18.11  18.11  18.07  18.05  18.04  18.02  17.71  14.46  11.83  10.01   8.66
  7.78   7.34   6.97   6.58   6.31   6.10   5.89   5.73   5.49   5.26   5.08   4.96
  4.88   4.77   4.69   4.65   4.62   4.62   4.63
 19.44  19.42  19.24  19.07  19.06  18.80  18.22  17.58  15.95  13.62  11.23   9.25
  8.19   7.64   7.18   6.70   6.41   6.17   5.87   5.71   5.48   5.31   5.10   4.99
  4.88   4.82   4.76   4.69   4.64   4.64   4.63
 19.45  19.37  19.20  19.08  19.03  19.08  18.38  17.90  15.90  13.50  10.91   9.12
  8.02   7.54   7.02   6.68   6.44   6.17   5.88   5.74   5.48   5.31   5.10   4.98
  4.88   4.81   4.75   4.69   4.64   4.64   4.63
 15.83  15.81  15.77  15.73  15.69  15.65  15.60  15.52  15.35  15.14  15.10  13.53
  9.83   8.41   7.39   6.74   6.42   6.11   5.84   5.72   5.53   5.36   5.23   5.11
  5.00   4.84   4.80   4.75   4.71   4.70   4.63
 15.87  15.83  15.81  15.78  15.76  15.74  15.68  15.61  15.28  15.14  15.12  13.04
  9.61   8.23   7.26   6.69   6.38   6.11   5.92   5.76   5.55   5.37   5.23   5.10
  4.98   4.83   4.79   4.75   4.70   4.70   4.63
```

```
LYSTER          31
 0.0    1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00
12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.00  24.00  26.00
28.00  30.00  32.50  35.00  37.50  40.00  49.99
 1710000.  1613787.  1520782.  1434192.  1357224.  1293085.  1243361.  1205098.
 1174554.  1147987.  1121654.  1092543.  1061131.  1028945.   997507.   968342.
  942278.   917815.   892967.   865749.   834176.   755060.   668921.   595483.
  536435.   475669.   381888.   281924.   192791.   118390.        0.
 12
  119   119   125   127   189   191   203   205   231   233   254   256
1980
 5.42  5.41  5.37  5.28  5.28  5.26  5.24  5.20  5.20  5.16  5.11  5.08
 5.06  5.04  5.02  5.02  5.02  5.01  5.01  5.00  4.99  5.00  4.97  4.87
 4.72  4.56  4.42  4.34  4.30  4.29  4.28
 5.32  5.31  5.29  5.28  5.26  5.24  5.22  5.21  5.21  5.19  5.19  5.17
 5.14  5.10  5.07  5.05  5.03  5.02  5.01  5.01  5.00  4.96  4.88  4.79
 4.70  4.60  4.49  4.40  4.33  4.28  4.28
17.33 17.32 17.31 17.31 17.31 17.27 16.93 16.55 15.25 13.31 11.55  9.48
 8.51  7.58  6.97  6.68  6.37  6.09  5.96  5.85  5.78  5.60  5.40  5.28
 5.24  5.16  5.07  5.03  4.99  4.95  4.94
17.22 17.33 17.31 17.31 17.31 17.27 16.93 16.55 15.25 13.33 11.55  9.57
 8.07  7.46  6.99  6.62  6.44  6.13  6.01  5.91  5.82  5.64  5.44  5.31
 5.24  5.17  5.07  5.03  4.99  4.95  4.94
20.53 20.54 20.54 20.53 20.09 19.02 18.27 17.21 16.17 13.84 11.50 10.12
 9.19  8.41  7.62  7.22  6.80  6.36  6.02  5.80  5.70  5.51  5.39  5.27
 5.19  5.07  5.01  4.95  4.90  4.87  4.83
20.53 20.54 20.54 20.53 20.09 19.03 18.27 17.22 16.14 13.37 11.28 10.03
 8.88  8.32  7.47  6.98  6.88  6.22  5.94  5.54  5.69  5.44  5.33  5.24
 5.14  5.07  5.01  4.94  4.90  4.87  4.83
18.56 18.55 18.55 18.54 18.53 18.53 18.51 18.55 16.97 13.18 11.36  9.69
 8.82  7.70  7.28  6.94  6.49  6.18  6.00  5.77  5.59  5.38  5.30  5.20
 5.14  5.03  4.97  4.92  4.90  4.90  4.83
18.52 18.51 18.51 18.51 18.50 18.49 18.47 18.45 17.01 13.24 11.36  9.91
 8.98  7.93  7.34  6.88  6.47  6.18  5.96  5.80  5.60  5.39  5.29  5.19
 5.14  5.03  4.97  4.93  4.91  4.90  4.83
17.10 17.09 17.08 17.06 17.03 17.02 16.89 16.83 16.78 16.03 12.52 10.71
 9.18  8.31  7.62  7.06  6.73  6.40  6.08  5.85  5.59  5.45  5.32  5.26
 5.21  5.13  5.06  5.01  4.98  4.97  4.83
17.03 17.02 17.08 17.06 17.03 17.02 16.89 16.81 16.59 15.79 12.78 10.82
 9.02  8.26  7.57  6.97  6.68  6.39  6.07  5.84  5.58  5.45  5.32  5.26
 5.20  5.15  5.06  5.00  4.97  4.97  4.83
```

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MASSAWIPPI   38
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.50 25.00 27.50
30.00 32.50 35.00 37.50 40.00 42.50 45.00 47.50 50.00 55.00 60.00 70.00
80.00 85.95
21000000. 20627909. 20253911. 19876095. 19492556. 19101383. 18700670. 18288035.
17858549. 17406420. 16925857. 16411072. 15856271. 15258404. 14634648. 14011254.
13414511. 12870713. 12406149. 12043997. 11776394. 11351981. 10954675. 10368440.
 9746906.  9263216.  8918952.  8641010.  8379561.  8118126.  7844408.  7554241.
 7246624.  6655579.  6230112.  5319786.  2422441.        0.
 14
  157  159  178  180  199  201  213  215  231  233  251  253  270  272
1979
19.05 17.67 17.32 17.11 16.73 14.98 11.36 10.29  9.62  9.54  9.24  8.51
 8.18  7.33  6.89  6.58  6.20  5.94  5.67  5.49  5.35  5.21  4.96  4.63
 4.52  4.47  4.40  4.30  4.21  4.16  4.12  4.06  3.99  3.91  3.87  3.79
 3.71  3.71
19.05 17.67 17.32 17.11 16.73 14.98 11.36 10.29  9.62  9.54  9.24  8.51
 8.18  7.33  6.89  6.58  6.20  5.72  5.56  5.41  5.40  5.24  5.07  4.73
 4.57  4.47  4.38  4.30  4.23  4.17  4.11  4.05  3.99  3.91  3.87  3.79
 3.74  3.73
18.25 18.19 18.08 17.99 17.77 17.62 17.40 17.16 10.71  8.43  7.48  7.16
 6.84  6.61  6.27  6.10  6.07  5.80  5.59  5.47  5.22  5.05  4.81  4.64
 4.45  4.40  4.33  4.24  4.20  4.17  4.12  4.07  3.99  3.93  3.84  3.77
 3.76  3.73
18.28 18.18 18.13 17.91 17.89 17.80 17.40 16.98 11.82  7.85  7.18  6.89
 6.62  6.36  6.21  6.17  6.15  5.88  5.56  5.40  5.18  5.01  4.80  4.66
 4.47  4.41  4.34  4.27  4.23  4.19  4.15  4.10  4.02  3.96  3.84  3.77
 3.76  3.73
22.87 22.77 22.76 22.59 22.62 19.82 18.87 17.04 15.43 10.85  9.40  8.39
 7.46  7.02  6.71  6.58  6.42  6.14  5.98  5.82  5.46  5.17  4.96  4.78
 4.65  4.52  4.39  4.28  4.19  4.11  4.06  4.01  3.96  3.92  3.86  3.80
 3.79  3.73
22.85 22.83 22.71 22.52 22.53 19.63 18.87 17.39 15.55 11.10  9.91  9.02
 7.61  7.04  6.77  6.64  6.52  6.17  5.97  5.88  5.45  5.28  5.03  4.83
 4.67  4.55  4.42  4.28  4.18  4.11  4.06  4.01  3.96  3.92  3.85  3.80
 3.79  3.73
25.05 24.78 24.56 24.46 24.41 23.83 21.06 14.58 13.04 12.91 12.00 10.64
 8.83  7.86  7.19  6.77  6.41  6.20  6.13  6.11  5.77  5.47  5.17  4.92
 4.78  4.63  4.51  4.43  4.34  4.25  4.20  4.16  4.08  4.00  3.87  3.80
 3.79  3.73
25.19 24.89 24.62 24.51 24.36 24.05 20.07 14.31 13.17 13.10 11.47 10.31
 8.89  8.06  7.54  7.07  6.67  6.28  6.12  6.05  5.79  5.49  5.20  4.93
 4.77  4.63  4.51  4.42  4.34  4.27  4.21  4.17  4.09  4.00  3.87  3.80
 3.79  3.73
18.96 18.92 18.91 18.90 18.89 18.92 18.76 19.34 14.87 11.54  9.91  8.84
 7.87  7.25  7.06  6.87  6.63  6.39  6.18  5.96  5.67  5.40  5.13  4.96
 4.83  4.68  4.54  4.41  4.32  4.26  4.20  4.15  4.07  4.03  3.97  3.84
 3.82  3.73
18.98 18.93 18.91 18.90 18.89 18.91 18.81 19.13 16.24 12.10 10.10  8.87
 7.72  7.19  7.01  6.82  6.60  6.37  6.16  5.95  5.65  5.38  5.11  4.94
 4.81  4.66  4.52  4.40  4.32  4.25  4.19  4.14  4.07  4.02  3.96  3.83
 3.82  3.73
19.77 19.66 19.55 19.48 19.43 19.37 19.34 19.25 19.42 14.24 11.36  9.02
 7.87  7.37  7.10  6.87  6.65  6.39  6.23  6.14  5.80  5.47  5.22  4.97
 4.74  4.57  4.45  4.36  4.28  4.22  4.17  4.12  4.03  3.96  3.93  3.84
 3.83  3.73
```

19.93	19.65	19.55	19.47	19.42	19.37	19.31	19.35	17.22	13.38	10.71	9.04
7.95	7.42	7.15	6.91	6.68	6.52	6.30	6.19	5.89	5.54	5.27	5.06
4.77	4.62	4.50	4.39	4.30	4.24	4.18	4.12	4.03	3.96	3.93	3.84
3.83	3.73										
15.02	15.02	15.00	14.98	14.98	14.98	14.96	14.96	14.96	14.95	14.94	14.89
13.54	9.49	8.76	8.26	7.86	7.46	7.19	6.96	6.49	6.17	5.84	5.48
5.23	5.05	4.93	4.79	4.64	4.50	4.41	4.35	4.31	4.21	4.10	3.96
3.88	3.88										
15.02	15.02	15.00	14.98	14.98	14.98	14.96	14.96	14.96	14.94	14.92	14.84
14.41	9.50	8.86	8.38	7.96	7.61	7.31	7.04	6.78	6.24	5.89	5.53
5.32	5.13	4.95	4.79	4.64	4.51	4.42	4.36	4.32	4.21	4.09	3.96
3.88	3.88										

```
MASSAWIPPI    38
 0.0    1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00 10.00 11.00
12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.50  25.00  27.50
30.00  32.50  35.00  37.50  40.00  42.50  45.00  47.50  50.00  55.00  60.00  70.00
80.00  85.95
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17858549. 17406420. 16925857. 16411072. 15856271. 15258404. 14634648. 14011254.
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 7246624.  6655579.  6230112.  5319786.  2422441.        0.
 18
  120   120   119   169   169   185   185   204   204   220   220   232   232   255   255   271
  285   298
1980
15.75 15.78 15.74 15.54 15.48 14.72 14.55 11.74 11.60 10.15  8.90  8.63
 8.12  7.60  7.28  6.62  6.38  6.15  5.98  5.79  5.65  5.50  5.24  5.01
 4.87  4.75  4.60  4.36  4.34  4.32  4.24  4.14  4.05  3.96  3.91  3.76
 3.71  3.70
15.74 15.75 15.74 15.54 15.48 15.33 14.39 13.47 12.85 12.27 11.70  9.03
 8.62  8.09  7.66  7.48  6.75  6.57  6.37  6.03  5.68  5.50  5.20  4.93
 4.80  4.73  4.61  4.42  4.36  4.32  4.24  4.16  4.08  3.98  3.92  3.77
 3.71  3.70
19.97 19.69 19.45 19.30 19.15 16.25 14.23 11.47  9.76  8.92  8.15  7.55
 7.06  6.58  6.14  6.01  5.89  5.79  5.71  5.53  5.33  5.15  4.96  4.78
 4.66  4.54  4.45  4.34  4.27  4.20  4.12  4.05  3.96  3.92  3.84  3.77
 3.77  3.70
19.97 19.70 19.44 19.32 19.19 18.72 13.98 11.42  9.76  9.09  8.25  7.54
 7.14  6.85  6.43  6.12  5.98  5.87  5.78  5.68  5.41  5.23  5.06  4.80
 4.67  4.54  4.43  4.34  4.27  4.21  4.13  4.06  3.96  3.94  3.86  3.78
 3.78  3.70
21.43 21.39 21.32 20.81 20.51 18.67 17.60 16.92 11.64  9.58  8.67  8.02
 7.63  6.89  6.55  6.51  6.26  6.04  5.95  5.84  5.56  5.29  5.06  4.87
 4.73  4.62  4.50  4.41  4.29  4.22  4.17  4.12  4.02  3.92  3.72  3.69
 3.68  3.70
21.43 21.39 21.32 20.81 20.52 18.48 17.48 16.03 11.22  9.58  8.86  8.09
 7.61  6.81  6.55  6.53  6.33  6.07  5.97  5.84  5.53  5.28  5.06  4.89
 4.73  4.62  4.51  4.41  4.30  4.23  4.17  4.13  4.03  3.91  3.72  3.69
 3.68  3.70
22.78 22.66 22.81 22.83 22.68 22.46 20.45 16.06 13.65 12.46  9.66  8.27
 7.90  7.59  7.38  7.16  6.87  6.60  6.41  6.26  5.91  5.56  5.32  5.13
 4.96  4.81  4.71  4.59  4.46  4.39  4.33  4.28  4.19  4.12  4.03  3.95
 3.94  3.70
22.78 22.66 22.81 22.84 22.64 22.61 19.26 16.16 14.27 11.79  9.23  8.52
 8.22  7.78  7.49  7.23  6.87  6.64  6.49  6.32  5.92  5.55  5.34  5.14
 4.98  4.82  4.75  4.61  4.48  4.42  4.36  4.30  4.20  4.14  4.03  3.95
 3.95  3.70
20.19 20.19 20.11 20.07 20.03 20.05 19.66 18.22 14.83 11.67  9.93  8.58
 7.93  7.38  7.10  6.82  6.54  6.44  6.27  5.95  5.63  5.41  5.23  5.07
 4.86  4.75  4.67  4.43  4.35  4.28  4.24  4.16  4.08  4.00  3.84  3.82
 3.82  3.70
20.15 20.14 20.10 20.06 20.04 19.99 19.74 17.97 15.09 11.55  9.16  8.37
 7.60  7.15  6.99  6.83  6.51  6.36  6.29  6.22  5.81  5.48  5.31  5.13
 4.90  4.80  4.67  4.43  4.33  4.27  4.23  4.17  4.08  4.01  3.84  3.82
 3.82  3.70
18.45 18.36 18.27 18.16 18.03 17.87 17.85 17.83 17.86 14.95 11.61  9.43
 8.80  8.02  7.54  7.09  6.85  6.64  6.51  6.34  6.13  5.87  5.57  5.18
 4.94  4.76  4.63  4.53  4.43  4.36  4.33  4.25  4.12  4.08  3.95  3.83
```

3.82	3.70										
18.46	18.36	18.27	18.16	18.03	17.89	17.86	17.71	17.74	13.79	12.06	10.52
8.71	8.37	7.76	7.28	6.88	6.62	6.55	6.43	6.22	6.04	5.76	5.46
5.14	4.93	4.71	4.55	4.48	4.40	4.36	4.29	4.13	4.08	3.95	3.83
3.82	3.70										
14.26	14.25	14.23	14.21	14.20	14.20	14.21	14.21	14.16	14.10	14.07	13.75
13.31	12.63	10.76	9.54	8.21	7.73	7.53	7.43	7.29	7.02	6.48	5.84
5.64	5.50	5.37	5.15	4.94	4.73	4.67	4.57	4.48	4.25	4.12	3.92
3.85	3.85										

```
NORTH BASIN  26
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.00 24.00 26.00
28.00 33.20
18810000. 18176781. 17549367. 16933562. 16335172. 15760000. 15214127. 14704734.
14239277. 13825214. 13470000. 13170791. 12883538. 12553888. 12127493. 11550000.
10782948.  9851436.  8796449.  7658975.  6480000.  4164239.  2190769.   890432.
 283565.        0.
 12
  137  139  150  152  185  187  233  235  255  257  269  271
1979
16.07 12.54 11.12 10.68 10.49 10.28  9.46  8.41  7.98  7.77  7.69  7.60
 7.46  7.32  7.25  7.18  7.18  7.00  6.99  6.78  6.76  6.66  6.59  6.37
 6.13  6.14
16.08 12.55 11.11 10.64 10.50 10.29  9.45  8.39  7.99  7.78  7.70  7.60
 7.45  7.32  7.25  7.19  7.20  6.99  6.96  6.77  6.71  6.65  6.58  6.38
 6.11  6.13
13.22 13.22 13.22 13.20 13.20 13.20 13.19 12.93 12.22 11.92 11.05 10.51
 9.99  9.48  8.92  8.74  8.57  8.20  7.94  7.74  7.56  7.37  7.12  6.96
 6.80  6.81
13.22 13.22 13.21 13.20 13.20 13.18 13.18 13.10 12.63 11.93 11.12 10.44
 9.98  9.49  8.98  8.70  8.50  8.10  7.89  7.72  7.58  7.34  7.09  6.96
 6.84  6.85
19.03 19.03 19.02 19.02 19.00 18.98 18.98 18.92 18.87 18.84 18.67 17.80
13.91 11.41 10.47 10.27  9.57  9.48  9.31  9.27  9.13  8.94  8.88  8.69
 8.29  8.29
19.03 19.07 19.03 19.02 18.99 18.99 18.98 18.98 18.87 18.84 18.70 17.69
13.68 11.45 10.46 10.04  9.61  9.45  9.38  9.16  9.06  8.98  8.81  8.65
 8.31  8.31
20.49 19.81 19.65 19.50 19.43 19.39 19.34 19.32 19.30 19.28 19.26 17.95
14.49 11.86 11.07 10.67 10.46 10.11  9.91  9.81  9.56  9.41  9.19  9.01
 9.00  8.31
20.38 19.85 19.69 19.56 19.45 19.41 19.34 19.32 19.30 19.28 19.22 18.32
14.39 11.79 11.07 10.67 10.41 10.12  9.91  9.81  9.56  9.41  9.21  9.03
 9.01  8.31
18.52 18.47 18.45 18.43 18.32 18.42 18.41 18.40 18.40 18.35 18.34 18.32
18.28 17.47 13.76 12.19 11.07 10.66 10.46 10.37 10.29 10.11  9.88  9.69
 9.48  9.47
18.52 18.47 18.45 18.43 18.42 18.42 18.41 18.40 18.40 18.35 18.32 18.30
18.19 17.59 13.85 12.29 11.13 10.72 10.45 10.37 10.25 10.10  9.88  9.68
 9.47  9.47
15.99 15.96 15.94 15.93 15.92 15.91 15.90 15.89 15.89 15.88 15.86 15.85
15.86 15.73 15.91 13.50 11.90 11.31 10.91 10.55 10.31 10.10  9.94  9.65
 9.63  9.47
15.99 15.96 15.94 15.93 15.92 15.91 15.90 15.89 15.89 15.88 15.86 15.85
15.87 15.76 15.88 13.51 11.81 11.26 10.81 10.54 10.35 10.10  9.94  9.65
 9.63  9.47
```

```
NORTH BASIN  26
 0.0   1.00  2.00  3.00  4.00  5.00  6.00  7.00  8.00  9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.00 24.00 26.00
28.00 33.20
18810000. 18176781. 17549367. 16933962. 16335172. 15760000. 15214127. 14704734.
14239277. 13825214. 13470000. 13170791. 12883538. 12553888. 12127493. 11550000.
10782948.  9851436.  8796449.  7658975.  6480000.  4164239.  2190769.   890432.
  283565.        0.
 26
  113  115  121  132  134  135  137  149  151  163  165  178  180  191  193  205
  207  216  218  233  235  255  257  271  285  299
1980
 5.25  5.24  5.23  5.21  5.18  5.16  5.15  5.14  5.15  5.16  5.17  5.17
 5.16  5.14  5.12  5.10  5.07  5.04  5.02  4.99  4.97  4.93  4.91  4.90
 4.89  4.89
 8.25  8.03  7.78  7.69  7.61  7.59  7.56  7.49  7.36  7.28  7.22  7.18
 7.06  6.97  6.95  6.94  6.91  6.90  6.79  6.66  6.60  6.37  5.95  5.66
 5.60  5.44
 8.22  8.05  7.73  7.65  7.60  7.56  7.57  7.52  7.43  7.37  7.22  7.21
 7.14  6.99  6.96  6.95  6.94  6.88  6.78  6.68  6.62  6.35  5.95  5.64
 5.44  5.43
 8.46  8.44  8.37  8.23  8.14  7.98  7.95  7.94  7.92  7.91  7.90  7.76
 7.50  7.38  7.25  7.09  7.00  6.94  6.81  6.59  6.48  6.31  6.15  5.75
 5.65  5.64
 8.60  8.56  8.36  8.24  8.14  7.98  7.96  7.93  7.95  7.97  7.76  7.71
 7.55  7.45  7.34  7.18  7.06  6.99  6.77  6.57  6.50  6.34  6.14  5.70
 5.65  5.64
12.21 11.71 11.16 10.54 10.42 10.30 10.24 10.14  9.96  9.67  9.55  9.16
 9.00  8.86  8.66  8.59  8.38  8.23  8.12  7.93  7.87  7.57  7.44  7.22
 7.20  7.14
12.30 11.01 11.24 10.56 10.48 10.40 10.13  9.56  9.92  9.66  9.52  9.17
 9.00  8.86  8.66  8.63  8.46  8.25  8.14  7.95  7.86  7.56  7.43  7.23
 7.20  7.14
13.41 13.35 13.30 13.26 13.21 13.11 12.76 12.69 12.63 12.46 12.32 12.11
12.11 11.93 10.77  9.90  9.46  9.22  8.94  8.36  8.05  7.89  7.85  7.55
 7.36  7.27
13.41 13.35 13.30 13.26 13.21 13.11 12.76 12.68 12.63 12.46 12.31 12.11
12.11 11.83 10.86  9.77  9.49  9.22  8.98  8.32  8.04  7.94  7.85  7.52
 7.44  7.26
18.50 18.50 18.48 18.45 18.41 18.40 18.34 17.67 16.78 15.53 14.25 12.94
11.39 10.91 10.76 10.16  9.35  9.24  9.07  8.85  8.67  8.42  8.02  7.98
 7.84  7.71
18.57 18.56 18.56 18.55 18.54 18.52 18.31 17.25 16.72 15.86 15.21 13.38
12.46 12.08 11.00 10.22  9.99  9.37  9.25  9.02  8.56  8.45  8.06  7.99
 7.84  7.69
20.08 20.07 20.02 19.92 19.87 19.86 19.70 19.18 18.33 17.19 14.85 12.75
11.63 11.27 10.41  9.99  9.75  9.70  9.62  9.46  9.33  9.27  9.01  8.66
 8.53  8.33
20.27 20.07 20.02 19.92 19.87 19.86 19.70 19.18 18.33 17.19 15.31 12.96
11.48 11.19 10.45 10.04  9.70  9.66  9.60  9.35  9.32  9.22  8.98  8.65
 8.55  8.33
21.79 21.79 21.79 21.75 21.67 21.53 21.47 21.17 18.25 16.33 15.08 13.84
12.57 11.74 10.85  9.97  9.86  9.70  9.59  9.48  9.35  9.17  9.02  8.84
 8.60  8.60
21.79 21.79 21.75 21.68 21.54 21.47 21.20 19.08 16.67 15.83 13.45 12.53
11.59 10.51  9.99  9.87  9.72  9.59  9.46  9.35  9.18  9.05  8.85  8.61
 8.60  8.60
```

23.68 23.48 23.12 22.76 22.62 22.49 22.25 21.97 20.49 17.54 15.53 13.80
11.97 10.72 10.28 10.20 9.87 9.66 9.56 9.54 9.40 8.97 8.87 8.84
8.75 8.60
23.69 23.48 23.12 22.75 22.62 22.49 22.25 21.97 20.41 17.28 15.41 14.19
11.93 10.91 10.34 10.13 9.94 9.82 9.57 9.53 9.42 8.97 8.87 8.84
8.76 8.60
21.49 20.87 20.77 20.69 20.61 20.52 20.48 20.35 20.20 19.83 16.76 13.11
11.54 10.87 10.59 10.43 10.23 10.16 9.99 9.83 9.61 9.34 9.20 8.98
8.95 8.60
21.46 20.88 20.77 20.69 20.61 20.52 20.48 20.35 20.20 19.82 17.72 13.13
11.54 10.93 10.55 10.40 10.22 10.13 9.97 9.83 9.60 9.35 9.20 8.98
8.95 8.60
18.44 18.37 18.32 18.29 18.27 18.25 18.23 18.22 18.20 18.22 17.94 17.99
14.36 12.58 11.83 11.26 10.89 10.65 10.51 10.39 10.14 10.02 9.78 9.67
9.67 8.60
18.45 18.37 18.32 18.29 18.27 18.25 18.23 18.22 18.17 18.21 17.94 17.97
14.27 12.46 11.87 11.31 10.87 10.62 10.50 10.39 10.11 9.96 9.77 9.68
9.67 8.60
14.47 14.47 14.47 14.47 14.48 14.49 14.51 14.52 14.54 14.54 14.54 14.53
14.50 14.46 14.42 14.44 13.83 12.21 11.05 10.61 10.19 9.97 9.80 9.72
9.71 8.60

```
ORFORD          30
  0.0    1.00    2.00    3.00    4.00    5.00    6.00    7.00    8.00    9.00   10.00   11.00
 12.00   13.00   14.00   15.00   16.00   17.00   18.00   19.00   20.00   22.00   24.00   26.00
 28.00   30.00   32.50   35.00   37.50   49.00
  1278000.   1197117.   1117765.   1041477.    969784.    904218.    846311.    797240.
   756277.    722049.    693183.    668307.    646047.    625150.    605216.    586218.
   568131.    550928.    534583.    519052.    504104.    474601.    443357.    408375.
   372810.    342062.    315438.    285878.    228334.         0.
  12
   191   193   205   207   220   222   232   234   249   251   262   264
1979
21.84 21.79 21.57 20.30 19.59 18.79 18.32 16.03 12.18  9.78  8.29  7.58
 6.83  5.66  5.51  5.37  5.21  5.17  5.04  4.95  4.86  4.73  4.66  4.58
 4.52  4.46  4.42  4.39  4.38  4.38
21.86 21.84 21.62 20.27 19.52 18.76 18.21 16.05 12.78  9.95  8.34  7.26
 6.60  5.67  5.51  5.33  5.24  5.11  5.04  4.98  4.89  4.75  4.68  4.59
 4.54  4.47  4.42  4.39  4.38  4.38
25.50 25.44 25.32 24.66 23.82 21.74 19.38 16.30 13.42 10.10  8.59  7.38
 6.90  5.96  5.76  5.56  5.42  5.27  5.14  4.99  4.88  4.76  4.66  4.59
 4.53  4.47  4.45  4.37  4.34  4.34
25.61 25.55 25.40 24.77 23.94 21.04 18.92 16.41 12.84  9.52  8.54  7.43
 6.98  6.33  5.87  5.67  5.51  5.36  5.22  5.05  4.92  4.79  4.67  4.60
 4.55  4.49  4.41  4.39  4.35  4.35
22.35 22.35 22.35 22.35 22.35 22.35 22.32 17.58 13.98 10.94  8.74  7.58
 6.57  6.24  5.92  5.67  5.42  5.22  5.10  4.97  4.85  4.72  4.64  4.57
 4.50  4.46  4.41  4.35  4.33  4.33
22.36 22.36 22.35 22.35 22.35 22.35 22.25 17.17 13.28 10.91  8.50  7.54
 6.52  6.14  5.79  5.54  5.31  5.17  5.06  4.94  4.83  4.71  4.63  4.55
 4.50  4.45  4.40  4.35  4.33  4.33
18.42 18.13 18.05 18.02 18.00 17.98 17.95 17.93 16.21 11.14  9.10  7.94
 6.94  6.26  5.84  5.60  5.36  5.19  5.07  4.96  4.87  4.73  4.64  4.54
 4.49  4.43  4.41  4.36  4.35  4.35
18.45 18.15 18.06 18.01 17.99 17.97 17.95 17.88 16.35 10.94  9.38  7.98
 6.95  6.16  5.82  5.55  5.32  5.15  5.04  4.94  4.87  4.74  4.64  4.55
 4.49  4.44  4.42  4.30  7.73  7.86
19.75 19.76 19.76 17.01 19.70 19.68 19.68 18.84 16.40 12.43  9.59  8.19
 7.28  6.63  6.13  5.75  5.45  5.31  5.18  5.08  4.98  4.82  4.70  4.59
 4.56  4.48  4.38  4.35  4.33  4.33
19.76 19.76 19.76 19.73 19.70 19.70 19.68 18.66 15.81 12.78  9.58  8.13
 7.23  6.67  6.16  5.73  5.47  5.29  5.17  5.05  4.97  4.80  4.70  4.59
 4.55  4.48  4.38  4.35  4.33  4.33
16.00 16.02 16.02 16.02 16.01 15.98 15.98 15.98 15.96 15.79 12.21  8.52
 7.42  6.78  6.28  5.77  5.49  5.31  5.17  5.08  4.99  4.77  4.67  4.56
 4.50  4.46  4.41  4.37  4.37  4.36
16.00 16.02 16.02 16.02 16.01 15.98 15.98 15.98 16.04 15.75 12.40  8.84
 7.60  6.84  6.26  5.78  5.46  5.31  5.17  5.08  4.96  4.78  4.67  4.57
 4.51  4.48  4.41  4.37  4.36  4.36
```

```
ORFORD        30
 0.0    1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00
12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.00  24.00  26.00
28.00  30.00  32.50  35.00  37.50  49.00
 1278000.  1197117.  1117765.  1041477.   969784.   904218.   846311.   797240.
  756277.   722049.   693183.   668307.   646047.   625150.   605216.   586218.
  568131.   550928.   534583.   519052.   504104.   474601.   443357.   408375.
  372810.   342062.   315438.   285878.   228334.        0.
 23
  115   115   122   122   132   132   190   190   203   203   209   209   216   216   226   226
  237   237   263   263   271   285   298
1980
 5.94  5.91  5.91  5.90  5.91  5.92  5.91  5.85  5.25  5.15  5.11  5.04
 4.97  4.91  4.84  4.78  4.73  4.68  4.63  4.58  4.54  4.48  4.44  4.41
 4.39  4.37  4.35  4.34  4.33  4.33
 5.90  5.91  5.91  5.90  5.91  5.87  5.86  5.81  5.73  5.15  5.08  5.15
 5.16  5.13  5.07  4.99  4.89  4.78  4.67  4.57  4.48  4.37  4.33  4.33
 4.35  4.36  4.36  4.34  4.32  4.33
 8.82  8.71  8.68  8.64  8.59  8.59  8.55  8.50  8.01  7.09  6.81  6.37
 6.19  5.96  5.38  5.16  5.06  4.98  4.89  4.77  4.69  4.59  4.53  4.49
 4.43  4.41  4.40  4.36  4.35  4.32
 8.87  8.71  8.68  8.64  8.59  8.59  8.55  8.66  8.43  7.25  6.96  6.10
 5.99  5.26  5.13  5.01  4.97  4.87  4.78  4.71  4.66  4.58  4.53  4.46
 4.44  4.42  4.39  4.37  4.35  4.32
15.92 16.02 16.05 16.02 16.02 16.01 15.93 13.44 11.46  9.59  7.60  6.51
 6.17  5.65  5.08  4.91  4.64  4.53  4.41  4.38  4.28  4.22  4.12  4.07
 4.04  3.99  3.96  3.94  3.92  3.94
18.98 18.95 18.84 18.75 18.56 18.37 16.78 14.71 12.43  9.94  8.20  7.14
 6.41  5.94  5.46  5.20  4.96  4.86  4.75  4.65  4.53  4.33  4.24  4.19
 4.17  4.11  4.07  4.02  4.00  3.94
21.09 21.07 21.06 21.05 21.00 19.48 18.52 15.65 13.26 10.73  8.97  7.59
 6.72  6.33  6.00  5.72  5.53  5.26  5.04  4.90  4.77  4.55  4.44  4.39
 4.32  4.30  4.26  4.23  4.22  4.20
21.09 21.07 21.06 21.05 21.00 19.46 18.51 15.91 12.94 10.63  8.90  7.61
 6.75  6.33  5.96  5.75  5.49  5.15  4.96  4.86  4.73  4.51  4.43  4.39
 4.32  4.29  4.26  4.22  4.22  4.20
21.67 21.67 21.57 21.48 21.53 20.57 19.50 16.61 13.78 11.03  9.26  7.91
 6.83  6.38  5.73  5.45  5.25  5.03  4.87  4.78  4.71  4.56  4.46  4.42
 4.88  4.33  4.30  4.26  4.24  4.23
22.10 21.67 21.57 21.48 21.53 20.57 19.50 16.61 13.78 11.03  9.58  8.04
 6.97  6.49  5.96  5.60  5.37  5.14  4.95  4.84  4.75  4.59  4.51  4.43
 4.38  4.33  4.29  4.26  4.25  4.22
22.40 22.45 22.43 22.40 22.40 22.39 20.30 16.72 13.86 11.54  9.83  8.15
 7.29  6.62  5.84  5.53  5.31  5.09  5.02  4.85  4.78  4.66  4.57  4.49
 4.44  4.38  4.31  4.27  4.25  4.24
22.65 22.45 22.43 22.40 22.63 21.55 20.68 16.68 13.76 11.61  9.46  8.03
 7.31  6.62  6.07  5.86  5.63  5.38  5.24  5.17  5.06  4.68  4.58  4.48
 4.44  4.39  4.31  4.28  4.25  4.24
21.17 21.18 21.15 21.13 21.09 21.07 20.99 18.61 14.36 11.91 10.01  8.37
 6.64  6.37  5.98  5.71  5.50  5.29  5.10  4.97  4.92  4.76  4.60  4.50
 4.42  4.39  4.33  4.29  4.27  4.26
21.17 21.18 21.15 21.13 21.09 20.99 20.72 17.94 14.36 11.33  9.86  8.41
 7.06  6.46  6.08  5.74  5.49  5.31  5.13  4.99  4.91  4.74  4.60  4.51
 4.43  4.39  4.34  4.32  4.27  4.26
21.30 21.21 21.18 21.12 21.04 20.06 19.82 18.79 15.86 12.47  8.82  8.30
 7.26  6.60  6.25  6.00  5.70  5.41  5.16  4.96  4.82  4.66  4.58  4.53
 4.45  4.40  4.32  4.30  4.28  4.26
```

21.19	21.21	21.18	21.12	21.04	20.06	19.82	19.18	15.38	12.55	9.12	8.00
6.91	6.42	6.10	5.83	5.56	5.33	5.13	4.91	4.81	4.64	4.58	4.53
4.45	4.40	4.32	4.29	4.27	4.26						
15.66	15.66	15.57	15.53	15.52	15.49	15.47	15.45	15.32	15.40	11.23	8.57
7.54	6.77	6.29	5.85	5.53	5.26	5.05	4.90	4.78	4.62	4.51	4.45
4.40	4.34	4.26	4.25	4.24	4.22						
15.57	15.66	15.57	15.53	15.52	15.49	15.47	15.45	15.35	14.97	12.25	8.32
7.40	6.60	6.22	5.30	5.48	5.20	5.01	4.87	4.78	4.62	4.49	4.45
4.39	4.33	4.26	4.24	4.24	4.22						
13.17	13.17	13.17	13.17	13.17	13.16	13.17	13.18	13.15	13.12	12.95	10.74
7.55	6.97	6.30	5.88	5.53	5.26	5.14	5.01	4.84	4.70	4.57	4.49
4.40	4.36	4.29	4.25	4.24	4.24						

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STUKELEY      27
 0.0   1.00   2.00   3.00   4.00   5.00   6.00   7.00   8.00   9.00  10.00  11.00
12.00  13.00  14.00  15.00  16.00  17.00  18.00  19.00  20.00  22.00  24.00  26.00
28.00  30.00  33.53
 3660000.  3386349.  3118927.  2863960.  2627676.  2416304.  2236071.  2091327.
 1976268.  1881672.  1798312.  1716964.  1628403.  1524712.  1407332.  1281784.
 1153606.  1028335.   911509.   808192.   718721.   571779.   451445.   340453.
  235858.   140962.        0.
14
  169   171   193   195   205   207   219   221   232   234   249   251   262   264
1979
19.34 19.10 19.01 18.82 18.53 17.67 17.16 15.86 11.63  9.63  7.92  7.71
 7.02  6.61  6.44  6.36  6.26  6.20  6.15  6.09  6.05  6.00  5.94  5.87
 5.83  5.83  5.83
19.38 19.36 18.96 18.82 18.53 17.66 17.06 15.85 11.40  9.71  8.25  7.62
 6.94  6.58  6.43  6.32  6.25  6.21  6.17  6.11  6.06  6.00  5.92  5.89
 5.84  5.83  5.83
22.74 22.46 21.79 20.30 19.53 18.83 18.02 17.09 14.99 11.44 10.20  8.97
 8.22  7.78  7.11  6.73  6.62  6.45  6.37  6.26  6.18  6.11  6.02  5.99
 5.99  5.96  5.96
22.92 22.58 21.86 20.26 19.42 18.79 18.19 17.31 14.76 11.68 10.23  8.97
 8.13  7.80  7.33  6.78  6.60  6.46  6.34  6.26  6.18  6.10  6.02  5.99
 5.99  5.96  5.96
25.02 24.91 24.74 24.32 23.56 21.82 18.77 17.05 14.62 12.53 10.79  9.52
 8.61  7.74  7.15  6.78  6.61  6.51  6.41  6.33  6.27  6.13  6.11  6.08
 6.01  6.00  5.99
25.07 24.97 24.71 24.34 23.41 21.99 19.03 17.07 14.36 12.36 10.84  9.68
 8.60  7.65  7.08  6.76  6.59  6.48  6.39  6.32  6.26  6.13  6.10  6.07
 6.01  6.00  5.99
22.92 22.92 22.95 22.93 22.93 22.92 22.77 17.80 14.90 12.86 10.92  9.45
 8.35  7.51  6.99  6.71  6.59  6.53  6.42  6.38  6.32  6.20  6.15  6.11
 6.08  6.03  6.02
22.91 22.93 22.93 22.92 22.92 22.92 22.89 17.86 15.00 12.72 11.14  9.65
 8.38  7.50  6.99  6.71  6.59  6.53  5.91  6.37  6.32  6.20  6.15  6.12
 6.07  6.03  6.02
19.06 18.84 18.45 18.33 18.28 18.24 18.18 18.15 17.93 13.21 11.55  9.68
 8.90  8.02  7.25  6.97  6.72  6.53  6.45  6.40  6.37  6.28  6.21  6.15
 6.12  6.09  6.08
19.23 18.77 18.45 18.32 18.28 18.22 18.16 18.13 17.82 13.24 11.46  9.65
 8.80  7.80  7.22  6.96  6.74  6.55  6.44  6.40  6.37  6.27  6.20  6.15
 6.12  6.09  6.08
19.74 19.74 19.74 19.69 19.68 19.67 19.64 17.91 15.39 12.61 10.20  8.65
 7.97  7.23  7.03  6.89  6.73  6.53  6.48  6.44  6.31  6.28  6.21  6.18
 6.15  6.14  6.08
19.76 19.75 19.71 19.70 19.69 19.68 19.51 17.92 14.90 12.84 10.16  8.64
 7.97  7.29  7.01  6.90  6.74  6.54  6.49  6.44  6.30  6.26  6.21  6.17
 6.15  6.14  6.08
16.00 16.00 16.00 15.99 15.95 15.93 15.91 15.87 15.82 15.80 15.71 12.88
 9.87  8.27  7.54  7.16  7.01  6.90  6.80  6.73  6.67  6.51  6.43  6.37
 6.33  6.29  6.29
16.00 16.00 16.00 15.99 15.95 15.93 15.91 15.87 15.82 15.81 15.72 12.84
 9.91  8.26  7.54  7.16  7.02  6.91  6.80  6.72  6.67  6.51  6.43  6.36
 6.33  6.29  6.29
```

STOKELEY 27

0.0 1.00 2.00 3.00 4.00 5.00 6.00 7.00 8.00 9.00 10.00 11.00
12.00 13.00 14.00 15.00 16.00 17.00 18.00 19.00 20.00 22.00 24.00 26.00
28.00 30.00 33.53

3660000. 3386349. 3118927. 2863960. 2627676. 2416304. 2236071. 2091327.
1976268. 1881672. 1798312. 1716964. 1628403. 1524712. 1407332. 1281784.
1153606. 1028335. 911509. 808192. 718721. 571779. 451445. 340453.
235858. 140962. 0.

21

113 122 122 153 153 176 176 188 195 195 202 202 218 218 237 237
263 263 271 285 297

1980

7.22 7.17 7.11 7.00 5.93 5.59 5.49 5.48 5.40 5.38 5.33 5.29
5.25 5.23 5.21 5.19 5.16 5.12 5.07 5.02 4.97 4.88 4.81 4.75
4.70 4.66 4.65

7.22 7.17 7.11 6.99 5.93 5.62 5.49 5.48 5.40 5.38 5.30 5.23
5.19 5.18 5.18 5.17 5.16 5.13 5.08 5.02 4.97 4.89 4.82 4.76
4.70 4.65 4.65

15.39 15.39 15.32 15.26 15.17 14.18 13.76 11.87 11.15 9.85 9.16 8.38
8.10 7.80 7.33 6.86 6.64 6.42 6.24 6.12 6.07 6.06 6.01 5.98
5.94 5.93 5.92

15.40 15.39 15.32 15.26 15.17 14.18 13.76 12.05 11.41 9.93 9.42 8.66
8.28 7.89 7.38 6.92 6.61 6.41 6.26 6.13 6.08 6.06 6.00 5.98
5.94 5.93 5.92

18.81 18.79 18.75 18.74 18.64 16.72 15.05 13.39 12.35 11.24 9.86 9.01
8.48 7.89 7.37 7.00 6.82 6.71 6.69 6.65 6.58 6.44 6.38 6.32
6.31 6.29 6.26

18.79 18.79 18.75 18.74 18.61 16.72 15.05 13.39 12.81 11.45 9.69 8.94
8.31 7.67 7.27 6.92 6.76 6.69 6.65 6.64 6.57 6.44 6.38 6.32
6.31 6.29 6.26

19.55 19.54 19.54 19.49 18.92 18.80 17.12 15.34 13.40 11.88 11.02 9.74
8.64 8.12 7.49 7.20 7.07 6.77 6.71 6.63 6.60 6.48 6.46 6.46
6.36 6.35 6.35

19.71 19.70 19.60 19.44 19.30 19.27 17.27 15.08 13.36 11.51 10.58 9.50
8.89 7.97 7.33 7.07 6.92 6.81 6.68 6.62 6.58 6.52 6.46 6.43
6.39 6.36 6.36

19.66 19.69 19.61 19.44 19.30 19.27 17.27 15.12 13.64 11.78 10.52 9.80
8.92 7.90 7.40 7.05 6.90 6.82 6.69 6.62 6.58 6.51 6.46 6.43
6.38 6.36 6.35

21.11 21.11 21.09 20.97 20.13 19.28 18.43 16.26 13.25 11.71 10.71 9.65
8.37 7.76 7.14 6.95 6.81 6.63 6.53 6.44 6.39 6.35 6.28 6.23
6.22 6.17 6.15

21.11 21.11 21.09 20.97 20.13 19.28 18.43 16.26 13.39 11.77 10.59 9.56
8.47 7.83 7.16 6.97 6.84 6.65 6.58 6.46 6.41 6.36 6.30 6.24
6.23 6.18 6.15

23.21 23.20 23.07 23.00 22.22 21.80 21.09 17.87 15.51 12.43 11.66 10.55
9.53 8.39 7.50 7.28 7.13 7.06 7.00 6.90 6.83 6.78 6.73 6.71
6.68 6.65 6.65

23.39 23.20 23.07 23.00 22.22 21.80 21.11 17.63 15.68 12.32 11.33 10.07
9.37 8.68 7.49 7.30 7.14 7.03 6.96 6.89 6.82 6.78 6.73 6.71
6.68 6.66 6.66

21.36 21.33 21.30 21.04 20.16 19.84 19.61 19.23 17.69 13.22 11.53 10.20
8.88 7.88 7.36 7.07 6.98 6.90 6.82 6.78 6.71 6.64 6.59 6.55
6.52 6.45 6.44

21.37 21.33 21.29 21.04 20.16 19.84 19.61 19.18 17.63 13.29 11.69 9.76
8.75 7.87 7.48 7.10 6.96 6.88 6.81 6.75 6.69 6.64 6.58 6.55
6.52 6.45 6.44

15.82	15.71	15.69	15.66	15.65	15.65	15.65	15.64	15.64	15.62	15.35	13.35
10.09	8.71	8.01	7.61	7.32	7.17	6.99	6.91	6.86	6.78	6.75	6.70
6.67	6.65	6.64									
15.81	15.71	15.69	15.66	15.65	15.65	15.65	15.64	15.64	15.56	15.22	13.14
9.96	8.80	8.00	7.58	7.36	7.11	6.99	6.90	6.85	6.77	6.75	6.70
6.67	6.65	6.64									
13.43	13.43	13.43	13.43	13.43	13.42	13.42	13.39	13.24	13.07	13.03	13.28
12.78	9.06	8.29	7.83	7.48	7.31	7.22	7.14	7.06	7.01	6.93	6.83
6.78	6.75	6.75									

```
TROITE        19
  0.0    1.00   2.00   3.00   4.00   5.00   5.50   6.00   6.50   7.00   7.50   8.00
  8.50   9.00  10.00  11.00  12.00  13.00  15.50
   394600.    322582.    258894.    211865.    186834.    175247.    170560.    164511.
   155733.    144364.    131222,    117127.    102898.     89357.     66769.     49898.
    37322.     27517.        0.
  18
   142  144  155  157  165  167  169  171  176  178  183  185  197  199  211  213
   226  228
1979
18.10 18.07 17.78 16.22 12.23  8.65  7.56  6.63  6.16  5.88  5.70  5.56
 5.45  5.35  5.20  5.13  5.04  4.97  4.98
18.09 18.06 17.79 16.17 12.44  8.22  6.81  6.19  5.88  5.74  5.66  5.53
 5.40  5.31  5.20  5.13  5.04  4.96  4.98
21.53 20.10 19.48 16.81 14.15  9.77  7.86  6.83  6.21  5.90  5.71  5.52
 5.34  5.23  5.12  5.03  4.99  4.98  4.98
20.26 20.04 20.43 19.07 14.10  9.41  7.36  6.62  6.03  5.86  5.70  5.49
 5.33  5.22  5.10  5.04  4.99  4.99  4.98
18.90 18.81 18.59 17.94 15.78 11.02  8.84  7.78  7.48  6.86  6.14  5.73
 5.51  5.39  5.24  5.13  5.10  4.98  5.00
18.96 18.88 18.73 18.28 15.96 11.24  9.21  8.06  7.59  6.86  6.06  5.61
 5.49  5.43  5.25  5.14  5.10  4.98  5.00
23.48 22.50 20.55 20.03 16.42  9.85  8.80  7.85  7.25  6.66  6.24  5.88
 5.70  5.57  5.33  5.20  5.08  5.02  5.02
23.84 22.56 20.80 20.13 16.29 10.06  8.99  7.97  7.33  6.69  6.20  5.91
 5.70  5.55  5.34  5.21  5.08  5.02  5.02
19.35 19.06 18.30 18.22 16.97 12.10  9.50  7.43  6.85  6.03  5.71  5.46
 5.32  5.24  5.10  5.05  5.03  5.03  5.02
19.34 19.05 18.31 18.25 17.37 12.82  9.20  7.45  6.69  6.02  5.66  5.40
 5.29  5.24  5.10  5.06  5.03  5.03  5.02
21.23 21.15 20.61 19.10 17.80 13.10 10.47  8.64  7.31  6.27  5.86  5.62
 5.48  5.39  5.26  5.14  5.11  5.07  5.07
21.26 21.14 20.61 19.40 18.14 13.17 11.08  8.81  7.25  6.27  5.89  5.63
 5.55  5.52  5.38  5.25  5.14  5.11  5.10
 6.32 25.18 24.53 24.30 24.08 17.70 13.42 10.62  8.43  7.32  6.55  6.08
 5.89  5.77  5.42  5.30  5.19  5.13  5.13
 6.35 25.22 24.52 24.30 24.01 17.58 13.49 10.39  8.33  7.34  6.50  6.15
 5.97  5.80  5.42  5.31  5.20  5.13  5.13
 5.10 25.56 25.52 25.52 24.85 22.88 15.20 12.74 10.59  8.74  7.47  6.82
 6.57  6.38  5.65  5.36  5.25  5.15  5.14
 5.13 25.51 25.51 25.49 24.95 22.70 15.06 13.09 11.00  9.00  7.39  6.80
 6.57  6.34  5.65  5.34  5.25  5.15  5.14
18.81 18.58 18.85 18.85 18.83 17.73 14.02 10.61  8.87  8.00  7.29  6.94
 6.75  6.08  5.64  5.39  5.27  5.26  5.14
18.89 18.97 18.86 18.85 18.83 17.83 14.81 10.67  9.08  8.10  7.34  7.00
 6.81  6.12  5.67  5.38  5.27  5.26  5.14
```

```
TRUITE        19
 0.0    1.00   2.00   3.00   4.00   5.00   5.50   6.00   6.50   7.00   7.50   8.00
 8.50   9.00  10.00  11.00  12.00  13.00  15.50
  394600.    322582.    258894.    211865.    186834.    175247.    170560.    164511.
  155733.    144364.    131222.    117127.    102898.     89357.     66769.     49898.
   37322.     27517.         0.
 24
  113  113  120  120  132  132  146  146  153  153  159  167  167  176  176  181
  181  196  196  256  256  271  285  298
1980
12.20 12.14 12.16 11.66  9.81  7.51  6.36  5.33  5.20  4.92  4.84  4.70
 4.63  4.58  4.49  4.44  4.42  4.39  4.38
12.31 12.31 12.26 11.64 10.37  8.34  6.59  5.40  5.18  4.89  4.78  4.66
 4.58  4.53  4.49  4.46  4.41  4.40  4.39
16.22 16.22 16.09 16.34 15.13  8.77  7.24  6.43  5.68  5.41  5.34  5.12
 4.87  4.69  4.55  4.42  4.36  4.35  4.34
16.22 16.21 16.10 16.32 14.36  8.08  7.41  6.59  5.80  5.36  5.07  4.79
 4.70  4.59  4.51  4.41  4.36  4.35  4.34
17.05 17.00 16.91 16.82 14.85  9.53  7.89  6.57  5.67  5.32  5.05  4.87
 4.73  4.63  4.49  4.43  4.39  4.38  4.43
17.06 17.00 16.90 16.72 15.21 10.28  8.14  6.83  5.90  5.36  5.07  4.89
 4.75  4.62  4.50  4.42  4.38  4.37  4.43
16.41 16.41 16.35 16.20 15.78 12.19  9.10  7.47  6.51  5.40  5.22  4.98
 4.78  4.65  4.52  4.42  4.40  4.38  4.38
17.46 17.23 16.69 15.93 14.70 12.38  9.87  8.77  6.99  5.79  5.40  5.13
 4.87  4.71  4.54  4.45  4.42  4.41  4.40
17.44 17.25 16.86 16.08 14.67 12.03  9.56  8.34  7.14  5.88  5.41  5.12
 4.86  4.72  4.54  4.45  4.42  4.41  4.40
21.59 20.87 20.04 17.25 15.47 11.84 10.28  8.25  6.79  5.96  5.43  5.19
 4.98  4.78  4.57  4.48  4.46  4.43  4.43
21.32 20.88 20.04 17.23 15.24 12.47 11.00  8.16  6.76  5.90  5.40  5.07
 4.89  4.75  4.57  4.47  4.46  4.44  4.44
20.68 20.61 20.54 19.29 15.61 11.79 10.29  8.00  6.97  5.92  5.42  5.16
 4.92  4.76  4.57  4.52  4.47  4.45  4.45
20.55 20.61 20.54 19.29 15.61 12.25 10.46  8.16  6.95  6.06  5.51  5.17
 4.91  4.76  4.58  4.51  4.46  4.45  4.45
21.06 20.95 19.88 18.87 12.78  9.82  8.19  7.40  6.41  5.79  5.30  5.03
 4.85  4.62  4.55  4.50  4.49  4.49  4.45
21.05 20.87 19.72 18.28 12.33  9.52  8.30  7.30  6.25  5.62  5.28  5.03
 4.82  4.60  4.54  4.50  4.50  4.49  4.45
17.25 17.18 17.13 16.92 16.44 15.90 14.45 11.46  8.29  6.83  6.61  6.23
 5.62  5.05  4.91  4.82  4.81  4.80  4.45
17.25 17.18 17.14 16.85 16.58 15.39 13.30 10.69  8.30  6.95  6.37  5.93
 5.51  5.05  4.90  4.82  4.80  4.79  4.45
12.53 12.40 12.35 12.33 12.27 12.21 12.12 11.96 11.90 12.02 11.44  9.18
 6.49  5.41  5.12  4.87  4.85  4.84  4.45
```

APPENDIX FOUR

Oxygen concentrations within the hypolimnion measured during this study. Data are structured by lines:

1. Lake name, number of dates sampled, year of study.
2. Julian day on which samples listed below were collected, number of depths sampled, number of profiles collected.
3. Depth sampled (meters below lake surface), mean of duplicate oxygen concentration determinations (mg/L), variance in duplicate titrations, profile number, device used to collect the water samples.

Duplicate samples from a depth were collected in separate water samplers. If only one bottle was titrated the variance was set to 99. The devices were coded as follows:

0. Vandorn
1. Metallic water sampler
2. Peristaltic pump

Note: No variances were calculated for the concnetrations measured during 1978. In 1978 all oxygen profiles (except the central basin of Lake Memphremagog) were measured using the metallic sampler. Central basin samples were measured with a Vandorn sampler.

```
BROMPTON        06  1978
173      13 1
08.0 09.50                1 2
10.0 09.85                1 2
12.0 10.01                1 2
14.0 10.08                1 2
16.0 10.07                1 2
18.0 09.97                1 2
20.0 10.04                1 2
22.0 09.94                1 2
24.0  9.94                1 2
26.0  9.86                1 2
28.0  9.81                1 2
30.0  9.81                1 2
35.0  9.75                1 2
179      13 1
10.0  9.26                1 2
12.0  9.51                1 2
14.0  9.75                1 2
16.0  9.84                1 2
18.0  9.73                1 2
20.0  9.70                1 2
22.5  9.63                1 2
24.0  9.62                1 2
27.5  9.61                1 2
30.0  9.61                1 2
32.5  9.61                1 2
35.0  9.47                1 2
37.5  9.41                1 2
221      15 1
10.0  7.81                1 2
12.0  8.22                1 2
14.0  8.48                1 2
16.0  8.59                1 2
18.0  8.56                1 2
20.0  8.55                1 2
22.0  8.59                1 2
24.0  8.60                1 2
26.0  8.55                1 2
28.0  8.47                1 2
30.0  8.45                1 2
32.5  8.40                1 2
35.0  8.26                1 2
37.5  8.20                1 2
40.0  8.18                1 2
230      16 1
08.0  8.15                1 2
10.0  7.20                1 2
12.0  7.55                1 2
14.0  8.24                1 2
16.0  8.24                1 2
18.0  8.32                1 2
20.0  8.40                1 2
22.0  8.40                1 2
24.0  8.32                1 2
26.0  8.29                1 2
28.0  8.18                1 2
```

30.0	8.18		1 2
32.5	8.06		1 2
35.0	8.06		1 2
37.5	7.91		1 2
40.0	7.90		1 2
237	15	1	
08.0	8.25		1 2
10.0	6.99		1 2
12.0	7.81		1 2
14.0	8.08		1 2
16.0	8.11		1 2
18.0	8.04		1 2
20.0	8.12		1 2
22.0	8.03		1 2
24.0	8.07		1 2
26.0	8.06		1 2
28.0	8.05		1 2
30.0	7.94		1 2
32.5	7.95		1 2
35.0	7.88		1 2
37.5	7.75		1 2
258	12	1	
14.0	7.75		1 2
16.0	7.45		1 2
18.0	7.45		1 2
20.0	7.50		1 2
22.0	7.43		1 2
24.0	7.42		1 2
26.0	7.46		1 2
28.0	7.39		1 2
30.0	7.38		1 2
32.5	7.44		1 2
35.0	7.40		1 2
37.5	7.31		1 2

BROMPTON		6	1979		
175	15 1				
10.0	9.3750	0.00005	1	1	
12.0	9.5750	0.00005	1	1	
14.0	9.8500	0.00080	1	1	
16.0	9.8200	0.00020	1	1	
18.0	9.9700	0.00020	1	1	
20.0	9.7500	0.00020	1	1	
22.0	9.7500	0.00020	1	1	
24.0	9.6800	0.00080	1	1	
26.0	9.6850	0.00005	1	1	
28.0	9.6250	0.00245	1	1	
30.0	9.6500	0.00080	1	1	
32.5	9.5950	0.00125	1	1	
35.0	9.5500	0.00020	1	1	
37.5	9.4500	0.00000	1	1	
40.0	9.3800	0.00000	1	1	
198	14 1				
10.0	8.4500	0.00020	1	1	
12.0	8.8450	0.00045	1	1	
14.0	9.1100	0.00020	1	1	
16.0	9.0300	0.00080	1	1	
18.0	9.0300	0.00000	1	1	
20.0	8.9100	0.00020	1	1	
22.0	8.7350	0.00125	1	1	
24.0	8.6650	0.00045	1	1	
26.0	8.6850	0.00005	1	1	
28.0	8.7650	0.00005	1	1	
30.0	8.6900	99.99001	1	1	
32.5	8.6350	0.00125	1	1	
35.0	8.4850	0.00005	1	1	
37.5	8.3600	0.00000	1	1	
212	15 1				
10.0	7.7400	0.00080	1	1	
12.0	8.3200	0.00000	1	1	
14.0	8.5500	0.00000	1	1	
16.0	8.3200	0.00000	1	1	
18.0	8.2450	0.00005	1	1	
20.0	8.2100	0.00080	1	1	
22.0	8.1850	0.00245	1	1	
24.0	8.2900	0.00020	1	1	
26.0	8.2700	0.00020	1	1	
28.0	8.1850	0.00005	1	1	
30.0	8.2000	0.00020	1	1	
32.5	8.1450	0.00005	1	1	
35.0	8.0600	0.00000	1	1	
37.5	7.9200	0.00020	1	1	
40.0	7.8600	0.00020	1	1	
227	14 1				
10.0	7.1150	0.01805	1	1	
12.0	7.2550	0.04205	1	1	
14.0	7.8900	99.99001	1	1	
16.0	7.6800	99.99001	1	1	
18.0	7.6600	99.99001	1	1	
20.0	7.8250	0.00005	1	1	
22.0	8.0350	0.00245	1	1	
24.0	7.9850	0.00125	1	1	

26.0	7.8750	0.00045	1	1
28.0	7.6300	99.99001	1	1
30.0	7.4450	0.00045	1	1
32.5	7.4150	0.00405	1	1
35.0	7.4600	0.00320	1	1
37.5	7.4450	0.00045	1	1
241	15 1			
10.0	7.7350	0.00005	1	1
12.0	7.3350	0.00005	1	1
14.0	7.7000	0.00000	1	1
16.0	7.8100	0.00000	1	1
18.0	7.6250	0.00005	1	1
20.0	7.3750	0.00045	1	1
22.0	7.4950	0.00845	1	1
24.0	7.1950	0.00125	1	1
26.0	7.2200	0.00080	1	1
28.0	7.1950	0.00045	1	1
30.0	7.2450	0.00005	1	1
32.5	6.8750	0.00005	1	1
35.0	6.8350	0.00045	1	1
37.5	6.5250	0.00005	1	1
40.0	6.4800	0.00000	1	1
255	15 1			
10.0	8.6500	0.00720	1	1
12.0	8.2900	0.00000	1	1
14.0	6.9350	0.00405	1	1
16.0	6.9300	0.00020	1	1
18.0	6.8400	0.00020	1	1
20.0	6.8750	0.00005	1	1
22.0	6.8050	0.00125	1	1
24.0	6.8000	0.00000	1	1
26.0	6.8200	0.00000	1	1
28.0	6.8600	0.00320	1	1
30.0	6.7600	0.00000	1	1
32.5	6.7400	0.00020	1	1
35.0	6.5500	0.00180	1	1
37.5	6.5950	0.00125	1	1
40.0	6.4750	0.00045	1	1

```
BROMPTON          9    1980
113. 119   5  1
  0.0 11.3491    0.00024  1  2
 12.0 11.3175    0.00000  1  2
 20.0 11.3458    0.00049  1  2
 28.0 11.3212    0.00342  1  2
 35.0 11.2124    0.00003  1  2
122  129   5  1
  0.0 11.8125    0.00049  1  2
 12.0 11.5117    0.00122  1  2
 20.0 11.4546    0.00024  1  2
 28.0 11.3618    0.00098  1  2
 35.0 11.3347    0.00000  1  2
148  154  12  1
 14.0 10.5656    0.05823  1  1
 16.0 10.7115    0.00090  1  1
 18.0 10.7474    0.00002  1  1
 20.0 10.7331    0.00011  1  1
 22.0 10.7344    0.00249  1  1
 24.0 10.6567    0.00066  1  1
 26.0 10.6579    0.00000  1  1
 28.0 10.6009    0.00113  1  1
 30.0 10.5204    0.00060  1  1
 32.5 10.6007    0.00142  1  2
 35.0 10.6545    0.00044  1  2
 37.5 10.5557    0.00005  1  2
167  177   9  1
 14.0  9.8494    0.00121  1  1
 16.0  9.9326    0.00233  1  1
 20.0  9.8086    0.00058  1  1
 24.0  9.6768    0.00134  1  1
 28.0  9.6552    0.00134  1  1
 30.0  9.7415    0.00175  1  1
 32.5  9.6632    0.01247  1  0
 35.0  9.5674    0.00000  1  0
 37.5  9.6895    0.01056  1  0
188  189  16  2
 37.5  8.6931    0.00009  1  0
 35.0  8.7221    0.00002  1  0
 32.5  8.6717    0.00259  1  0
 30.0  8.7599    0.02875  1  1
 28.0  8.6748    0.00000  1  1
 26.0  8.6730    0.00052  1  1
 24.0  8.6706    0.00212  1  1
 22.0  8.7900    0.00601  1  1
 20.0  8.9229    0.00002  1  1
 18.0  8.7577    0.00003  1  1
 16.0  8.7321    0.00055  1  1
 37.5  8.7013    0.00197  2  0
 30.0  8.7136    0.00211  2  0
 24.0  8.7914   99.99001  2  0
 20.0  8.7763    0.00029  2  0
 16.0  8.8949    0.00137  2  0
197  203  16  2
 26.0  8.2636    0.00076  1  1
 28.0  8.2569    0.00006  1  1
 30.0  8.2576    0.00015  1  1
```

32.5	8.1595	0.00014	1	1	
35.0	8.1520	0.00024	1	1	
37.5	8.0690	0.00308	1	1	
14.0	8.6046	0.00066	1	0	
16.0	8.4796	0.00198	1	0	
16.0	8.4957	0.00058	2	0	
18.0	8.4628	0.00037	1	0	
20.0	8.4422	0.00035	1	0	
20.0	8.4795	0.00133	2	0	
22.0	8.5617	0.00169	1	0	
24.0	8.5942	0.00008	1	0	
30.0	8.3051	0.00034	2	0	
37.5	8.2304	0.00000	2	0	
211	220	17	2		
16.0	7.7746	0.00070	2	0	
20.0	7.9028	0.00125	2	0	
24.0	7.7549	0.00009	2	0	
30.0	7.5933	0.00047	2	0	
37.5	7.6257	0.00000	2	0	
14.0	7.8699	0.00023	1	1	
16.0	7.7194	0.00047	1	1	
18.0	7.8004	0.00641	1	1	
20.0	7.7539	0.00008	1	1	
22.0	7.7267	0.00047	1	1	
24.0	7.7402	0.00000	1	1	
26.0	7.7112	0.00000	1	1	
28.0	7.5847	0.00008	1	1	
30.0	7.6419	0.00075	1	1	
32.5	7.6149	0.00163	1	1	
35.0	7.5519	0.00027	1	1	
37.5	7.4604	0.00043	1	1	
223	230	17	2		
14.0	7.5020	0.00003	1	1	
16.0	7.6741	0.00328	1	1	
18.0	7.3937	0.00110	1	1	
20.0	7.2421	0.00053	1	1	
22.0	7.4073	0.00005	1	1	
24.0	7.2937	0.00000	1	1	
26.0	7.2972	0.00011	1	1	
28.0	7.1868	0.00165	1	1	
30.0	7.0785	0.00096	1	1	
32.5	7.0005	0.00003	1	1	
35.0	6.9582	0.00003	1	1	
37.5	6.9686	0.00008	1	1	
16.0	7.5382	0.00098	2	0	
0.0	7.2964	0.00044	2	0	
24.0	7.3519	0.00012	2	0	
30.0	7.1747	0.00026	2	0	
37.5	6.9879	0.00003	2	0	
230	233	17	2		
14.0	7.1989	0.00011	1	1	
16.0	7.1958	0.00023	1	1	
18.0	7.3639	0.00032	1	1	
20.0	7.3526	0.00000	1	1	
22.0	7.1096	0.00023	1	1	
24.0	7.0230	0.00314	1	1	
26.0	7.0283	0.00005	1	1	

28.0	6.9880	99.99001	1	1
30.0	6.9876	0.00003	1	1
32.5	6.7960	0.00000	1	1
35.0	6.8671	0.00015	1	1
37.5	6.8193	0.01024	1	0
16.0	7.1433	0.00023	2	0
20.0	7.3572	0.00008	2	0
24.0	7.0363	0.00002	2	0
30.0	7.0587	0.00002	2	0
37.5	6.7897	0.00154	2	0

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135	13	1		
07.5	11.02		1	2
10.0	10.89		1	2
16.0	11.18		1	2
18.0	10.99		1	2
20.0	10.90		1	2
22.0	11.06		1	2
26.0	11.06		1	2
30.0	11.06		1	2
35.0	11.11		1	2
40.0	11.00		1	2
50.0	10.82		1	2
70.0	11.00		1	2
90.0	9.74		1	2
142	13	1		
07.5	11.16		1	2
10.0	11.11		1	2
16.0	11.06		1	2
18.0	10.82		1	2
20.0	10.88		1	2
22.0	10.80		1	2
26.0	10.64		1	2
30.0	10.58		1	2
35.0	10.49		1	2
40.0	10.59		1	2
50.0	10.02		1	2
70.0	10.07		1	2
90.0	8.55		1	2
149	13	1		
07.5	11.72		1	2
10.0	11.75		1	2
16.0	10.58		1	2
18.0	10.52		1	2
20.0	10.28		1	2
22.0	10.05		1	2
26.0	10.25		1	2
30.0	10.06		1	2
35.0	10.15		1	2
40.0	10.10		1	2
50.0	9.85		1	2
70.0	9.48		1	2
90.0	9.10		1	2
163	13	1		
07.5	9.05		1	2
10.0	09.08		1	2
16.0	9.58		1	2
18.0	9.12		1	2
20.0	9.47		1	2
22.0	9.18		1	2
26.0	9.46		1	2
30.0	9.49		1	2
35.0	9.39		1	2
40.0	9.16		1	2
50.0	9.29		1	2
70.0	8.91		1	2
90.0	8.59		1	2

177	13	1	
07.5	9.06		1 2
10.0	8.76		1 2
16.0	8.56		1 2
18.0	8.63		1 2
20.0	8.76		1 2
22.0	9.01		1 2
26.0	8.98		1 2
30.0	9.20		1 2
35.0	9.22		1 2
40.0	9.19		1 2
50.0	9.16		1 2
70.0	8.87		1 2
90.0	8.72		1 2
205	13	1	
07.5	7.53		1 2
10.0	6.68		1 2
16.0	6.9		1 2
18.0	7.61		1 2
20.0	7.58		1 2
22.0	8.03		1 2
26.0	9.32		1 2
30.0	9.06		1 2
35.0	9.52		1 2
40.0	9.40		1 2
50.0	9.51		1 2
70.0	9.18		1 2
90.0	9.32		1 2
219	14	1	
07.5	7.62		1 2
10.0	7.56		1 2
16.0	6.49		1 2
18.0	7.02		1 2
20.0	7.40		1 2
22.0	8.12		1 2
26.0	8.44		1 2
30.0	8.97		1 2
35.0	8.86		1 2
40.0	8.92		1 2
50.0	8.86		1 2
70.0	8.84		1 2
90.0	8.18		1 2
102.	7.70		1 2
233	14	1	
07.5	7.76		1 2
10.0	7.73		1 2
16.0	5.96		1 2
18.0	6.60		1 2
20.0	7.34		1 2
22.0	7.59		1 2
26.0	8.18		1 2
30.0	8.63		1 2
35.0	8.64		1 2
40.0	7.22		1 2
50.0	8.86		1 2
70.0	8.75		1 2
90.0	8.32		1 2

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144	15	1			
12.5	11.3300	0.00000	1	1	
15.0	11.3200	0.00000	1	1	
17.5	11.2300	0.00000	1	1	
20.0	11.1150	0.00005	1	1	
22.5	11.1050	0.00045	1	1	
25.0	11.0250	0.00045	1	1	
27.5	11.0200	0.00080	1	1	
32.5	10.9650	0.00045	1	1	
35.0	11.0350	0.01445	1	1	
37.5	10.8400	0.02420	1	1	
40.0	10.9300	0.00020	1	1	
45.0	11.0050	0.02645	1	1	
50.0	10.8800	0.00000	1	1	
60.0	10.8450	0.00045	1	1	
70.0	10.7900	0.00500	1	1	
165	16	1			
12.5	9.2050	0.00005	1	1	
15.0	9.7950	0.00005	1	1	
17.5	10.0450	0.00045	1	1	
20.0	10.1250	0.00005	1	1	
22.5	10.3000	0.00020	1	1	
25.0	10.4000	0.00020	1	1	
27.5	10.4500	0.00000	1	1	
30.0	10.4900	0.00020	1	1	
32.5	10.5500	0.00000	1	1	
35.0	10.4100	0.00180	1	1	
40.0	10.5450	0.00005	1	1	
45.0	10.4700	0.00020	1	1	
50.0	10.5050	0.00125	1	1	
60.0	10.4800	0.00020	1	1	
70.0	10.4300	0.00000	1	1	
80.0	10.3050	0.00605	1	1	
189	17	1			
10.0	8.5800	0.00000	1	1	
12.5	7.9400	0.00080	1	1	
15.0	8.2350	0.00005	1	1	
17.5	9.1050	0.00005	1	1	
20.0	9.4250	0.00005	1	1	
22.5	9.6300	0.00000	1	1	
25.0	9.7800	0.00080	1	1	
27.5	10.0100	0.00020	1	1	
30.0	10.1600	0.00080	1	1	
32.5	9.8400	0.00020	1	1	
35.0	10.1750	0.00045	1	1	
40.0	10.2600	0.00080	1	1	
45.0	10.2400	0.00020	1	1	
50.0	10.2550	0.00005	1	1	
60.0	10.2450	0.00005	1	1	
70.0	10.2300	0.00000	1	1	
80.0	10.1550	0.00005	1	1	
199	15	1			
10.0	8.0350	0.00005	1	1	
12.5	7.7200	0.00020	1	1	
15.0	7.9600	99.99001	1	1	
17.5	8.6500	0.00080	1	1	

```
20.0   9.2700    0.00000 1 1
22.5   9.2500    0.00020 1 1
25.0   9.7550    0.00005 1 1
27.5   9.8250    0.00005 1 1
30.0  10.0450    0.00045 1 1
35.0  10.2550    0.00005 1 1
40.0  10.4900    0.06480 1 1
50.0  10.2200    0.00020 1 1
60.0  10.2400    0.00000 1 1
70.0   9.9700    0.00020 1 1
80.0   9.8150    0.00405 1 1
 213     18 1
10.0   7.0400    0.00020 1 1
12.5   6.0600    0.00080 1 1
15.0   6.9650    0.00005 1 1
17.5   8.5800    0.00020 1 1
20.0   9.0650    0.00405 1 1
22.5   9.2950    0.00005 1 1
25.0   9.4350    0.00045 1 1
27.5   9.6650    0.00005 1 1
30.0   9.8650    0.00125 1 1
32.5  10.0800    0.00020 1 1
35.0  10.0900    0.00000 1 1
37.5  10.0900    0.00180 1 1
40.0  10.0550    0.00005 1 1
45.0  10.0350    0.00005 1 1
50.0  10.0100    0.00020 1 1
60.0  10.0000    0.00020 1 1
70.0   9.9900    0.00020 1 1
80.0   9.2850    0.00045 1 1
 228     17 1
10.0   8.3400    0.00000 1 1
12.5   8.2950    0.00245 1 1
15.0   6.7150    0.00045 1 1
17.5   7.7800    0.00500 1 1
20.0   8.3350    0.00245 1 1
22.5   8.6950    0.00045 1 1
25.0   9.0000    0.00720 1 1
27.5   9.3400    0.00020 1 1
30.0   9.5000    0.00720 1 1
32.5   9.6250    0.00045 1 1
35.0   9.6600    0.02000 1 1
40.0   9.8550    0.00005 1 1
45.0   9.7350    0.00005 1 1
50.0   9.7250    0.00005 1 1
60.0   9.7100    0.00020 1 1
70.0   9.7750    0.00005 1 1
80.0   9.6850    0.00045 1 1
 240     17 1
10.0   8.6200   99.99001 1 1
12.5   8.2800   99.99001 1 1
15.0   6.9450    0.00005 1 1
17.5   7.2300    0.00020 1 1
20.0   7.9100    0.00180 1 1
22.5   8.4350    0.00005 1 1
25.0   8.7500    0.00000 1 1
27.5   9.0700    0.00080 1 1
```

30.0	9.3050	0.05445	1	1
32.5	9.6850	0.00045	1	1
35.0	9.7050	0.00005	1	1
40.0	9.6550	0.00005	1	1
45.0	9.6500	0.00020	1	1
50.0	9.7650	0.00005	1	1
60.0	9.6850	0.00045	1	1
70.0	9.5300	0.00020	1	1
80.0	9.4600	0.00020	1	1
265	16 1			
10.0	9.0000	0.03380	1	1
12.5	8.0400	0.00080	1	1
15.0	8.9900	0.00080	1	1
17.5	7.5450	0.00005	1	1
20.0	7.4900	0.00000	1	1
22.5	7.9750	0.00045	1	1
25.0	8.2100	0.00020	1	1
27.5	8.5000	0.00000	1	1
30.0	9.0150	0.00005	1	1
35.0	9.5150	0.00045	1	1
37.5	9.5300	99.99001	1	1
40.0	9.6500	0.00000	1	1
45.0	9.6700	0.00020	1	1
50.0	9.6350	0.00045	1	1
60.0	9.6250	0.00125	1	1
70.0	9.5300	0.00180	1	1

```
CENTRAL          10     1980
114 121   5  1
  0.0 11.5435   99.99001  1  2
 20.0 11.5149   99.99001  1  2
 30.0 11.4144   99.99001  1  2
 50.0 11.4832    0.01953  1  2
 70.0 11.4065    0.00269  0  0
121 127   5  1
  0.0 11.7052    0.00562  1  2
 20.0 11.7165    0.02197  1  2
 30.0 11.5895    0.00146  1  2
 50.0 11.7581    0.00098  1  2
 70.0 11.6288    0.02979  1  2
133 144   5  1
  0.0 12.4397    0.00098  1  1
 20.0 11.8728    0.02466  1  2
 35.0 11.6018    0.02319  1  2
 50.0 11.4735    0.00317  1  2
 70.0 11.6165    0.00000  1  2
143 151  12  1
 15.0 11.9016   99.99001  1  2
 17.5 11.7549    0.00049  1  2
 20.0 11.5311    0.00269  1  2
 22.5 11.6000    0.00146  1  2
 25.0 11.5493    0.00317  1  2
 27.5 11.3684    0.00073  1  0
 32.5 11.5239    0.00024  1  2
 40.0 11.4238   99.99001  1  2
 45.0 11.3635    0.00024  1  2
 50.0 11.3691    0.00073  1  2
 60.0 11.3432    0.00513  1  2
 70.0 11.2083    0.00061  1  2
157 162  13  1
 17.5 10.8708    0.00008  1  0
 20.0 10.9147    0.00069  1  0
 22.5 10.9411   99.99001  1  0
 25.0 10.9817    0.00064  1  0
 27.5 11.0283    0.00005  1  0
 30.0 11.0170    0.00031  1  0
 32.5 11.0558    0.00017  1  0
 35.0 11.0478    0.00008  1  0
 40.0 11.0428    0.00000  1  0
 45.0 11.0800    0.00128  1  0
 50.0 11.0699    0.00055  1  0
 60.0 11.0959    0.00000  1  0
 70.0 11.0199    0.00017  1  0
174 178  13  1
 17.5  9.6847    0.00034  1  0
 20.0  9.8785    0.00029  1  0
 27.5 10.2554    0.00023  1  0
 35.0 10.6883    0.00002  1  0
 50.0 10.7418    0.00000  1  0
 70.0 10.7156    0.00005  1  0
 22.5 10.0208    0.00000  1  0
 25.0 10.1306    0.00005  1  0
 30.0 10.4954    0.00034  1  0
 32.5 10.6211    0.00665  1  0
```

```
40.0 10.7161   0.00024 1 0
45.0 10.7823   0.00018 1 0
60.0 10.8246   0.00000 1 0
183 186 14 1
17.5  9.7171   0.00066 1 0
20.0  9.7377   0.00081 1 0
22.5 10.0688   0.02098 1 0
25.0 10.1598   0.03033 1 0
27.5 10.2813   0.00165 1 0
30.0 10.4668  99.99001 1 0
32.5 10.5243   0.00005 1 0
35.0 10.6498   0.00212 1 0
37.5 10.6814   0.00098 1 0
40.0 10.6641   0.00000 1 0
45.0 10.6908   0.00012 1 0
50.0 10.7025   0.00069 1 0
60.0 10.7025   0.00020 1 0
70.0 10.7074   0.00043 1 0
199 204 12 1
17.5  8.6851   0.00069 1 0
20.0  9.0992   0.00043 1 0
22.5  9.3528   0.00002 1 0
25.0  9.6479   0.00005 1 0
27.5  9.8417   0.00497 1 0
30.0  9.9669   0.00137 1 0
35.0 10.3050   0.00331 1 0
40.0 10.3872   0.00089 1 0
45.0 10.3782   0.00006 1 0
50.0 10.3913   0.00040 1 0
60.0 10.4443   0.00035 1 0
70.0 10.3758   0.00002 1 0
213 219 18 2
70.0 10.3125   0.00017 1 0
70.0 10.3048   0.00208 2 0
60.0 10.2432   0.00172 1 0
50.0 10.1752   0.00027 1 0
45.0 10.2273   0.00003 1 0
40.0 10.1574   0.00105 1 0
35.0 10.1835   0.00140 1 0
35.0 10.1790   0.00011 2 0
30.0  9.8460   0.00015 1 0
27.5  9.5169   0.00049 1 0
27.5  9.6219   0.00024 2 0
25.0  9.2578   0.00012 1 0
22.5  8.9773   0.00012 1 0
20.0  8.8065   0.00009 1 0
20.0  8.8231   0.00594 2 0
17.5  8.5317   0.02039 1 0
15.0  7.6832   0.00038 1 0
50.0 10.2432   0.00159 2 0
231 233 16 2
20.0  8.5925   0.00017 1 0
22.5  8.8418   0.00000 1 0
25.0  9.1246   0.00005 1 0
27.5  9.3861   0.00169 1 0
30.0  9.5033   0.00002 1 0
35.0  9.9219   0.00002 1 0
```

40.0	10.1428	0.00006	1	0
45.0	10.2163	0.00011	1	0
50.0	10.2145	0.00015	1	0
60.0	10.2838	0.00002	1	0
70.0	10.1947	0.00024	1	0
20.0	8.6058	0.00005	2	0
27.5	9.3121	0.00031	2	0
35.0	10.0510	0.00021	2	0
50.0	10.2273	0.00015	2	0
70.0	10.2216	0.00006	2	0

```
FITCH                6      1979
 131       4 1
10.0 11.5250    0.00245  1 1
12.0 10.5700    0.00500  1 1
14.0  8.8350    0.00125  1 1
16.0  8.2100    0.00080  1 1
 136       6 1
12.0  9.4500    0.00180  1 1
13.0  8.4950    0.00125  1 1
14.0  8.3600    0.00000  1 1
15.0  8.1150    0.00045  1 1
16.0  7.4300    0.00020  1 1
17.0  7.3550    0.00605  1 1
 155       4 1
10.0  9.9350    0.00005  1 1
12.0  9.6400    0.00020  1 1
14.0  7.7550    0.00005  1 1
16.0  5.7900    0.00000  1 1
 176       8 1
10.0  6.5150    0.00245  1 1
11.0  7.0200    0.00080  1 1
12.0  6.9200    0.00000  1 1
13.0  5.8600    0.00000  1 1
14.0  4.5600    0.00980  1 1
15.0  3.5200    0.00080  1 1
16.0  2.2900    0.00080  1 1
17.0  2.0850    0.00005  1 1
 190       8 1
10.0  6.7400    0.00180  1 1
11.0  5.3150    0.00045  1 1
12.0  4.8900    0.00000  1 1
13.0  3.9900    0.25920  1 1
14.0  1.1800    0.00000  1 1
15.0  0.7800    0.00000  1 1
16.0  0.3750    0.00005  1 1
17.0  0.2850    0.00045  1 1
 209       7 1
10.0  4.6150    0.00125  1 1
11.0  3.3000    0.00180  1 1
12.0  2.5150    0.00005  1 1
13.0  1.5800    0.00020  1 1
14.0  0.4200    0.00000  1 1
15.0  0.4600    0.00180  1 1
16.0  0.7450    0.00245  1 1
```

```
FITCH              13
114 119   5 1
  0.0 12.6073    0.00024 1 2
 10.0 12.4332    0.00024 1 2
 12.0 10.9552    0.00256 1 2
 14.0 10.9795    0.00200 1 2
 16.0 10.3393    0.00159 1 2
121 121   5 1
  0.0 12.1568    0.00049 1 2
 10.0 12.2094    0.00000 1 2
 12.0 10.3978    0.00055 1 2
 14.0 10.1197    0.00000 1 2
 16.0  9.5704    0.00003 1 2
128 130   7 1
 10.0 12.6276    0.00098 1 0
 11.0 12.5729    0.00000 1 0
 12.0 12.5260    0.00000 1 0
 13.0 11.9904   99.99001 1 0
 14.0 10.8980    0.00034 1 0
 15.0  8.7804    0.00348 1 0
 16.0  8.5485    0.00017 1 0
133 148   7 1
 10.0 11.7144    0.00000 1 1
 11.0 11.2572    0.00000 1 1
 12.0 11.2870    0.08815 1 1
 13.0 10.6250    0.00002 1 1
 14.0 10.6430    2.40100 1 1
 15.0  9.5322    0.17337 1 1
 16.0  9.2285    0.01596 1 1
136 137   7 1
 10.0 11.2946    0.00074 1 1
 11.0 11.1905    0.00008 1 1
 12.0 10.6401    0.00041 1 1
 13.0 10.3495    0.00011 1 1
 14.0  9.5230    0.00848 1 1
 15.0  8.6972   99.00000 1 1
 16.0  7.8516    0.00177 1 1
143 151   5 1
 12.0  9.1260    0.00255 1 1
 13.0  8.6517    0.00082 1 1
 14.0  7.8371    0.00026 1 1
 15.0  6.9619    0.08052 1 1
 16.0  6.0359    0.00014 1 1
152 153  11 2
 11.0  9.7601    0.00024 1 0
 12.0  8.1422    0.00011 1 0
 13.0  7.7194    0.00003 1 0
 14.0  6.5796    0.00075 1 0
 15.0  5.6005    0.00034 1 0
 16.0  4.8706    0.00011 1 0
 12.0  8.1186    0.00011 2 1
 13.0  7.4353    0.00407 2 1
 14.0  5.9408    0.01375 2 1
 15.0  5.1620    0.00011 2 1
 16.0  4.9438    0.00015 2 1
157 162   7 1
 10.0  8.9824    0.00226 1 0
```

```
11.0   8.7479   0.00005 1 0
12.0   8.3521   0.00269 1 0
13.0   7.7189   0.00002 1 0
14.0   5.8385   0.00087 1 0
15.0   4.0558   0.00027 1 0
16.0   3.3014   0.00009 1 0
161 164  6 1
11.0   7.7339   0.00006 1 0
12.0   7.6104   0.00171 1 0
13.0   7.2948   0.00053 1 0
14.0   6.4592   0.00832 1 0
15.0   4.8680   0.00027 1 0
16.0   3.1760   0.00096 1 0
164 175 11 2
11.0   8.2777   0.03104 1 0
12.0   7.8177   0.00009 1 0
13.0   7.3237   0.00017 1 0
14.0   6.9218   0.00267 1 0
15.0   4.2911   0.00043 1 0
16.0   4.1143   0.00067 1 0
12.0   7.5364   0.00000 2 1
13.0   7.1852   0.00005 2 1
14.0   6.0616   0.00264 2 1
15.0   4.0711   0.00003 2 1
16.0   1.6867   0.00003 2 1
171 175  6 1
11.0   7.0403   0.01410 1 1
12.0   6.4864   0.00076 1 1
13.0   5.1830   0.00005 1 1
14.0   4.3995   0.00089 1 1
15.0   1.4686   0.00029 1 1
16.0   2.2584   0.00004 1 1
179 180 11 2
12.0   5.4449   0.00006 1 0
13.0   4.3804   0.00017 1 0
14.0   2.6032   0.00008 1 0
15.0   0.8134   0.00000 1 0
16.0   0.4945   0.00032 1 0
11.0   6.2832   0.25839 2 1
12.0   5.0769   0.00069 2 1
13.0   2.7549   0.01900 2 1
14.0   1.0955   0.00001 2 1
15.0   0.4100   0.00085 2 1
16.0   0.4046   0.00733 2 1
183 186 10 2
12.0   4.8042   0.00021 1 1
13.0   2.4648   0.02378 1 1
14.0   1.0707   0.00221 1 1
15.0   0.3131   0.00110 1 1
16.0   0.3622   0.00533 1 1
12.0   4.3704   0.00067 2 1
13.0   2.8748   0.00282 2 1
14.0   1.1765   0.00003 2 1
15.0   0.2376   0.00167 2 1
16.0   0.4333   0.09384 2 1
```

```
LITTLEBROMPTON  8      1980
125  127   6  1
  0.0  11.9276    0.00000 1  2
  8.0  11.6105    0.00000 1  2
 10.0  11.4004    0.00000 1  2
 12.0  11.2532    0.00000 1  2
 14.0  11.2149    0.00128 1  2
 15.0  11.0429    0.00002 1  2
162  164   6  1
 10.0   7.8209    0.00047 1  0
 11.0   7.9528    0.00009 1  0
 12.0   8.1520    0.00069 1  0
 13.0   7.4743    0.00017 1  0
 14.0   7.6148    0.00264 1  0
 15.0   6.3913    0.00017 1  0
178  187   8  1
  9.0   7.0410    0.00124 1  1
 10.0   8.3756    0.00012 1  1
 11.0   8.0096    0.00034 1  1
 12.0   7.0630    0.00023 1  1
 13.0   6.5699    0.00024 1  1
 14.0   5.9632    0.00281 1  1
 15.0   4.6844    0.00009 1  1
 16.0   4.3394    0.00014 1  1
197  203  13  2
  8.0   5.5530    0.00000 1  1
 10.0   5.5947    0.00096 1  1
 11.0   4.7979    0.01103 1  1
 12.0   5.0309    0.00386 1  1
 13.0   4.8669    0.01466 1  1
 14.0   3.9836    0.00000 1  1
 15.0   3.8984    0.00656 1  1
 16.0   2.6212    0.00042 1  1
 10.0   5.9741    0.00101 2  0
 11.0   4.8612    0.00012 2  0
 12.0   4.9086    0.00031 2  0
 14.0   4.8583    0.00052 2  0
 16.0   3.1905    0.00035 2  0
211  219  13  2
 10.0   3.5502    0.00002 2  0
 12.0   4.2727    0.00259 2  0
 11.0   4.1684    0.00293 2  0
 14.0   3.3095    0.00296 2  0
 16.0   1.5282    0.00064 2  0
  9.0   5.0758    0.00002 1  1
 10.0   3.7407    0.00011 1  1
 11.0   4.0893    0.00003 1  1
 12.0   4.2385    0.00078 1  1
 13.0   3.8392    0.00018 1  1
 14.0   2.5624    0.00001 1  1
 15.0   1.7459    0.00406 1  1
 16.0   1.3106    0.00052 1  1
223  226  13  2
  8.0   4.0045    0.00015 1  1
 10.0   3.0541    0.00089 1  1
 11.0   3.0223    0.00047 1  1
 12.0   3.3732    0.00003 1  1
```

```
 13.0   2.9849    0.00041 1 1
 14.0   2.0084    0.00025 1 1
 15.0   1.1278    0.00000 1 1
 16.0   0.4141    0.00008 1 1
 10.0   3.1109    0.00002 2 0
 11.0   3.4023    0.00090 2 0
 12.0   3.4652    0.00052 2 0
 13.0   3.0329    0.00076 2 0
 14.0   2.5040    0.00000 2 0
230 231 13 2
  8.0   3.4397    0.00002 1 1
 10.0   3.6786    0.00064 1 1
 11.0   3.1302    0.00015 1 1
 12.0   3.5258    0.00034 1 1
 13.0   2.3625    0.00003 1 1
 14.0   1.7150    0.00000 1 1
 15.0   0.8883   99.99999 1 1
 16.0   0.5263    0.00109 1 1
 10.0   3.1393    0.00066 2 0
 11.0   2.8825    0.00005 2 0
 12.0   3.4996    0.00119 2 0
 13.0   2.6874   99.99999 2 0
 14.0   1.9578    0.00032 2 0
238 238 13 2
 14.0   2.0670    0.00129 2 0
 13.0   2.4948    0.00000 2 0
 12.0   3.0612    0.00000 2 0
 11.0   2.6082    0.00016 2 0
 10.0   2.8276    0.00051 2 0
 16.0   0.2618    0.00209 1 1
 15.0   0.2583    0.00000 1 1
 14.0   1.2255    0.00003 1 1
 13.0   2.1657    0.00006 1 1
 12.0   2.6660    0.00000 1 1
 11.0   2.8221    0.00580 1 1
 10.0   3.1417    0.00002 1 1
  8.0   3.3636    0.00008 1 1
```

LOVERING 08 1978

174	07	1		
08.0	8.79		1	2
10.0	8.53		1	2
12.0	8.51		1	2
14.0	8.51		1	2
16.0	8.53		1	2
18.0	8.41		1	2
20.0	7.93		1	2
190	07	1		
08.0	6.99		1	2
10.0	7.07		1	2
12.0	6.99		1	2
14.0	6.87		1	2
16.0	6.97		1	2
18.0	6.85		1	2
20.0	7.03		1	2
201	08	1		
08.0	6.13		1	2
10.0	6.23		1	2
12.0	6.14		1	2
14.0	6.11		1	2
16.0	6.09		1	2
18.0	5.89		1	2
20.0	5.55		1	2
22.0	5.52		1	2
211	08	1		
08.0	6.10		1	2
10.0	5.39		1	2
12.0	5.50		1	2
14.0	5.49		1	2
16.0	5.40		1	2
18.0	5.50		1	2
20.0	5.26		1	2
22.0	4.92		1	2
217	08	1		
08.0	5.82		1	2
10.0	4.87		1	2
12.0	4.88		1	2
14.0	4.76		1	2
16.0	4.56		1	2
18.0	4.64		1	2
20.0	4.54		1	2
22.0	4.43		1	2
232	08	1		
08.0	5.00		1	2
10.0	3.96		1	2
12.0	4.08		1	2
14.0	3.99		1	2
16.0	4.23		1	2
18.0	3.95		1	2
20.0	3.64		1	2
22.0	3.21		1	2
236	08	1		
08.0	4.80		1	2
10.0	3.78		1	2
12.0	3.64		1	2

14.0	3.64		1 2
16.0	3.70		1 2
18.0	3.29		1 2
20.0	2.96		1 2
22.0	2.59		1 2
258	05	1	
14.0	2.51		1 2
16.0	2.22		1 2
18.0	1.87		1 2
20.0	1.58		1 2
22.0	0.94		1 2

LOVERING		0008	1979		
142	07 1				
12.0	10.4050	0.04805	1	1	
14.0	10.1600	0.00000	1	1	
16.0	10.0550	0.00605	1	1	
17.0	9.9100	0.00000	1	1	
18.0	9.8450	0.00005	1	1	
19.0	9.8200	0.00020	1	1	
20.0	9.7250	0.00005	1	1	
164	08 1				
12.0	8.2450	0.00005	1	1	
14.0	8.0550	0.00045	1	1	
16.0	8.1450	0.00005	1	1	
17.0	8.0650	0.00245	1	1	
18.0	8.0550	0.00005	1	1	
19.0	8.0200	0.00020	1	1	
20.0	7.9900	0.00000	1	1	
21.0	7.8050	0.00045	1	1	
191	11 1				
10.0	6.1150	0.00005	1	1	
12.0	6.1600	0.00080	1	1	
14.0	5.7650	0.00245	1	1	
15.0	5.9750	0.00045	1	1	
16.0	6.1700	0.00180	1	1	
17.0	5.7500	0.00020	1	1	
18.0	5.4400	0.00000	1	1	
19.0	5.4500	0.00720	1	1	
20.0	5.2400	0.00080	1	1	
21.0	5.0150	0.00005	1	1	
22.0	4.9050	0.00005	1	1	
205	10 1				
10.0	5.4500	0.00180	1	1	
12.0	5.4200	0.00080	1	1	
14.0	5.1000	0.00080	1	1	
16.0	5.2000	0.00320	1	1	
17.0	4.9250	0.00125	1	1	
18.0	4.7200	0.00020	1	1	
19.0	4.5700	0.02000	1	1	
20.0	4.1150	0.00045	1	1	
21.0	3.8700	0.00180	1	1	
22.0	3.6950	0.00005	1	1	
222	10 1				
10.0	4.5150	0.00005	1	1	
12.0	4.3150	0.00005	1	1	
14.0	3.6550	0.00045	1	1	
15.0	4.0950	0.00405	1	1	
16.0	3.8950	0.00005	1	1	
17.0	3.5750	0.08405	1	1	
18.0	3.6350	0.00005	1	1	
19.0	3.4450	0.02205	1	1	
20.0	3.7000	0.03380	1	1	
22.0	3.4600	0.00320	1	1	
236	10 1				
10.0	3.4550	0.00405	1	1	
12.0	3.0500	0.00980	1	1	
14.0	2.7700	0.00500	1	1	
15.0	2.7450	0.00045	1	1	

16.0	2.7350	0.00045	1	1
17.0	2.4150	0.00405	1	1
18.0	2.2350	0.01125	1	1
19.0	1.7350	0.03125	1	1
20.0	1.6250	0.02205	1	1
22.0	1.5200	0.00980	1	1
248	10 1.			
10.0	4.8000	0.00000	1	1
12.0	2.3150	0.00005	1	1
14.0	1.9400	0.00020	1	1
15.0	2.0750	0.00005	1	1
16.0	2.0500	0.00320	1	1
17.0	1.8300	0.00180	1	1
18.0	1.6250	0.00125	1	1
19.0	1.2450	0.00245	1	1
20.0	1.0550	0.00245	1	1
22.0	0.9450	0.00405	1	1
261	10 1			
10.0	8.4850	0.00005	1	1
12.0	6.8250	0.00125	1	1
14.0	1.7750	0.00005	1	1
15.0	1.4400	0.00980	1	1
16.0	1.4600	0.00020	1	1
17.0	1.2050	0.00605	1	1
18.0	0.9750	0.00125	1	1
19.0	0.4850	0.00045	1	1
20.0	0.4100	0.00020	1	1
22.0	0.4800	0.00020	1	1

```
LOVERING          11  · 1980
115 126  5 1
  0.0 11.7784   0.00024 1 2
 16.0 11.5509   0.00659 1 2
 18.0 11.4236   0.00439 1 2
 20.0 11.6257   0.04736 1 2
 22.0 11.4504  99.99001 1 2
120 127  5 1
  0.0 11.7010   0.00562 1 2
 14.0 11.3309   0.00024 1 2
 16.0 11.2204   0.00043 1 2
 18.0 11.1981   0.00003 1 2
 20.0 11.1320   0.00018 1 2
126 137  6 1
  0.0 11.8094   0.00391 1 2
 14.0 11.1686   0.08423 1 2
 16.0 11.0350   0.02097 1 2
 18.0 11.0206   0.00316 1 2
 20.0 11.0369   0.00211 1 2
 22.0 10.9856   0.00957 1 2
134 135  9 1
 12.0 10.8674   0.00179 1 1
 14.0 10.7412   0.00064 1 1
 15.0 10.7047   0.00002 1 1
 16.0 10.5796   0.00006 1 1
 17.0 10.6391   0.00017 1 1
 18.0 10.6128   0.00154 1 1
 19.0 10.5196  99.99001 1 1
 20.0 10.4239   0.00006 1 1
 22.0 10.3750   0.00000 1 1
145 148  8 1
 14.0 10.0212   0.00018 1 1
 15.0  9.9715   0.00012 1 1
 16.0  9.9767   0.00000 1 1
 17.0  9.9549   0.00011 1 1
 18.0  9.9275   0.00011 1 1
 19.0  9.8827   0.00092 1 1
 20.0  9.7529   0.00012 1 1
 22.0  9.7168   0.00037 1 1
159 164 13 2
 14.0  8.6060   0.00012 1 0
 15.0  8.5730   0.00006 1 0
 16.0  8.3017   0.00002 1 0
 17.0  8.1351   0.00006 1 0
 18.0  8.0052   0.00017 1 0
 19.0  7.9047   0.00012 1 0
 20.0  7.8348   0.00130 1 0
 22.0  7.7939   0.00067 1 0
 16.0  8.3492   0.00026 2 1
 17.0  8.1070   0.00002 2 1
 18.0  7.9975   0.00000 2 1
 20.0  7.7350   0.00002 2 1
 22.0  7.7638   0.00151 2 1
181 185 12 2
 16.0  6.2911   0.00002 2 1
 17.0  6.0788   0.00000 2 1
 18.0  5.8012   0.00008 2 1
```

20.0	5.4234	0.00000	2	1
19.0	5.7756	0.00026	2	1
22.0	4.7556	0.00015	2	1
15.0	6.4250	0.00043	1	0
14.0	6.4544	0.00011	1	0
16.0	6.2281	0.00044	1	0
18.0	5.8660	0.00003	1	0
20.0	5.7914	0.05403	1	0
22.0	4.8942	0.00266	1	0
202 204 13 2				
22.0	3.8726	0.00000	1	1
20.0	4.1950	0.00017	1	1
19.0	4.1572	0.00066	1	1
18.0	4.3118	0.00095	1	1
17.0	4.6946	0.00249	1	1
16.0	4.9539	0.00148	1	1
15.0	5.0226	0.00031	1	1
14.0	5.0743	0.00079	1	1
22.0	4.1730	0.00055	2	0
20.0	4.2723	0.00211	2	0
18.0	4.6087	0.00015	2	0
17.0	4.8526	0.00166	2	0
16.0	4.9678	0.00102	2	0
209 218 13 2				
14.0	3.7763	0.00041	1	1
15.0	3.9047	0.00029	1	1
16.0	3.7939	0.00128	1	1
17.0	3.1399	0.00003	1	1
18.0	3.1646	0.00092	1	1
19.0	2.8195	0.00166	1	1
20.0	2.8140	0.00032	1	1
22.0	2.3790	0.00031	1	1
16.0	3.8834	0.00423	2	0
17.0	3.6972	0.00043	2	0
18.0	4.2641	0.00002	2	0
20.0	2.7747	0.00006	2	0
22.0	2.5693	0.00016	2	0
225 231 13 2				
14.0	2.7310	0.00001	1	1
15.0	2.7526	0.00345	1	1
16.0	2.2260	0.00003	1	1
17.0	2.0601	0.06987	1	1
18.0	1.5009	0.00032	1	1
19.0	1.5010	0.00001	1	1
20.0	1.3085	0.00166	1	1
22.0	1.0366	0.00696	1	1
16.0	2.5535	0.00000	2	0
17.0	2.1503	0.00011	2	0
18.0	1.6072	0.00003	2	0
20.0	1.4309	0.00000	2	0.
22.0	1.2809	0.00084	2	0
238 238 14 2				
22.0	0.4021	0.00042	2	0
20.0	0.6160	0.00001	2	0
18.0	0.8462	0.00006	2	0
17.0	1.0458	0.00003	2	0
15.0	1.5419	0.00003	2	0

22.0	0.3698	0.00003	1	1
20.0	0.5298	0.00032	1	1
19.0	0.6232	0.00001	1	1
18.0	0.8444	0.00210	1	1
17.0	0.9073	0.00006	1	1
16.0	1.0583	0.00001	1	1
15.0	1.6121	0.00006	1	1
14.0	1.5563	0.00127	1	1
13.0	1.2075	0.00259	2	0

LYSTER 08 1978

175	14	1		
08.0	10.14		1	2
10.0	10.98		1	2
12.0	11.09		1	2
14.0	11.06		1	2
16.0	10.99		1	2
18.0	11.01		1	2
20.0	10.99		1	2
22.0	10.82		1	2
24.0	10.89		1	2
26.0	10.84		1	2
28.0	11.06		1	2
30.0	10.81		1	2
35.0	10.45		1	2
40.0	9.39		1	2
189	15	1		
08.0	9.56		1	2
12.0	10.57		1	2
14.0	10.93		1	2
16.0	10.69		1	2
18.0	10.96		1	2
20.0	10.97		1	2
22.0	10.47		1	2
24.0	10.73		1	2
26.0	10.69		1	2
28.0	10.64		1	2
30.0	10.59		1	2
32.5	10.41		1	2
35.0	10.23		1	2
37.5	9.63		1	2
40.0	9.09		1	2
207	16	1		
08.0	9.03		1	2
10.0	9.66		1	2
12.0	10.14		1	2
14.0	10.24		1	2
16.0	10.41		1	2
18.0	10.30		1	2
20.0	10.40		1	2
22.0	10.34		1	2
24.0	10.27		1	2
26.0	10.26		1	2
28.0	10.17		1	2
30.0	9.93		1	2
32.5	9.61		1	2
35.0	9.31		1	2
37.5	8.54		1	2
40.0	8.06		1	2
216	11	1		
08.0	8.78		1	2
10.0	9.65		1	2
12.0	10.01		1	2
14.0	10.09		1	2
16.0	10.04		1	2
18.0	10.25		1	2
20.0	10.29		1	2

24.0	9.97		1	2
30.0	9.57		1	2
35.0	9.08		1	2
40.0	7.79		1	2
222	16	1		
08.0	8.32		1	2
10.0	9.55		1	2
12.0	9.76		1	2
14.0	9.86		1	2
16.0	10.09		1	2
18.0	10.24		1	2
20.0	10.24		1	2
22.0	10.16		1	2
24.0	9.99		1	2
26.0	9.61		1	2
28.0	9.84		1	2
30.0	9.70		1	2
32.5	9.24		1	2
35.0	9.00		1	2
37.5	8.63		1	2
40.0	7.13		1	2
230	16	1		
08.0	8.47		1	2
10.0	9.45		1	2
12.0	9.74		1	2
14.0	10.27		1	2
16.0	10.21		1	2
18.0	10.18		1	2
20.0	10.22		1	2
22.0	10.14		1	2
24.0	10.13		1	2
26.0	9.80		1	2
28.0	9.70		1	2
30.0	9.51		1	2
32.5	9.29		1	2
35.0	8.88		1	2
37.5	8.52		1	2
40.0	7.84		1	2
239	16	1		
08.0	8.59		1	2
10.0	9.16		1	2
12.0	9.64		1	2
14.0	9.61		1	2
16.0	10.28		1	2
18.0	10.27		1	2
20.0	10.20		1	2
22.0	10.15		1	2
24.0	9.92		1	2
26.0	9.70		1	2
28.0	9.63		1	2
30.0	9.61		1	2
32.5	8.99		1	2
35.0	8.49		1	2
37.5	7.85		1	2
40.0	6.35		1	2
259	14	1		
12.0	9.37		1	2

14.0	9.73	1 2
16.0	10.12	1 2
18.0	10.10	1 2
20.0	10.04	1 2
22.0	9.99	1 2
24.0	9.61	1 2
26.0	9.48	1 2
28.0	9.26	1 2
30.0	9.24	1 2
32.5	8.90	1 2
35.0	8.04	1 2
37.5	7.38	1 2
40.0	6.58	1 2

LYSTER 6 1979

191	15 2			
10.0	9.7250	0.00845	1	1
12.0	10.2000	0.00180	2	1
14.0	10.1650	0.00605	1	1
16.0	10.2450	0.00005	2	1
18.0	10.4850	0.00005	1	1
20.0	10.5050	0.00045	2	1
22.0	10.4750	0.00045	1	1
24.0	10.1700	0.00000	2	1
26.0	10.1350	0.00605	1	1
28.0	10.1150	0.00005	2	1
30.0	9.8650	0.00005	1	1
32.5	9.4650	0.00005	2	1
35.0	9.4000	0.00080	1	1
37.5	9.2600	0.00020	2	1
40.0	8.0300	0.00180	1	1
205	15 2			
10.0	9.7950	0.00405	1	1
12.0	9.9950	0.01125	2	1
14.0	10.2100	0.00000	1	1
16.0	10.2450	0.00005	2	1
18.0	10.4000	0.00000	1	1
20.0	10.4400	0.00000	2	1
22.0	10.4200	0.00080	1	1
24.0	10.2550	0.00005	2	1
26.0	10.0700	0.00000	1	1
28.0	9.8750	0.00005	2	1
30.0	9.7700	0.00000	1	1
32.5	9.3700	0.00000	2	1
35.0	8.9450	0.00005	1	1
37.5	8.8450	0.00005	2	1
40.0	7.6600	0.00020	1	1
226	15 2			
10.0	8.6750	0.15125	1	1
12.0	9.4700	99.99001	2	1
14.0	9.7300	0.00020	1	1
16.0	9.8850	0.00405	2	1
18.0	10.0250	0.00045	1	1
20.0	10.0500	0.00080	2	1
22.0	10.0950	0.00005	1	1
24.0	9.7900	0.00000	2	1
26.0	9.5600	0.00180	1	1
28.0	9.5850	0.00245	2	1
30.0	9.4100	99.99001	1	1
32.5	8.8800	0.05120	2	1
35.0	8.2850	0.00045	1	1
37.5	7.6900	0.00000	2	1
40.0	6.7500	0.00500	1	1
236	15 2			
10.0	8.5900	0.00180	1	1
12.0	9.4450	0.00405	2	1
14.0	9.4000	0.00000	1	1
16.0	9.7900	0.00020	2	1
18.0	9.4600	0.00000	1	1
20.0	9.5750	0.00045	2	1
22.0	10.0200	0.00020	1	1

24.0	9.6950	0.00405	2	1
26.0	9.4550	0.00245	1	1
28.0	9.4650	0.00005	2	1
30.0	9.3950	0.00005	1	1
32.5	9.2050	0.00005	2	1
35.0	8.8850	0.00005	1	1
37.5	8.0200	0.00080	2	1
40.0	7.8200	0.00320	1	1
248	15 2			
10.0	8.5150	0.00005	1	1
12.0	9.2850	0.00045	2	1
14.0	9.3800	0.00000	1	1
16.0	9.3700	0.00000	2	1
18.0	9.6350	0.00005	1	1
20.0	9.5500	0.00000	2	1
22.0	9.5350	0.00045	1	1
24.0	9.3700	0.00000	2	1
26.0	9.3100	0.00020	1	1
28.0	9.2350	0.00005	2	1
30.0	9.1150	0.00005	1	1
32.5	8.7300	0.00000	2	1
35.0	8.2200	0.00020	1	1
37.5	7.4800	0.00020	2	1
40.0	5.9600	0.00020	1	1
261	15 2			
10.0	9.1700	0.00020	1	1
12.0	9.0700	0.00000	2	1
14.0	9.0200	0.00000	1	1
16.0	9.2350	0.00005	2	1
18.0	9.3750	0.00045	1	1
20.0	9.5550	0.00005	2	1
22.0	9.2850	0.00045	1	1
24.0	9.2700	0.00020	2	1
26.0	9.0650	0.00005	1	1
28.0	8.9950	0.00245	2	1
30.0	8.6400	0.00980	1	1
32.5	7.7350	0.00005	2	1
35.0	7.6500	0.00000	1	1
37.5	6.9250	0.00005	2	1
40.0	6.4550	0.00005	1	1

```
LYSTER          7    1980
120 122  5 1
 0.0 11.8105   0.00977 1 2
14.0 11.6067   0.00073 1 2
20.0 11.6029   0.00366 1 2
30.0 11.5998   0.00000 1 2
40.0 11.7570   0.00317 1 2
126 137  5 1
 0.0 11.7610   0.00757 1 2
14.0 11.8715   0.02148 1 2
20.0 11.7443   0.00366 1 2
30.0 11.7575   0.00000 1 2
40.0 11.7466   0.00464 1 2
190 192 14 2
14.0 10.9981   0.00378 1 0
16.0 11.0609   0.00124 1 0
18.0 11.0820   0.00003 1 0
20.0 11.0458   0.00008 1 0
26.0 10.6518   0.00032 1 0
30.0 10.4073   0.00081 1 0
32.5 10.0948   0.00136 1 0
35.0  9.6996   0.00050 1 0
27.5  9.5587   0.00282 1 0
16.0 10.8159   0.00139 2 1
20.0 10.8547   0.00012 2 1
24.0 10.4640   0.00023 2 1
30.0 10.3847   0.00153 2 1
37.5  9.4782   0.00160 2 1
220 223 16 2
37.5  7.3049   0.00003 2 0
30.0  8.9887   0.00066 2 0
24.0  9.5362   0.00027 2 0
20.0  9.9831   0.00078 2 0
16.0  9.6448   0.00063 2 0
37.5  7.0413   0.00035 1 1
35.0  7.6030   0.00043 1 1
32.5  8.1220   0.00044 1 1
30.0  8.9150   0.00015 1 1
28.0  9.0812   0.00014 1 1
26.0  9.1951   0.00035 1 1
24.0  9.2743   0.00133 1 1
22.0  9.5751   0.00000 1 1
20.0  9.9521   0.00067 1 1
16.0  9.7154   0.00124 1 1
14.0  9.5571   0.00066 1 1
204 212 16 2
37.5  8.8402   0.00000 1 0
37.5  8.7640   0.00006 2 0
35.0  8.9745   0.00026 1 0
32.5  9.1882   0.00003 1 0
30.0  9.3167   0.00002 1 0
28.0  9.7573   0.00018 1 0
26.0  9.7977   0.00031 1 0
24.0 10.0890   0.00011 1 0
24.0 10.0688   0.00053 2 0
22.0 10.2172   0.00006 1 0
20.0 10.3552   0.00002 1 0
```

```
20.0 10.3193   0.00296 2 0
18.0  9.9839  99.99001 1 0
16.0 10.2499   0.00000 1 0
16.0 10.0973   0.00000 2 0
14.0 10.2656   0.00041 1 0
232 235 16 2
37.5  7.3460   0.00095 1 0
37.5  7.7375   0.00002 2 0
35.0  8.0040   0.00101 1 0
32.5  8.4495   0.00003 1 0
30.0  8.9801   0.00246 2 0
28.0  8.9429   0.00003 1 0
26.0  9.0652   0.00002 1 0
24.0  9.3929   0.00055 2 0
24.0  9.3211   0.00027 1 0
22.0 10.1925   0.00008 1 0
20.0  9.9586   0.00020 2 0
20.0  9.7236   0.00034 1 0
18.0  9.8980   0.00006 1 0
16.0  9.7783   0.00375 2 0
16.0  9.9998   0.00832 1 0
14.0  9.8725  99.99001 1 0
255 255 10 2
20.0  9.0544   0.00049 1 1
16.0  9.6488   0.00015 1 0
24.0  8.9491   0.00128 1 0
30.0  8.2052   0.00040 1 0
37.5  7.0437   0.00209 1 0
16.0  9.5771   0.00002 2 0
20.0  8.9949   0.00038 2 0
24.0  8.7811   0.00839 2 0
30.0  8.2224   0.00064 2 0
37.5  6.9648   0.00021 2 0
```

MASSAWIPPI		6	1979	
158	15	1		
12.5	10.7100	0.00500	1	1
15.0	10.8700	0.00000	1	1
17.5	10.7950	0.00005	1	1
20.0	10.8050	0.00005	1	1
22.5	10.9200	0.00000	1	1
25.0	11.3950	0.00045	1	1
27.5	10.9700	0.00020	1	1
30.0	10.9900	0.00020	1	1
32.5	11.0250	0.00125	1	1
35.0	11.0250	0.00045	1	1
40.0	11.0450	0.00005	1	1
45.0	11.0500	0.00020	1	1
50.0	11.0700	0.00000	1	1
60.0	11.0600	0.00000	1	1
70.0	11.0500	0.00000	1	1
179	16	1		
10.0	9.6600	0.11520	1	1
12.5	9.9200	0.00180	1	1
15.0	10.0100	0.00000	1	1
17.5	10.2250	0.00605	1	1
20.0	10.2800	0.00000	1	1
22.5	10.4000	0.00080	1	1
25.0	10.4200	0.00080	1	1
27.5	10.6000	0.00020	1	1
30.0	10.6650	0.00005	1	1
32.5	10.7100	0.00180	1	1
35.0	10.7100	0.00020	1	1
40.0	10.7300	0.00020	1	1
45.0	10.7300	0.00080	1	1
50.0	10.7450	0.00045	1	1
60.0	10.7850	0.00005	1	1
70.0	10.5300	0.00500	1	1
200	15	1		
10.0	8.4550	0.00125	1	1
12.5	9.2150	0.00045	1	1
15.0	9.4150	0.00005	1	1
17.5	9.5350	0.00045	1	1
20.0	9.9400	0.00020	1	1
25.0	10.2550	0.00045	1	1
27.5	10.3350	0.00125	1	1
30.0	10.4800	0.00020	1	1
35.0	10.5000	0.00020	1	1
40.0	10.7500	99.99001	1	1
45.0	10.8100	0.00020	1	1
50.0	10.8800	99.99001	1	1
60.0	10.9400	0.00020	1	1
70.0	10.8500	0.00020	1	1
80.0	9.2900	0.00000	1	1
232	17	1		
10.0	7.4150	0.00005	1	1
12.5	7.3100	0.00720	1	1
15.0	8.0100	0.02420	1	1
17.5	8.6250	0.00045	1	1
20.0	8.9550	0.00045	1	1
22.5	9.3150	0.00005	1	1

25.0	9.9250	0.00005	1	1
27.5	9.7750	0.00045	1	1
30.0	9.9050	0.00845	1	1
32.5	10.1100	0.00020	1	1
35.0	10.1350	0.00045	1	1
40.0	10.3900	0.00020	1	1
45.0	10.4650	0.00125	1	1
50.0	10.3250	0.00245	1	1
60.0	10.3450	0.00845	1	1
70.0	10.1650	0.00005	1	1
80.0	7.1900	0.00080	1	1
252	17 1			
10.0	7.1800	99.99001	1	1
12.5	7.1500	0.00000	1	1
15.0	7.7100	0.00020	1	1
17.5	8.0150	0.00125	1	1
20.0	8.4050	0.00005	1	1
22.5	8.7600	0.00000	1	1
25.0	9.1350	0.00245	1	1
27.5	9.4500	99.99001	1	1
30.0	9.6550	0.00005	1	1
32.5	9.8750	0.00005	1	1
35.0	9.9450	0.00125	1	1
40.0	10.0950	0.00005	1	1
45.0	10.1700	0.00180	1	1
50.0	10.1750	0.00045	1	1
60.0	10.1150	0.00045	1	1
70.0	9.6000	0.02000	1	1
80.0	6.6100	0.00000	1	1
271	16 1			
10.0	9.5700	99.99001	1	1
12.5	9.5200	99.99001	1	1
15.0	7.2150	0.00245	1	1
17.5	7.2250	0.00005	1	1
20.0	7.4300	0.00000	1	1
22.5	7.9350	0.00005	1	1
25.0	8.2050	0.00005	1	1
27.5	8.5900	0.00020	1	1
30.0	9.0400	0.00020	1	1
32.5	9.0400	0.00020	1	1
35.0	9.2450	0.00125	1	1
40.0	9.5050	0.00125	1	1
45.0	9.5650	0.00005	1	1
50.0	9.7950	0.00005	1	1
60.0	10.1100	0.00020	1	1
70.0	10.0900	0.00000	1	1

```
MASSAWIPPI      10      1980
120  127   5  1
00.0  11.4200    0.00098  1  2
15.0  11.3801    0.00073  1  2
30.0  11.3967    0.00073  1  2
50.0  11.4408    0.00024  1  2
70.0  11.4682    0.00220  1  2
126  137   4  1
00.0  12.6696    0.10425  1  2
15.0  11.6314    0.01440  1  2
30.0  11.5635    0.00513  1  2
50.0  11.7959    0.00391  1  2
141  151  14  1
14.0  11.7838   99.99001  1  2
16.0  11.5757    0.00830  1  2
18.0  11.6120    0.00269  1  2
20.0  11.4409    0.00000  1  1
22.5  11.5965    0.01050  1  2
25.0  11.6287    0.00195  1  2
27.5  11.4281    0.00024  1  1
30.0  11.5895    0.00049  1  2
35.0  11.4354    0.00073  1  2
40.0  11.4493    0.00049  1  2
45.0  11.4551    0.00024  1  2
50.0  11.3837    0.00000  1  2
60.0  11.3746    0.00220  1  2
70.0  11.2046    0.00223  1  2
155  160  13  1
15.0  11.4503    0.00049  1  0
17.5  11.3507   99.99000  1  0
20.0  11.3373    0.00073  1  0
22.5  11.2249    0.00092  1  0
25.0  11.0952    0.00000  1  0
27.5  11.0813    0.00000  1  0
30.0  11.0813    0.00000  1  0
32.5  11.1786   99.99999  1  0
35.0  11.1321    0.00076  1  0
40.0  11.1044    0.00000  1  0
50.0  11.0324    0.00055  1  0
60.0  10.9806    0.00134  2  0
70.0  10.8590    0.00078  1  0
169  177  12  1
15.0  10.9247    0.00053  1  1
17.5  11.0424    0.00108  1  1
20.0  10.8472    0.00009  1  1
25.0  10.9352    0.00513  1  1
27.5  10.9293    0.00049  1  1
30.0  10.9320    0.00055  1  1
35.0  10.9212    0.00009  1  1
40.0  10.9126    0.00156  1  0
45.0  11.0139    0.00267  1  0
50.0  10.9711    0.00153  1  0
60.0  11.0003    0.00000  1  0
70.0  10.9804    0.00005  1  0
185  187  14  1
70.0  10.7353    0.00990  1  0
60.0  10.6918    0.00000  1  0
```

```
 50.0 10.6450   0.00002 1 0
 45.0 10.5218   0.00009 1 0
 40.0 10.4278   0.00006 1 0
 35.0 10.4789   0.00081 1 0
 32.5 10.4577   0.00221 1 0
 30.0 10.4066   0.00070 1 0
 27.5 10.3621   0.00075 1 0
 25.0 10.4282   0.00050 1 0
 22.5 10.3340   0.00018 1 0
 20.0 10.2193   0.00017 1 0
 17.5 10.3187   0.00040 1 0
 15.0 10.2928   0.00000 1 0
204 210 20 2
 70.0  9.8164   0.00198 1 0
 70.0  9.9508   0.00032 2 0
 60.0 10.1813  99.99000 1 0
 50.0 10.2035   0.00076 1 0
 50.0 10.1099   0.00047 2 0
 45.0 10.3609   0.00003 1 0
 40.0 10.0058   0.00055 1 0
 35.0 10.2533   0.00060 1 0
 35.0 10.2409  99.99001 2 0
 32.5 10.2498   0.00000 1 0
 30.0 10.1389   0.00114 1 0
 27.5 10.0695   0.00101 1 0
 27.5 10.1066  99.99001 2 0
 25.0  9.8901   0.00014 1 0
 22.5  9.6541   0.00026 1 0
 20.0  9.8593   0.00084 1 0
 20.0  9.9606  99.99001 2 0
 17.5  9.8690   0.00034 1 0
 15.0  9.5187   0.00049 1 0
 12.5  9.4545  99.99001 1 0
220 223 18 2
 70.0  9.7671   0.00006 1 0
 70.0  9.7486   0.00000 2 0
 60.0 10.2552   0.00020 1 0
 50.0 10.2845   0.00000 1 0
 50.0 10.2623   0.00053 2 0
 45.0 10.2980   0.00085 1 0
 40.0 10.2240   0.00006 1 0
 35.0 10.1007   0.00180 1 0
 35.0 10.2118   0.00000 2 0
 30.0 10.0887   0.00002 1 0
 27.5  9.9486   0.00047 1 0
 27.5  9.9478   0.00002 2 0
 25.0  9.8116   0.00000 1 0
 22.5  9.5432   0.00000 1 0
 20.0  9.2455   0.00032 1 0
 20.0  9.2303   0.00002 2 0
 17.5  8.9505   0.00032 1 0
 15.0  9.1738   0.00024 1 0
232 238 18 2
 70.0  9.8454   0.00044 2 0
 50.0  9.9249   0.00233 2 0
 35.0  9.9638   0.00002 2 0
 27.5  9.7470   0.00003 2 0
```

```
20.0   8.8248    0.00186 2 0
70.0   9.7506    0.02986 1 0
60.0   9.7490    0.00034 1 0
50.0   9.7678    0.00075 1 0
45.0  10.0246    0.00258 1 0
40.0  10.1169    0.00159 1 0
35.0  10.0527    0.00240 1 0
30.0   9.8691    0.00154 1 0
27.5   9.7235    0.00014 1 0
25.0   9.7091    0.00046 1 0
22.5   9.0198    0.00035 1 0
20.0   8.8402    0.01125 1 0
17.5   8.7286    0.00116 1 0
15.0   8.7406    0.00023 1 0
255 253 10 2
20.0   7.9812    0.00011 1 0
27.5   9.1980    0.00093 1 0
35.0   9.4885    0.00069 1 0
50.0   9.7702    0.00061 1 0
70.0   9.3882    0.00061 1 0
20.0   8.0034    0.00165 2 0
27.5   9.1915    0.00400 2 0
35.0   9.5731    0.00102 2 0
50.0   9.7904    0.00061 2 0
70.0   9.5493    0.00000 2 0
```

MAGOG			6	1979	
152	7 1				
10.0	7.8950	0.00045	1	1	
11.0	7.6500	0.00020	1	1	
12.0	7.4100	0.00720	1	1	
13.0	6.9400	0.00000	1	1	
14.0	6.7550	0.00045	1	1	
15.0	5.8800	0.00000	1	1	
16.0	5.8600	0.00020	1	1	
157	7 1				
10.0	6.9900	0.00020	1	1	
11.0	6.5500	0.00080	1	1	
12.0	6.0250	0.00005	1	1	
13.0	5.3450	0.00045	1	1	
14.0	5.1350	0.00005	1	1	
15.0	5.2950	0.00005	1	1	
16.0	5.0300	0.00000	1	1	
167	8 1				
9.0	6.3200	0.00000	1	1	
10.0	5.8100	0.00020	1	1	
11.0	4.8850	0.00605	1	1	
12.0	4.1700	0.02880	1	1	
13.0	3.6350	0.00125	1	1	
14.0	3.6450	0.00005	1	1	
15.0	3.4600	0.00000	1	1	
16.0	2.4550	0.00005	1	1	
171	8 1				
9.0	5.5300	0.00020	1	1	
10.0	4.5950	0.00005	1	1	
11.0	3.6800	0.00020	1	1	
12.0	3.3600	99.99001	1	1	
13.0	2.6000	0.00020	1	1	
14.0	2.2700	99.99001	1	1	
15.0	1.8650	0.00005	1	1	
16.0	1.8500	0.00000	1	1	
177	8 1				
9.0	7.3500	0.00080	1	1	
10.0	5.8550	0.00045	1	1	
11.0	3.1050	0.00045	1	1	
12.0	1.7050	0.00005	1	1	
13.0	1.7650	0.00045	1	1	
14.0	1.1800	0.00020	1	1	
15.0	0.8900	0.00080	1	1	
16.0	0.3850	0.00045	1	1	
187	7 1				
9.0	7.3500	0.00020	1	1	
10.0	1.7400	0.00080	1	1	
11.0	0.8350	0.00845	1	1	
12.0	0.3600	0.02000	1	1	
13.0	0.5250	0.03645	1	1	
14.0	0.2300	0.00020	1	1	
15.0	0.2050	0.00005	1	1	

```
LITTLEMAGOG     10      1980
115 121   5 1
  0.0 10.9455    0.00069 1 2
  8.0 10.3460    0.00014 1 2
 10.0 10.2926    0.00017 1 2
 12.0 10.2361    0.00044 1 2
 16.0 10.1230    0.00024 1 2
120 127   5 1
  0.0 12.6480    0.10059 1 2
 10.0 10.3491    0.00266 1 2
 12.0 10.6492    0.00000 1 2
 14.0 10.4795    0.00966 1 2
 16.0 10.0000    0.04045 1 2
130 137   7 1
 10.0 12.1678    0.00000 1 1
 11.0 11.9760    0.00244 1 1
 12.0 11.9094    0.00073 1 1
 13.0 10.2337    0.00037 1 1
 14.0  9.7610    0.00050 1 1
 15.0  9.4958    0.00031 1 1
 16.0  9.2044    0.00049 1 1
134 135   7 1
  9.0 11.1457    0.00056 1 1
 10.0 11.0867    0.00003 1 1
 11.0 11.0694    0.00012 1 1
 12.0 10.5380    0.00310 1 1
 13.0 10.1846    0.00014 1 1
 14.0  9.7132    0.00015 1 1
 15.0  8.9071    0.00003 1 1
141 151   7 1
 10.0 10.6888    0.01906 1 1
 11.0 10.1776   99.99001 1 1
 12.0  9.5540   99.99001 1 1
 13.0  9.4685    0.00044 1 1
 14.0  8.9106    0.00000 1 1
 15.0  8.1183    0.00230 1 1
 16.0  8.1548    0.00005 1 1
148 151  10 2
 13.0  8.7074   99.99001 2 1
 14.0  8.6575    0.00012 2 1
 15.0  8.4510    0.00131 2 1
 16.0  8.0709    0.00179 2 1
 12.0  9.0191    0.00000 1 2
 13.0  8.7987    0.00003 1 2
 14.0  8.6321    0.00012 1 2
 15.0  8.5675    0.00026 1 2
 16.0  8.2269    0.00003 1 2
 17.0  8.2274    0.00002 1 2
155 158  15 2
 10.0  8.4616    0.00098 2 1
 11.0  8.2119    0.00128 2 1
 12.0  7.6453    0.00146 2 1
 13.0  7.2164    0.00006 2 1
 14.0  6.3208    0.01375 2 1
 15.0  5.6305    0.00017 2 1
 16.0  5.4755    0.00000 2 1
 10.0  8.7242    0.00278 1 0
```

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11.0   8.2257   0.00037 1 0
12.0   7.7669   0.00975 1 0
13.0   7.2360   0.00008 1 0
14.0   6.5232   0.00012 1 0
15.0   6.1406   0.00008 1 0
16.0   5.7787   0.02933 1 0
17.0   5.4805   0.00003 1 0
162 164  7 1
11.0   8.8653   0.00212 1 0
12.0   5.3246   0.00047 1 0
13.0   5.1192   0.01227 1 0
14.0   5.0412   0.00011 1 0
15.0   4.6353   0.00096 1 0
16.0   4.4566   0.00029 1 0
17.0   4.1436   0.00928 1 0
169 175 11 2
11.0   6.2572   0.01291 1 1
12.0   5.8594   0.00043 1 1
13.0   4.9368   0.00008 1 1
14.0   4.4973   0.00212 1 1
15.0   3.3556   0.00023 1 1
16.0   3.2330   0.00439 1 1
12.0   5.2712   0.00597 2 0
13.0   5.1729   0.00000 2 0
14.0   5.0990   0.00188 2 0
15.0   3.8798   0.00011 2 0
16.0   3.3014   0.00844 2 0
178 182 12 2
12.0   4.1087   0.00055 2 0
13.0   3.7080   0.00015 2 0
14.0   2.5494   0.00000 2 0
15.0   1.9019   0.00132 2 0
16.0   0.8609   0.00042 2 0
11.0   4.6922   0.00368 1 1
12.0   4.0879   0.00056 1 1
13.0   3.6137   0.00020 1 1
14.0   2.2742   0.00011 1 1
15.0   1.2414   0.00004 1 1
10.6   0.4190   0.10021 1 1
17.0   0.5814   0.00000 1 1
```

NORTH		9	1979		
138	10 1				
10.0	11.9000	99.99001	1	1	
12.0	11.7500	0.00180	1	1	
14.0	11.7150	0.00245	1	1	
16.0	11.6750	0.00005	1	1	
18.0	11.4300	0.00000	1	1	
20.0	11.2650	0.00045	1	1	
22.0	11.1700	0.00180	1	1	
24.0	11.0700	0.00000	1	1	
26.0	10.9700	0.00000	1	1	
28.0	10.7200	0.00000	1	1	
151	10 1				
10.0	10.6350	0.00125	1	1	
12.0	10.3750	0.00045	1	1	
14.0	10.4000	0.00720	1	1	
16.0	10.2450	0.00045	1	1	
18.0	9.9650	0.00005	1	1	
20.0	9.8800	0.00020	1	1	
22.0	9.7350	0.00045	1	1	
24.0	9.4700	0.00080	1	1	
26.0	9.2650	0.00125	1	1	
28.0	8.8450	0.00045	1	1	
186	10 1				
10.0	8.8950	0.00125	1	1	
12.0	7.8650	0.00045	1	1	
14.0	7.1950	0.00125	1	1	
16.0	6.6050	0.00005	1	1	
18.0	6.4450	0.00045	1	1	
20.0	6.5100	0.00000	1	1	
22.0	6.3150	0.00005	1	1	
24.0	6.2950	0.00005	1	1	
26.0	6.4100	0.00000	1	1	
28.0	5.9900	0.18000	1	1	
204	10 1				
10.0	7.2700	0.00080	1	1	
12.0	6.5300	0.00720	1	1	
14.0	5.5000	0.00180	1	1	
16.0	5.3800	0.00720	1	1	
18.0	5.2400	0.00720	1	1	
20.0	5.1300	0.00080	1	1	
22.0	5.0300	0.00320	1	1	
24.0	5.0100	0.00320	1	1	
26.0	4.9250	0.00405	1	1	
28.0	4.2650	0.00125	1	1	
219	10 1				
10.0	6.8800	0.00020	1	1	
12.0	5.7750	0.00245	1	1	
14.0	5.2900	0.00020	1	1	
16.0	5.2550	0.00125	1	1	
18.0	5.1600	0.00500	1	1	
20.0	5.0650	0.00005	1	1	
22.0	4.9650	0.00125	1	1	
24.0	4.7100	0.02420	1	1	
26.0	4.5000	0.00720	1	1	
28.0	4.0000	0.00000	1	1	
234	10 1				

10.0	8.4450	0.00045	1	1
12.0	8.0650	0.00125	1	1
14.0	4.2400	0.00020	1	1
16.0	4.0800	0.00000	1	1
18.0	4.0000	0.01280	1	1
20.0	3.7900	0.00020	1	1
22.0	3.8000	0.00180	1	1
24.0	3.5750	0.00005	1	1
26.0	2.5250	0.01805	1	1
28.0	2.0550	0.00005	1	1
256	10 1			
10.0	8.6300	0.00020	1	1
12.0	8.5800	0.00000	1	1
14.0	4.4300	0.00020	1	1
16.0	3.1800	0.00180	1	1
18.0	2.8150	0.00045	1	1
20.0	2.5050	0.00005	1	1
22.0	2.7050	0.00005	1	1
24.0	2.8750	0.00125	1	1
26.0	2.5900	0.00500	1	1
28.0	2.2700	0.00080	1	1
265	10 1			
10.0	8.9850	0.00005	1	1
12.0	8.9900	0.00020	1	1
14.0	8.8050	0.00005	1	1
16.0	5.7250	0.00045	1	1
18.0	3.8150	0.00245	1	1
20.0	2.7100	0.00020	1	1
22.0	2.1800	0.00080	1	1
24.0	2.0350	0.00005	1	1
26.0	1.8050	0.00405	1	1
28.0	1.2350	0.00125	1	1
270	10 1			
10.0	9.2550	0.00005	1	1
12.0	9.2400	0.00020	1	1
14.0	9.2300	0.00180	1	1
16.0	6.0950	0.00045	1	1
18.0	2.4400	0.00000	1	1
20.0	2.0500	0.00000	1	1
22.0	1.8350	0.00005	1	1
24.0	1.8700	0.00020	1	1
26.0	1.3950	0.00045	1	1
28.0	1.0150	0.00405	1	1

```
NORTH                10    1980
114 121   5 1
  0.0 12.3575   0.01782 1 2
 16.0 12.0667   0.00269 1 2
 20.0 11.9910   0.00024 1 2
 24.0 12.0033   0.00000 1 2
 28.0 11.9338   0.04126 1 2
121 127   4 1
  0.0 12.0774   0.00098 1 2
 16.0 11.9289   0.00049 1 2
 20.0 11.9467   0.00073 1 2
 24.0 11.8681   0.00024 1 2
133 142   5 1
  0.0 12.3257   0.00000 1 2
 16.0 12.1010   0.00879 1 2
 20.0 11.9846   0.02051 1 2
 24.0 11.7364   0.00000 1 2
 28.0 11.4061   0.01172 1 2
136 137  11 1
 14.0 11.9458   0.00024 1 1
 15.0 11.9069   0.00000 1 1
 16.0 11.9039   0.00562 1 1
 17.0 11.8984   0.00195 1 1
 18.0 11.7101   0.00000 1 1
 19.0 11.5790   0.00049 1 1
 20.0 11.4461   0.00049 1 1
 22.0 11.3488   0.00098 1 1
 24.0 11.2371   0.00038 1 1
 26.0 10.9981   0.00052 1 1
 28.0 10.8351   0.00000 1 1
164 168   9 1
 14.0  9.7241   0.00162 1 0
 16.0  9.6047   0.00002 1 0
 18.0  9.3557   0.00085 1 0
 20.0  8.8738   0.00215 1 0
 22.0  8.8199   0.00131 1 0
 24.0  8.8502   0.00380 1 0
 26.0  8.4841   0.00012 1 0
 28.0  7.7975   0.00060 1 0
 30.0  7.5254   0.00002 1 0
179 184  14 2
 16.0  8.0641   0.00003 1 1
 18.0  7.8722   0.00000 1 1
 20.0  7.6353   0.00261 1 1
 24.0  6.9112   0.00014 1 1
 28.0  6.7119   0.00047 1 1
 14.0  8.4460   0.01102 1 1
 22.0  7.5143   0.05019 1 1
 26.0  6.8169   0.00032 1 1
 30.0  6.6794   0.00066 1 1
 16.0  8.1840   0.00002 2 0
 18.0  7.7433   0.00008 2 0
 20.0  7.7369   0.00000 2 0
 24.0  7.2931   0.00131 2 0
 28.0  6.9209   0.00003 2 0
192 196   8 1
 28.0  5.4564   0.00314 1 1
```

```
26.0   5.8758   0.00267 1 1
24.0   6.2984   0.00238 1 1
22.0   6.4571   0.00076 1 1
20.0   6.5493   0.00775 1 1
18.0   6.5748   0.00000 1 1
16.0   6.7170   0.00073 1 1
14.0   7.2725   0.00020 1 1
206 215 13 2
16.0   5.9621   0.00034 2 0
18.0   5.7966   0.00079 2 0
20.0   5.9490   0.00043 2 0
24.0   4.9708   0.00098 2 0
28.0   4.4129   0.00064 2 0
14.0   6.0004   0.00009 1 1
16.0   6.0452   0.00002 1 1
20.0   5.5875   0.02090 1 1
18.0   5.7591   0.00070 1 1
22.0   5.2843   0.00305 1 1
24.0   5.0179   0.00645 1 1
26.0   4.5903   0.00035 1 1
28.0   4.1298   0.00655 1 1
217 220 13 2
14.0   5.7546   0.00009 2 0
16.0   5.0826   0.00002 2 0
18.0   4.6971   0.00064 2 0
28.0   3.6110   0.00063 2 0
20.0   4.4861   0.00005 2 0
24.0   4.1328   0.00000 2 0
16.0   5.2313   0.00006 1 1
18.0   4.8554   0.00040 1 1
20.0   4.5338   0.00006 1 1
22.0   4.2825   0.00014 1 1
24.0   3.7871   0.00003 1 1
26.0   3.5856   0.00041 1 1
28.0   3.5076   0.00029 1 1
234 235 13 2
28.0   1.9881   0.00208 1 0
26.0   2.0960   0.00066 1 0
24.0   3.0900   0.00006 1 0
22.0   3.4696   0.00023 1 0
20.0   3.5300   0.00011 1 0
18.0   3.6620   0.00015 1 0
16.0   4.0197   0.00044 1 0
28.0   2.0691   0.00031 2 1
24.0   3.2953   0.00015 2 1
20.0   3.6585   0.00017 2 1
18.0   3.8037   0.00000 2 1
16.0   4.1888   0.00003 2 1
14.0   4.4836   0.00024 2 1
```

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192	15	2		
10.0	11.7000	0.02880	1	1
12.0	11.3650	0.00005	2	1
14.0	10.8150	0.00245	1	1
16.0	10.5950	0.00045	2	1
18.0	10.4300	0.00020	1	1
20.0	10.1300	0.00000	2	1
22.0	10.3500	0.00080	1	1
24.0	10.3200	0.00000	2	1
26.0	10.2950	0.00005	1	1
28.0	10.3050	0.00005	2	1
30.0	10.2350	0.00005	1	1
32.5	9.3700	0.00020	2	1
35.0	8.9350	0.00005	1	1
37.5	8.2550	0.00045	2	1
40.0	7.8550	0.00005	1	1
206	14	2		
10.0	12.3100	0.00000	1	1
12.0	11.6350	0.00005	2	1
14.0	11.0600	0.00000	1	1
16.0	10.7450	0.00005	2	1
18.0	10.5600	0.00080	1	1
20.0	10.4600	0.00020	2	1
22.0	10.4000	0.00020	1	1
24.0	10.2700	0.00020	2	1
26.0	10.2900	0.00020	1	1
28.0	9.9850	0.00005	2	1
30.0	9.9350	0.00005	1	1
32.5	8.8550	0.00045	2	1
35.0	8.6750	0.00045	1	1
37.5	7.8950	0.00005	2	1
221	14	2		
10.0	12.3300	0.00000	1	1
12.0	11.0500	0.00000	2	1
14.0	10.5450	0.00005	1	1
16.0	10.4500	0.00000	2	1
18.0	10.2050	0.00125	1	1
20.0	10.2800	0.00080	2	1
22.0	10.2200	0.01620	1	1
26.0	10.2450	0.00005	2	1
28.0	10.1350	0.00005	1	1
30.0	9.5700	0.00000	2	1
32.5	9.0750	0.00005	1	1
35.0	8.2500	0.00500	2	1
37.5	7.2650	0.00045	1	1
40.0	6.5800	0.00000	2	1
233	15	2		
10.0	12.2350	0.00405	1	1
12.0	11.1000	0.00320	2	1
14.0	10.5150	0.00005	1	1
16.0	10.2900	0.00080	2	1
18.0	10.2150	0.00005	1	1
20.0	10.2050	0.00005	2	1
22.0	9.9350	0.00125	1	1
24.0	10.0000	0.00000	2	1
26.0	9.8750	0.00005	1	1

```
28.0   9.5700    0.00020 2 1
30.0   9.3400    0.00000 1 1
32.5   8.7250    0.00125 2 1
35.0   7.6650    0.00045 1 1
37.5   6.8900    0.00080 2 1
40.0   6.5950    0.00045 1 1
 250     14 2
10.0  12.3650    0.00005 1 1
12.0  11.0000    0.00180 2 1
14.0  10.5650    0.00125 1 1
16.0  10.1300    0.00000 2 1
18.0  10.0900    0.00080 1 1
20.0   9.8850    0.00005 2 1
22.0   9.7200    0.00020 1 1
24.0   9.8850    0.00005 2 1
26.0   9.3800    0.00000 1 1
28.0   8.9400    0.00080 2 1
30.0   9.1600    0.00020 1 1
32.5   8.2400    0.00080 2 1
35.0   6.8050    0.00005 1 1
37.5   6.3600    0.00020 2 1
 263     14 2
10.0  11.3550    0.00045 1 1
12.0  10.9300    0.00020 2 1
14.0  10.1550    0.00005 1 1
16.0   9.9150    0.00005 2 1
18.0   9.8600    0.00000 1 1
20.0   9.6100    0.00080 2 1
22.0   9.6500    0.00000 1 1
24.0   9.5300    0.00020 2 1
26.0   9.6050    0.00005 1 1
28.0   9.3500    0.00000 2 1
30.0   8.6650    0.00005 1 1
32.5   7.8650    0.00045 2 1
35.0   6.9500    0.00180 1 1
37.5   5.8050    0.00005 2 1
```

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ORFORD                8     1980
122 129   5 1
  0.0 11.7902   0.00098 1 0
 10.0 11.8862   0.04077 1 2
 20.0 11.5424   0.00220 1 2
 30.0 11.5451   0.02319 1 2
 35.0 11.4761   0.00293 1 2
132 137   6 1
  0.0 11.5825   0.00024 1 2
 12.0 11.6364   0.00269 1 2
 16.0 11.5305   0.00000 1 2
 20.0 11.3917   0.00220 1 2
 30.0 11.2144   0.00098 1 2
 35.0 11.2958   0.07057 1 2
190 191  19 2
 12.0 13.0500  99.99000 1 1
 37.5  8.5227   0.00002 1 1
 30.0  9.9254   0.00093 1 1
 24.0 10.5099   0.00002 1 1
 20.0 10.6917   0.00110 1 1
 16.0 10.8163   0.00160 1 1
 37.5  8.7155   0.00035 2 0
 35.0  9.2124   0.00008 2 0
 32.5  9.6716   0.00064 2 0
 30.0 10.1698   0.00032 2 0
 28.0 10.3305   0.00209 2 0
 26.0 10.4034   0.00000 2 0
 24.0 10.6055   0.00111 2 0
 22.0 10.6290   0.00011 2 0
 20.0 10.7699   0.00000 2 0
 18.0 10.8333   0.00000 2 0
 16.0 10.8800   0.00017 2 0
 14.0 11.2795   0.01120 2 0
 12.0 13.0554  99.99001 2 0
203 204  19 2
 12.0 12.9800  99.99001 2 0
 16.0 10.7534   0.00000 2 0
 20.0 10.4551   0.00002 2 0
 24.0 10.4000   0.00003 2 0
 30.0  9.8320   0.00000 2 0
 37.5  8.1294   0.00006 2 0
 12.0 12.9800  99.99001 1 0
 14.0 11.1606  99.99001 1 0
 16.0 10.6942   0.00003 1 0
 18.0 10.6628   0.00000 1 0
 20.0 10.4059   0.00133 1 0
 22.0 10.4002   0.00180 1 0
 24.0 10.3134   0.00002 1 0
 26.0 10.2544   0.00024 1 0
 28.0  9.9985   0.00005 1 0
 30.0  9.9535   0.00000 1 0
 32.5  9.0476   0.00000 1 0
 35.0  8.3539   0.00508 1 0
 37.5  7.7951   0.00000 0 0
209 216  19 2
 12.0 12.5100  99.99001 2 0
 37.5  7.5909   0.00002 2 0
```

```
30.0   9.6089    0.00003 2 0
24.0   9.9796    0.00111 2 0
20.0  10.3768   99.99001 2 0
16.0  10.5986    0.00113 2 0
37.5   7.3605    0.00160 1 1
35.0   7.7859    0.00154 1 1
32.5   8.7728    0.00023 1 1
30.0   9.2339    0.00128 1 1
28.0   9.7621    0.00168 1 1
26.0  10.0011    0.00000 1 1
24.0  10.0532    0.00070 1 1
22.0   9.9818    0.00023 1 1
20.0  10.3870    0.00006 1 1
18.0  10.4418    0.00208 1 1
16.0  10.6166    0.01610 1 1
14.0  10.7675    0.00015 1 1
12.0  12.5191    0.00000 1 1
216 220 18 2
12.0  11.0300   99.99001 2 0
16.0  10.4067    0.00014 2 0
20.0  10.2368    0.00003 2 0
24.0   9.9068    0.00305 2 0
30.0   9.4171   99.99001 2 0
37.5   7.4153    0.00102 2 0
14.0  11.0329   99.99001 1 1
16.0  10.4033    0.00053 1 1
18.0  10.2825    0.00002 1 1
20.0  10.0387    0.00024 1 1
22.0  10.0623    0.00027 1 1
24.0   9.9491    0.00064 1 1
26.0   9.5802    0.00002 1 1
28.0   9.5749    0.00000 1 1
30.0   9.3394    0.00018 1 1
32.5   8.6735    0.00146 1 1
35.0   7.8992    0.00027 1 1
37.5   7.0141    0.00000 1 1
226 230 18 2
14.0  10.9700   99.99001 2 0
14.0  10.9692    0.00006 1 0
16.0  10.3292    0.00029 1 0
18.0  10.2726    0.00008 1 0
20.0  10.2202    0.00015 1 0
22.0   9.8462    0.00980 1 0
24.0   9.7607    0.00024 1 0
26.0   9.5537    0.00000 1 0
28.0   9.4709    0.00006 1 0
30.0   9.2525    0.00006 1 0
32.5   9.0772    0.00253 1 0
35.0   8.0273    0.00046 1 0
37.5   6.9668    0.00217 1 0
16.0  10.2847    0.00011 2 1
20.0   9.9555    0.00096 2 1
26.0   9.4888    0.00058 2 1
30.0   9.0776    0.00256 2 1
37.5   6.6459    0.00040 2 1
237 238 19 2
12.0  12.6500   99.99001 2 0
```

37.5	6.3856	0.00009	1	0
37.5	6.5404	0.00056	2	0
35.0	7.6005	0.00043	1	0
32.5	8.6250	0.00043	1	0
30.0	9.0350	0.00128	1	0
30.0	8.9483	0.00000	2	0
28.0	9.4648	0.00011	2	0
26.0	9.7476	0.00021	1	0
24.0	9.6635	99.99001	1	0
24.0	9.8301	99.99001	2	0
22.0	9.9537	99.99001	1	0
20.0	9.9071	0.00053	1	0
20.0	9.8026	0.02260	2	0
18.0	10.1458	99.99001	0	0
16.0	10.2279	0.00038	1	0
16.0	10.1561	99.99001	2	0
14.0	11.1455	0.00026	1	0
12.0	12.6509	0.00171	1	0

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181	12	1		
08.0	10.86		1	2
10.0	11.02		1	2
12.0	10.88		1	2
14.0	10.66		1	2
16.0	10.57		1	2
18.0	10.56		1	2
20.0	10.44		1	2
22.0	10.49		1	2
24.0	10.45		1	2
26.0	10.34		1	2
28.0	10.30		1	2
30.0	10.05		1	2
201	12	1		
08.0	9.60		1	2
10.0	9.86		1	2
12.0	10.12		1	2
14.0	10.10		1	2
16.0	9.87		1	2
18.0	9.93		1	2
20.0	9.92		1	2
22.0	9.77		1	2
24.0	9.65		1	2
26.0	9.50		1	2
28.0	9.45		1	2
30.0	9.38		1	2
216	11	1		
08.0	9.45		1	2
10.0	9.52		1	2
12.0	9.61		1	2
14.0	9.82		1	2
16.0	9.52		1	2
18.0	9.60		1	2
20.0	9.62		1	2
22.0	9.44		1	2
24.0	9.45		1	2
26.0	9.25		1	2
28.0	9.22		1	2
230	13	1		
08.0	9.11		1	2
10.0	9.11		1	2
12.0	9.29		1	2
14.0	9.61		1	2
16.0	9.45		1	2
18.0	9.14		1	2
20.0	9.09		1	2
22.0	9.00		1	2
24.0	8.96		1	2
26.0	8.76		1	2
28.0	8.65		1	2
30.0	8.72		1	2
32.0	8.59		1	2
239	12	1		
08.0	8.82		1	2
10.0	8.79		1	2
12.0	8.93		1	2

14.0	9.48	1 2
16.0	9.11	1 2
18.0	9.12	1 2
20.0	9.06	1 2
22.0	8.94	1 2
24.0	8.74	1 2
26.0	8.61	1 2
28.0	8.42	1 2
30.0	8.31	1 2

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170	11 1			
10.0	10.4250	0.00005	1	1
12.0	10.5300	0.00020	1	1
14.0	10.6500	0.00000	1	1
16.0	10.6500	0.00000	1	1
18.0	10.5550	0.00005	1	1
20.0	10.5450	0.00005	1	1
22.0	10.5500	0.00000	1	1
24.0	10.4550	0.00005	1	1
26.0	10.4200	0.00000	1	1
28.0	10.3450	0.00005	1	1
30.0	10.2800	99.99001	1	1
194	11 1			
10.0	9.1150	0.00405	1	1
12.0	9.4850	0.00605	1	1
14.0	10.0000	0.00180	1	1
16.0	10.1750	0.07605	1	1
18.0	9.8350	0.00005	1	1
20.0	9.8350	0.00005	1	1
22.0	9.8200	0.00000	1	1
24.0	9.5000	99.99001	1	1
26.0	9.6200	0.00080	1	1
28.0	9.5000	0.00000	1	1
30.0	9.4750	0.00005	1	1
206	11 1			
10.0	9.0250	0.00005	1	1
12.0	9.5100	0.00080	1	1
14.0	9.7350	0.00045	1	1
16.0	9.7350	0.00005	1	1
18.0	9.7450	0.00125	1	1
20.0	9.6700	0.00080	1	1
22.0	9.5050	0.00005	1	1
24.0	9.5000	0.00080	1	1
26.0	9.4850	0.00005	1	1
28.0	9.3800	0.00000	1	1
30.0	9.3100	0.03380	1	1
220	11 1			
10.0	8.5800	0.00020	1	1
12.0	8.9000	0.00000	1	1
14.0	9.2800	0.00000	1	1
16.0	9.2700	0.00020	1	1
18.0	9.2450	0.00005	1	1
20.0	9.1400	0.00020	1	1
22.0	8.9150	0.00005	1	1
24.0	8.9400	0.00080	1	1
26.0	8.8500	0.00020	1	1
28.0	8.7850	0.00005	1	1
30.0	8.6600	0.00020	1	1
233	11 1			
10.0	8.1300	0.00020	1	1
12.0	8.5800	0.00080	1	1
14.0	8.8900	0.00000	1	1
16.0	8.9200	0.00020	1	1
18.0	8.8200	0.00080	1	1
20.0	8.8700	0.00020	1	1
22.0	8.8700	0.00000	1	1

24.0	8.6300	0.00020	1	1
26.0	8.4850	0.00005	1	1
28.0	8.4700	0.00020	1	1
30.0	8.2900	0.01620	1	1
250	11 1			
10.0	7.6800	0.00020	1	1
12.0	8.2650	0.00005	1	1
14.0	8.5350	0.00005	1	1
16.0	8.3150	0.00045	1	1
18.0	8.4450	0.00125	1	1
20.0	8.3150	0.00005	1	1
22.0	8.1600	0.00000	1	1
24.0	8.2000	0.00020	1	1
26.0	8.0650	0.00005	1	1
28.0	8.0400	0.00080	1	1
30.0	8.0050	0.00005	1	1
263	11 1			
10.0	8.9450	0.00005	1	1
12.0	7.8050	0.00005	1	1
14.0	8.1450	0.00005	1	1
16.0	8.0350	0.00045	1	1
18.0	8.1300	0.00000	1	1
20.0	8.0250	0.00245	1	1
22.0	7.9700	0.00020	1	1
24.0	7.8950	0.00005	1	1
26.0	7.9350	0.00005	1	1
28.0	7.8250	0.00005	1	1
30.0	7.7500	0.00000	1	1

```
STOKELEY          10    1980
113 119  5 1
 0.0 11.9483    0.00000 1 2
10.0 11.9379    0.00122 1 2
16.0 11.8959    0.00073 1 2
22.0 11.8956    0.00049 1 2
28.0 11.9589    0.00244 1 2
122 129  5 1
 0.0 12.2505    0.00024 1 2
10.0 12.1414    0.00171 1 2
16.0 12.1291    0.00024 1 2
22.0 12.0667    0.00073 1 2
28.0 12.0146    0.00049 1 2
139 142 10 1
12.0 11.5657    0.00806 1 1
14.0 11.5408    0.00000 1 1
16.0 11.5403    0.00122 1 1
18.0 11.5531    0.00000 1 1
20.0 11.5442    0.00049 1 1
22.0 11.5209    0.00000 1 1
24.0 11.5303    0.00000 1 1
26.0 11.4975    0.00000 1 1
28.0 11.4824    0.00049 1 1
30.0 11.4345    0.00073 1 1
153 157 14 2
14.0 11.3409    0.00024 1 0
16.0 11.2491    0.00217 1 0
18.0 11.1413    0.00027 1 0
20.0 11.1846    0.00334 1 0
22.0 11.2016    0.00027 1 0
24.0 11.0580    0.00000 1 1
26.0 11.0424   99.99001 1 1
28.0 10.9730    0.00024 1 1
30.0 10.9722    0.00191 1 1
16.0 11.2462    0.00002 2 0
18.0 11.2123    0.00006 2 0
20.0 11.2386    0.00851 2 0
24.0 11.1160    0.00005 2 0
30.0 10.9268   99.99001 2 0
176 182 15 2
16.0 10.4058    0.00002 1 1
18.0 10.3500    0.00121 1 1
20.0 10.2999    0.00003 1 1
24.0 10.1860    0.00018 1 1
30.0  9.9222    0.02032 1 1
12.0 10.5171    0.00002 1 1
14.0 10.5071    0.00238 1 1
22.0 10.2800    0.00002 1 1
26.0 10.1695    0.00244 1 1
28.0 10.1519    0.00020 1 1
16.0 10.4209    0.00014 2 0
18.0 10.3852    0.00005 2 0
20.0 10.3716    0.00150 2 0
24.0 10.2476    0.00055 2 0
30.0 10.0991    0.00012 2 0
188 189 14 2
30.0  9.5213    0.00002 1 1
```

28.0	9.5788	0.00078	1	1
26.0	9.7793	0.00003	1	1
24.0	9.8198	0.00165	1	1
22.0	9.8974	0.00026	1	1
20.0	9.9689	0.00002	1	1
18.0	9.9837	0.00000	1	1
16.0	10.0213	0.00127	1	1
14.0	10.2140	0.00000	1	1
30.0	9.6849	0.00122	2	0
26.0	9.8184	0.00000	2	0
22.0	9.9029	0.00014	2	0
18.0	10.0103	0.00011	2	0
16.0	10.0583	0.00031	2	0
195	196	14	2	
30.0	9.0474	0.00002	1	1
28.0	9.1940	0.00098	1	1
26.0	9.3569	0.00034	1	1
24.0	9.4039	0.00061	1	1
22.0	9.5068	0.00011	1	1
20.0	9.4656	0.00008	1	1
18.0	9.6109	0.00003	1	1
16.0	9.5932	0.00090	1	1
14.0	9.7779	0.00023	1	1
28.0	9.2938	0.00044	2	0
24.0	9.4184	0.00014	2	0
20.0	9.5086	0.00034	2	0
18.0	9.5783	0.00153	2	0
16.0	9.6687	0.00009	2	0
202	204	14	2	
16.0	9.6048	0.00000	2	0
18.0	9.6032	0.00000	2	0
20.0	9.4876	0.00002	2	0
24.0	9.2447	0.00002	2	0
28.0	9.0664	0.00003	2	0
14.0	9.6721	0.00330	1	0
16.0	9.5699	0.00029	1	0
18.0	9.5733	0.00005	1	0
20.0	9.3066	0.00014	1	0
22.0	9.2454	0.00015	1	0
24.0	9.2552	0.00003	1	0
26.0	9.1540	0.00047	1	0
28.0	8.9588	0.00011	1	0
30.0	8.8110	0.00034	1	0
218	223	13	2	
16.0	9.1792	0.00002	1	0
18.0	8.9144	0.00343	1	0
20.0	8.9250	0.00032	1	0
24.0	8.6820	0.00043	1	0
28.0	8.4277	0.00021	1	0
18.0	9.0274	0.00032	2	0
20.0	8.9096	0.00002	2	0
22.0	8.8724	0.00003	1	0
24.0	8.6382	0.00023	2	0
26.0	8.4072	0.00000	2	0
28.0	8.3248	0.00050	2	0
16.0	9.1849	0.00000	2	0
14.0	9.1001	0.00043	2	0

```
237 238 13 2
28.0   7.7552    0.00002 1 0
28.0   7.7646    0.00015 2 0
26.0   7.9520    0.00011 1 0
24.0   7.9875    0.00005 1 0
24.0   8.0677    0.00043 2 0
22.0   8.2411    0.00011 1 0
20.0   8.3372    0.00021 1 0
20.0   8.2539    0.00006 2 0
18.0   8.2515    0.00128 1 0
18.0   8.2475    0.00087 2 0
16.0   8.3900    0.00006 1 0
16.0   8.3806    0.00002 2 0
14.0   8.4159    0.00052 1 0
```

TROITE 7 1979

143	7 1			
6.0	7.6550	0.00125	1	1
7.0	7.2650	0.00045	1	1
8.0	6.8350	0.00045	1	1
9.0	6.0300	0.00020	1	1
10.0	5.8350	0.00005	1	1
11.0	5.0250	0.00005	1	1
12.0	4.1900	0.00320	1	1
149	7 1			
6.0	8.2950	0.00045	1	1
7.0	8.0200	0.00020	1	1
8.0	7.0000	0.00020	1	1
9.0	6.6450	0.00125	1	1
10.0	6.3700	0.00500	1	1
11.0	5.3100	0.00000	1	1
12.0	5.0600	0.00000	1	1
157	7 1			
6.0	7.2850	0.00045	1	1
7.0	6.5450	0.00045	1	1
8.0	6.0000	0.00020	1	1
9.0	5.3600	0.00020	1	1
10.0	4.4400	0.00080	1	1
11.0	3.6450	0.00045	1	1
12.0	2.8400	0.00020	1	1
166	7 1			
6.0	7.4250	0.00005	1	1
7.0	6.6250	0.00245	1	1
8.0	6.1350	0.00045	1	1
9.0	6.0750	0.06125	1	1
10.0	5.3050	0.00045	1	1
11.0	4.9050	0.00005	1	1
12.0	3.5300	0.00020	1	1
171	7 1			
6.0	7.8350	0.00405	1	1
7.0	6.0750	0.00045	1	1
8.0	5.0400	0.00020	1	1
9.0	5.3500	0.00020	1	1
10.0	4.4800	0.00020	1	1
11.0	3.9800	0.00000	1	1
12.0	2.4950	0.00045	1	1
178	8 1			
6.0	7.6750	0.00005	1	1
7.0	6.4600	0.00020	1	1
8.0	5.0850	0.00125	1	1
9.0	4.4350	0.00005	1	1
10.0	4.0400	0.00080	1	1
11.0	2.9250	0.00045	1	1
12.0	0.1650	0.00605	1	1
13.0	0.2800	0.00020	1	1
184	7 1			
6.0	6.0600	0.19220	1	1
7.0	4.9700	0.00020	1	1
8.0	4.1800	0.00180	1	1
10.0	3.3400	0.00020	1	1
11.0	2.1150	0.00125	1	1
12.0	0.4100	0.00000	1	1

13.0 0.2000 0.00000 1 1

```
TROITE          10      1980
113 121   5 1
  0.0 10.2597   0.00034  1 2
  6.0 10.2292   0.00031  1 2
  8.0 10.1959   0.00064  1 2
 10.0 10.2285   0.00101  1 2
 12.0 10.2290   0.00017  1 2
120 127   5 1
  0.0 10.9854   0.00139  1 2
  6.0 10.2525   0.00154  1 2
  8.0 10.0306   0.00189  1 2
 10.0  9.7491   0.00008  1 2
 12.0  9.2806   0.00128  1 2
132 148   7 1
  5.0 10.6766   0.00002  1 0
  6.0  9.9695   0.00034  1 0
  7.0  9.3866   0.00029  1 0
  9.0  8.7512   0.00105  1 0
 10.0  8.7565   0.00003  1 0
 11.0  8.2501   0.00005  1 0
 12.0  8.0502   0.00002  1 0
139 142   9 1
  5.0 10.3055   0.00043  1 1
  6.0  9.5767   0.00005  1 1
  7.0  9.3457   0.00026  1 1
  8.0  9.0335   0.00203  1 1
  9.0  8.6418   0.00002  1 1
 10.0  8.3579   0.00005  1 1
 11.0  7.7519   0.00000  1 1
 12.0  6.8549   0.00261  1 1
 13.0  6.6626   0.00003  1 1
145 148   9 1
  5.0 10.1100   0.00002  1 1
  6.0  9.4873   0.00009  1 1
  7.0  8.8774   0.00005  1 1
  8.0  8.2466   0.00009  1 1
  9.0  8.5404   0.00204  1 1
 10.0  8.2394   0.00014  1 1
 11.0  8.0882   0.00122  1 1
 12.0  7.5887   0.02505  1 1
 13.0  6.2617   0.00003  1 1
153 157  13 2
  5.0 10.5224   0.00015  2 0
  7.0  8.6753   0.00041  2 0
  9.0  8.0883   0.00015  2 0
 11.0  7.2468   0.00003  2 0
 13.0  5.6150   0.00043  2 0
  5.0 10.1504   0.00111  1 1
  6.0  8.9860   0.00044  1 1
  7.0  8.7083   0.00208  1 1
  8.0  8.3630   0.00069  1 1
  9.0  7.7556   0.00928  1 1
 10.0  7.1074   0.00798  1 1
 11.0  6.6036   0.00040  1 1
 12.0  5.9638   0.00713  1 1
159 164  11 2
  7.0  7.7446   0.00029  1 1
```

```
 8.0  7.7553   0.00461 1 1
10.0  7.0725   0.00021 1 1
11.0  6.1897   0.00066 1 1
12.0  5.0739   0.40649 1 1
13.0  4.3511   0.00000 1 1
 7.0  7.7396   0.00000 2 1
 8.0  7.6783   0.00009 2 1
 9.0  7.4266   0.00043 2 1
10.0  7.1974   0.02901 2 1
12.0  5.3998   0.00020 2 1
167 175 15 2
 7.0  7.8642   0.00003 2 0
 8.0  7.6876  99.99001 2 0
 9.0  7.6413   0.00002 2 0
10.0  6.6689   0.00040 2 0
11.0  5.4604   0.00002 2 0
12.0  4.4432   0.00166 2 0
13.0  3.1752   0.00023 2 0
 6.0  8.3269   0.00208 2 0
 7.0  7.8180   0.00101 1 1
 8.0  7.7424   0.00003 1 1
 9.0  7.5975   0.00018 1 1
10.0  6.8291   0.00084 1 1
11.0  5.6725   0.00089 1 1
12.0  4.1902   0.00041 1 1
13.0  3.1245   0.00023 1 1
176 182 14 2
 7.0  7.1539   0.00017 1 1
 8.0  6.4465   0.01089 1 1
 9.0  6.3396   0.00027 1 1
10.0  5.5490   0.00003 1 1
12.0  3.3259   0.00084 1 1
 5.0  9.4938   0.00058 1 1
 6.0  7.4981   0.00047 1 1
11.0  4.6258   0.00075 1 1
13.0  2.2451   0.00000 1 1
 6.0  7.6565   0.00027 2 0
 7.0  7.0068   0.00005 2 0
 8.0  6.3678   0.00070 2 0
10.0  5.7431   0.00029 2 0
12.0  4.0107   0.00259 2 0
181 185  8 1
 7.0  6.5807   0.00061 1 1
 8.0  6.7186   0.00130 1 1
 9.0  6.0742   0.00034 1 1
10.0  5.2492   0.00003 1 1
12.0  2.2953   0.00003 1 1
 6.0  7.4472   0.00038 1 1
11.0  4.0041   0.00035 1 1
13.0  1.3134   0.00093 1 1
```

APPENDIX FIVE

Coefficients of vertical eddy diffusivity (Kz) determined in each study lake using the technique outlined in Chapter 9. The data are arranged in columns as follows:

1. Lake name.
2. Year.
3. Depth.
4. Kz value (m2/day).
5. Variance in Kz value.
6. Number of degrees of freedom.
7. Square of the correlation coefficient for the regression of the heat content below depth against time.
8. Mean vertical gradient in temperature at the specified depth.
9. Standard deviation of the temperature gradient.

Note: Values which were not defined by the calcualtion technique are listed as ** or 00. Kz values calculated above the thermocline (maximum vertical temperature gradient) should be interpreted very cautiously because they may include some depths which were not stratified.

BROMPTON	1979	0.0	0000000	00000000	10.	3.5	-0.163	0.3358	-.523	1.018
BROMPTON	1979	1.00	0000000	00000000	10.	0.1	-0.077	0.1582	-.568	1.006
BROMPTON	1979	2.00	-5.0896	00000000	10.	3.9	-0.139	0.1922	0.894	0.941
BROMPTON	1979	3.00	-2.2541	00000000	10.	19.1	-0.158	0.2757	0.798	0.816
BROMPTON	1979	4.00	-1.6725	00000000	10.	39.4	-0.076	0.2515	0.353	0.644
BROMPTON	1979	5.00	0.0820	0.020084	10.	55.2	-0.328	0.4950	0.347	0.460
BROMPTON	1979	6.00	0.1992	0.089656	10.	63.0	-0.651	0.9163	0.384	0.306
BROMPTON	1979	7.00	0.3656	0.137469	10.	66.6	-0.538	0.5168	0.509	0.199
BROMPTON	1979	8.00	0.2071	0.043032	10.	67.4	-1.103	1.0243	0.689	0.128
BROMPTON	1979	9.00	0.1008	0.007254	10.	65.3	-2.186	1.5965	0.891	0.087
BROMPTON	1979	10.00	0.0625	0.001988	10.	55.2	-2.719	1.4717	0.157	0.069
BROMPTON	1979	11.00	0.0624	0.003386	10.	46.2	-1.918	1.3868	-.175	0.062
BROMPTON	1979	12.00	0.0530	0.002460	10.	48.0	-1.352	0.9598	-.504	0.062
BROMPTON	1979	13.00	0.0278	0.001952	10.	49.0	-1.179	1.3113	-.663	0.072
BROMPTON	1979	14.00	0.0503	0.003389	10.	51.0	-0.493	0.4476	-.630	0.068
BROMPTON	1979	15.00	0.0751	0.004561	10.	55.0	-0.287	0.2118	-.713	0.053
BROMPTON	1979	16.00	0.1879	0.017146	10.	63.4	-0.121	0.0746	0.185	0.035
BROMPTON	1979	17.00	0.1744	0.008868	10.	70.3	-0.126	0.0588	-.417	0.023
BROMPTON	1979	18.00	0.1623	0.007955	10.	76.3	-0.134	0.0649	-.067	0.015
BROMPTON	1979	19.00	0.2021	0.015977	10.	82.1	-0.108	0.0624	0.229	0.009
BROMPTON	1979	20.00	0.3353	0.103452	10.	86.5	-0.065	0.0601	0.172	0.006
BROMPTON	1979	22.00	0.5859	0.083016	10.	91.6	-0.035	0.0167	-.046	0.002
BROMPTON	1979	24.00	0.7119	0.036024	10.	93.9	-0.028	0.0069	0.172	0.001
BROMPTON	1979	26.00	0.6403	0.046302	10.	95.5	-0.031	0.0099	-.154	0.000
BROMPTON	1979	28.00	0.9787	0.425007	10.	96.0	-0.020	0.0134	-.049	0.000
BROMPTON	1979	30.00	2.1337	3.422460	10.	94.9	-0.009	0.0081	0.390	0.000
BROMPTON	1979	32.50	2.7222	2.853460	10.	94.7	-0.006	0.0040	-.075	0.000
BROMPTON	1979	35.00	1.5315	0.828486	10.	94.3	-0.009	0.0054	0.672	0.000
BROMPTON	1979	37.50	1.0347	0.277978	10.	92.5	-0.010	0.0048	0.536	0.000

BROMPTON	1980	0.0	0000000	00000000	15.	57.6	-0.325	0.6867	0.588	0.858
BROMPTON	1980	1.00	-3.4058	00000000	15.	58.7	-0.244	0.4065	0.561	0.690
BROMPTON	1980	2.00	-0.4857	0.314523	15.	60.0	-0.189	0.2200	0.422	0.531
BROMPTON	1980	3.00	2.1065	5.736882	15.	61.3	-0.127	0.1414	0.616	0.377
BROMPTON	1980	4.00	3.7750	00000000	15.	62.7	-0.117	0.1417	0.127	0.252
BROMPTON	1980	5.00	3.4003	00000000	15.	64.0	-0.149	0.2269	-.105	0.164
BROMPTON	1980	6.00	3.0869	00000000	15.	65.3	-0.165	0.2085	-.302	0.106
BROMPTON	1980	7.00	0.7837	1.103100	15.	66.5	-0.599	0.7845	-.217	0.069
BROMPTON	1980	8.00	0.6703	0.954492	15.	67.5	-0.626	0.8912	-.266	0.046
BROMPTON	1980	9.00	0.2427	0.043694	15.	67.9	-1.478	1.1923	-.192	0.030
BROMPTON	1980	10.00	0.2082	0.037356	15.	67.0	-1.497	1.2956	-.204	0.020
BROMPTON	1980	11.00	0.3693	0.084175	15.	66.1	-0.755	0.5601	-.499	0.013
BROMPTON	1980	12.00	0.2161	0.010425	15.	65.4	-1.119	0.4582	-.552	0.008
BROMPTON	1980	13.00	0.2637	0.017700	15.	64.0	-0.824	0.3668	-.528	0.005
BROMPTON	1980	14.00	0.3079	0.051436	15.	61.8	-0.637	0.4350	-.797	0.004
BROMPTON	1980	15.00	0.4612	0.226979	15.	60.3	-0.396	0.3910	-.692	0.002
BROMPTON	1980	16.00	0.6389	0.119837	15.	60.3	-0.270	0.1326	-.227	0.001
BROMPTON	1980	17.00	0.5813	0.149229	15.	60.1	-0.279	0.1723	-.850	0.001
BROMPTON	1980	18.00	1.1061	0.906223	15.	60.4	-0.140	0.1161	-.687	0.001
BROMPTON	1980	19.00	1.2120	1.025488	15.	61.6	-0.123	0.0987	0.207	0.000
BROMPTON	1980	20.00	1.3851	1.016286	15.	62.6	-0.103	0.0714	-.314	0.000
BROMPTON	1980	22.00	1.6477	1.531859	15.	65.1	-0.080	0.0579	-.003	0.000
BROMPTON	1980	24.00	2.3743	4.909095	15.	67.6	-0.053	0.0486	0.117	0.000
BROMPTON	1980	26.00	3.7240	00000000	15.	69.3	-0.034	0.0391	0.118	0.000
BROMPTON	1980	28.00	4.9847	00000000	15.	70.4	-0.026	0.0323	0.193	0.000
BROMPTON	1980	30.00	5.3277	00000000	15.	71.0	-0.023	0.0293	0.276	0.000
BROMPTON	1980	32.50	7.9396	00000000	15.	71.4	-0.014	0.0099	-.066	0.000
BROMPTON	1980	35.00	6.5973	00000000	15.	72.1	-0.013	0.0086	0.426	0.000
BROMPTON	1980	37.50	8.1445	00000000	15.	72.6	-0.007	0.0094	0.247	0.0

CENTRAL	1979	0.0	0000000	00000000	14.	2.5	-0.190	0.2424	0.051	0.973
CENTRAL	1979	1.00	-7.1373	00000000	14.	4.5	-0.198	0.2030	0.389	0.926
CENTRAL	1979	2.00	-4.3434	00000000	14.	7.5	-0.218	0.1269	0.199	0.883
CENTRAL	1979	3.00	-5.7143	00000000	14.	11.8	-0.112	0.0718	-.234	0.830
CENTRAL	1979	4.00	-3.6042	00000000	14.	18.0	-0.115	0.1314	0.334	0.763
CENTRAL	1979	5.00	-1.7353	2.171752	14.	25.9	-0.140	0.1016	0.459	0.684
CENTRAL	1979	6.00	-1.2424	3.442117	14.	35.0	-0.087	0.1277	0.377	0.595
CENTRAL	1979	7.00	-0.0182	0.000190	14.	44.0	-0.246	0.4301	0.255	0.502
CENTRAL	1979	8.00	0.3078	0.165744	14.	50.9	-0.254	0.3177	0.382	0.412
CENTRAL	1979	9.00	0.6869	0.681371	14.	55.4	-0.207	0.2400	0.681	0.332
CENTRAL	1979	10.00	0.4757	0.310423	14.	57.4	-0.392	0.4402	0.629	0.265
CENTRAL	1979	11.00	0.2594	0.081831	14.	56.9	-0.807	0.8350	0.600	0.213
CENTRAL	1979	12.00	0.1458	0.016536	14.	52.5	-1.426	1.1170	0.420	0.177
CENTRAL	1979	13.00	0.1647	0.029993	14.	47.7	-1.190	1.1287	0.094	0.153
CENTRAL	1979	14.00	0.1826	0.011928	14.	46.0	-0.959	0.4667	0.301	0.136
CENTRAL	1979	15.00	0.0978	0.003491	14.	43.6	-1.439	0.6532	-.380	0.125
CENTRAL	1979	16.00	0.0634	0.001876	14.	40.2	-1.780	0.8692	-.657	0.115
CENTRAL	1979	17.00	0.0808	0.002306	14.	38.1	-1.320	0.5304	-.275	0.099
CENTRAL	1979	18.00	0.1701	0.010917	14.	36.5	-0.628	0.2884	-.246	0.083
CENTRAL	1979	19.00	0.1740	0.010931	14.	34.8	-0.584	0.2529	-.594	0.068
CENTRAL	1979	20.00	0.2116	0.022633	14.	34.0	-0.473	0.2681	-.128	0.054
CENTRAL	1979	22.50	0.5024	0.132291	14.	34.8	-0.186	0.1133	0.479	0.031
CENTRAL	1979	25.00	0.3684	0.038368	14.	29.6	-0.200	0.0626	-.207	0.020
CENTRAL	1979	27.50	0.2889	0.037223	14.	24.4	-0.190	0.0837	-.625	0.013
CENTRAL	1979	30.00	0.3361	0.057544	14.	23.0	-0.132	0.0645	-.766	0.008
CENTRAL	1979	32.50	0.4066	0.055273	14.	27.0	-0.100	0.0355	-.364	0.005
CENTRAL	1979	35.00	0.5891	0.134752	14.	33.9	-0.068	0.0328	-.049	0.002
CENTRAL	1979	37.50	0.6846	0.137261	14.	40.8	-0.057	0.0242	0.265	0.001
CENTRAL	1979	40.00	0.9975	0.456914	14.	45.7	-0.038	0.0231	0.300	0.001
CENTRAL	1979	42.50	1.3692	0.761317	14.	47.9	-0.027	0.0154	-.269	0.000
CENTRAL	1979	45.00	1.4481	0.562284	14.	51.1	-0.026	0.0115	-.522	0.000
CENTRAL	1979	50.00	2.9359	5.969362	14.	59.0	-0.014	0.0113	0.415	0.000
CENTRAL	1979	55.00	2.7875	0.853645	14.	58.7	-0.014	0.0033	-.062	0.000
CENTRAL	1979	60.00	2.9372	2.801510	14.	58.3	-0.011	0.0055	-.459	0.000
CENTRAL	1979	70.00	5.9571	00000000	14.	62.8	-0.003	0.0029	-.246	0.0
CENTRAL	1979	80.00	4.1445	5.064440	14.	62.9	-0.004	0.0019	-.025	0.0
CENTRAL	1979	90.00	3.8143	7.918387	14.	58.5	-0.002	0.0018	0.371	0.0

CENTRAL	1980	0.00	-8.1731	00000000	16.	74.0	-0.441	0.7497	0.179	0.779
CENTRAL	1980	1.00	-3.1881	00000000	16.	75.1	-0.289	0.3534	0.201	0.626
CENTRAL	1980	2.00	-1.0105	1.018710	16.	76.3	-0.158	0.1584	0.066	0.529
CENTRAL	1980	3.00	1.9959	1.959457	16.	77.5	-0.128	0.0879	0.246	0.441
CENTRAL	1980	4.00	3.8884	00000000	16.	78.8	-0.129	0.1489	0.265	0.360
CENTRAL	1980	5.00	2.7244	00000000	16.	80.2	-0.236	0.2745	0.339	0.288
CENTRAL	1980	6.00	3.0932	8.840071	16.	81.5	-0.233	0.2216	0.210	0.227
CENTRAL	1980	7.00	3.6154	7.859666	16.	82.8	-0.209	0.1596	00000	0.176
CENTRAL	1980	8.00	2.7351	00000000	16.	83.8	-0.276	0.3683	0.011	0.136
CENTRAL	1980	9.00	1.8289	6.741037	16.	84.4	-0.401	0.5651	00000	0.104
CENTRAL	1980	10.00	1.5428	6.474000	16.	84.5	-0.452	0.7393	0.050	0.081
CENTRAL	1980	11.00	0.9450	1.127939	16.	83.9	-0.681	0.7537	00000	0.063
CENTRAL	1980	12.00	0.5713	0.489278	16.	83.1	-1.019	1.2199	00000	0.050
CENTRAL	1980	13.00	0.6895	0.385713	16.	83.0	-0.770	0.6775	00000	0.039
CENTRAL	1980	14.00	0.7810	0.295118	16.	82.8	-0.613	0.4148	00000	0.031
CENTRAL	1980	15.00	0.5999	0.134545	16.	82.5	-0.708	0.4180	00000	0.025
CENTRAL	1980	16.00	0.5638	0.131277	16.	81.9	-0.667	0.4133	00000	0.020
CENTRAL	1980	17.00	0.4399	0.209302	16.	81.4	-0.755	0.7613	00000	0.016
CENTRAL	1980	18.00	0.4934	0.264517	16.	81.6	-0.614	0.6230	00000	0.012
CENTRAL	1980	19.00	0.8657	0.291977	16.	81.9	-0.329	0.1991	00000	0.009
CENTRAL	1980	20.00	1.0839	0.537857	16.	82.0	-0.246	0.1621	00000	0.007
CENTRAL	1980	22.50	1.2287	0.494486	16.	82.2	-0.183	0.1018	00000	0.004
CENTRAL	1980	25.00	1.1533	0.394489	16.	82.0	-0.164	0.0866	00000	0.002
CENTRAL	1980	27.50	0.8791	0.248401	16.	80.3	-0.177	0.0966	00000	0.001
CENTRAL	1980	30.00	0.8481	0.200979	16.	77.4	-0.145	0.0734	00000	0.001
CENTRAL	1980	32.50	0.8214	0.249430	16.	74.5	-0.118	0.0688	00000	0.000
CENTRAL	1980	35.00	0.8667	0.394557	16.	72.6	-0.091	0.0633	00000	0.000
CENTRAL	1980	37.50	0.9194	0.348857	16.	72.6	-0.074	0.0454	00000	0.000
CENTRAL	1980	40.00	1.1809	0.702033	16.	72.5	-0.053	0.0365	00000	0.000
CENTRAL	1980	42.50	1.6003	0.745220	16.	72.5	-0.039	0.0201	00000	0.000
CENTRAL	1980	45.00	2.4554	2.167636	16.	73.0	-0.027	0.0154	00000	0.000
CENTRAL	1980	50.00	5.3381	7.685531	16.	74.7	-0.014	0.0068	0.390	0.000
CENTRAL	1980	55.00	6.2095	00000000	16.	76.2	-0.012	0.0062	00000	0.000
CENTRAL	1980	60.00	6.6427	8.896190	16.	77.4	-0.010	0.0042	0.199	0.000
CENTRAL	1980	70.00	9.1303	00000000	16.	75.6	-0.005	0.0062	0.310	0.000
CENTRAL	1980	80.00	8.8044	00000000	16.	77.1	-0.004	0.0015	00000	0.000
CENTRAL	1980	90.00	4.5802	00000000	16.	77.0	-0.004	0.0059	00000	0.000

FITCH	1979	0.0	0000000	00000000	10.	66.3	-0.142	2.1076	-.121	0.829
FITCH	1979	1.00	-3.7526	00000000	10.	68.3	-0.244	0.6667	0.260	0.716
FITCH	1979	2.00	-1.6626	00000000	10.	71.1	-0.273	0.5221	0.669	0.641
FITCH	1979	3.00	-0.6213	1.215384	10.	73.1	-0.299	0.5368	0.661	0.573
FITCH	1979	4.00	-0.0480	0.002033	10.	75.4	-0.456	0.5405	0.646	0.509
FITCH	1979	5.00	0.2086	0.050114	10.	77.9	-0.362	0.3646	0.028	0.451
FITCH	1979	6.00	0.7115	0.752915	10.	80.3	-0.183	0.2182	0.239	0.399
FITCH	1979	7.00	0.2551	0.037924	10.	82.9	-0.573	0.4125	0.631	0.355
FITCH	1979	8.00	0.1710	0.057735	10.	84.1	-0.776	1.0231	0.459	0.327
FITCH	1979	9.00	0.0501	0.002029	10.	78.3	-1.630	1.1835	-.450	0.329
FITCH	1979	10.00	0.0079	0.000161	10.	65.0	-2.811	1.8406	-.867	0.363
FITCH	1979	11.00	0.0020	0.000051	10.	60.3	-2.249	1.1495	-.777	0.388
FITCH	1979	12.00	0.0050	0.000044	10.	61.1	-1.299	0.4532	-.612	0.388
FITCH	1979	13.00	0.0056	0.000052	10.	64.7	-0.975	0.3733	-.528	0.381
FITCH	1979	14.00	0.0151	0.000083	10.	74.7	-0.537	0.1640	-.268	0.361
FITCH	1979	15.00	0.0494	0.004407	10.	86.5	-0.200	0.2212	0.441	0.340
FITCH	1979	16.00	0.0632	0.011803	10.	91.8	-0.112	0.1657	0.703	0.344
FITCH	1979	17.00	0.2923	00000000	10.	92.1	-0.007	0.0714	-.853	0.434

P.BROMPTON	1980	0.0	24.2178	00000000	18.	58.2	0.103	1.2829	-.144	0.887
P.BROMPTON	1980	1.00	-3.8778	00000000	18.	62.2	-0.234	0.3932	0.675	0.787
P.BROMPTON	1980	2.00	-1.5456	00000000	18.	67.1	-0.260	0.6322	0.409	0.698
P.BROMPTON	1980	3.00	-0.4584	0.679439	18.	73.6	-0.321	0.5897	0.178	0.604
P.BROMPTON	1980	4.00	-0.0189	0.000178	18.	81.5	-0.629	0.9893	0.254	0.505
P.BROMPTON	1980	5.00	0.0543	0.006700	18.	89.2	-0.989	1.2494	-.044	0.412
P.BROMPTON	1980	6.00	0.0312	0.001082	18.	93.9	-2.153	1.6965	-.150	0.335
P.BROMPTON	1980	7.00	0.0189	0.000382	18.	90.1	-2.819	1.8657	-.495	0.286
P.BROMPTON	1980	8.00	0.0230	0.000632	18.	81.1	-1.898	1.4108	-.709	0.256
P.BROMPTON	1980	9.00	0.0433	0.001090	18.	75.1	-0.860	0.5151	-.802	0.233
P.BROMPTON	1980	10.00	0.0354	0.002487	18.	68.8	-0.648	0.6989	-.672	0.226
P.BROMPTON	1980	11.00	0.0334	0.002427	18.	55.2	-0.437	0.4830	-.637	0.219
P.BROMPTON	1980	12.00	0.0458	0.001226	18.	44.8	-0.253	0.1430	-.808	0.195
P.BROMPTON	1980	13.00	0.0482	0.001633	18.	35.2	-0.214	0.1309	-.934	0.152
P.BROMPTON	1980	14.00	0.0903	0.003796	18.	29.8	-0.139	0.0683	-.670	0.097
P.BROMPTON	1980	15.00	0.1201	0.007482	18.	27.5	-0.102	0.0551	-.606	0.066
P.BROMPTON	1980	16.00	0.0967	0.007941	18.	27.0	-0.066	0.0490	-.083	0.074
P.BROMPTON	1980	17.00	0.4255	6.632247	18.	27.8	-0.006	0.0374	0.574	0.107

LOVERING	1979	0.0	0000000	00000000	10.	45.5	-0.112	0.2498	0.199	0.900
LOVERING	1979	1.00	-5.4990	00000000	10.	52.1	-0.179	0.1625	-.040	0.820
LOVERING	1979	2.00	-2.6714	00000000	10.	59.7	-0.180	0.3404	-.131	0.735
LOVERING	1979	3.00	-0.3585	0.342657	10.	67.8	-0.573	0.9551	0.077	0.636
LOVERING	1979	4.00	-0.0537	0.005109	10.	75.4	-0.789	1.2942	-.029	0.531
LOVERING	1979	5.00	0.3276	0.290111	10.	84.3	-0.194	0.3086	-.183	0.424
LOVERING	1979	6.00	0.1203	0.017743	10.	92.2	-0.968	0.9824	0.698	0.324
LOVERING	1979	7.00	0.0658	0.003680	10.	95.4	-1.972	1.5642	0.619	0.248
LOVERING	1979	8.00	0.0784	0.004959	10.	95.0	-1.575	1.2440	0.306	0.201
LOVERING	1979	9.00	0.0773	0.005291	10.	92.8	-1.267	1.0454	-.446	0.175
LOVERING	1979	10.00	0.0935	0.017720	10.	91.4	-0.800	1.0223	-.552	0.157
LOVERING	1979	11.00	0.0777	0.010617	10.	96.0	-0.706	0.8242	-.789	0.141
LOVERING	1979	12.00	0.0806	0.016780	10.	98.1	-0.546	0.7763	-.708	0.120
LOVERING	1979	13.00	0.1656	0.009026	10.	98.4	-0.263	0.1415	-.673	0.089
LOVERING	1979	14.00	0.1183	0.002158	10.	99.0	-0.332	0.1195	-.703	0.065
LOVERING	1979	15.00	0.1641	0.016544	10.	99.2	-0.220	0.1620	-.461	0.049
LOVERING	1979	16.00	0.1532	0.020931	10.	98.4	-0.192	0.1694	-.920	0.039
LOVERING	1979	17.00	0.2243	0.028600	10.	97.6	-0.104	0.0750	-.544	0.033
LOVERING	1979	18.00	0.1668	0.002002	10.	97.0	-0.101	0.0248	-.409	0.029
LOVERING	1979	19.00	0.1522	0.010407	10.	96.3	-0.076	0.0476	-.770	0.027
LOVERING	1979	20.00	0.1871	0.025379	10.	96.6	-0.043	0.0346	-.834	0.026
LOVERING	1979	21.00	0.1550	0.008970	10.	97.2	-0.036	0.0206	0.427	0.024
LOVERING	1979	22.00	0.1248	0.006250	10.	95.4	-0.028	0.0161	-.077	0.025

LOVERING	1980	0.0	0000000	00000000	15.	60.9	-0.098	0.1739	0.451	0.873
LOVERING	1980	1.00	-3.6778	00000000	15.	63.2	-0.277	0.6355	0.432	0.752
LOVERING	1980	2.00	-2.3405	00000000	15.	65.9	-0.159	0.2366	-.144	0.642
LOVERING	1980	3.00	-0.6161	7.781822	15.	69.0	-0.085	0.3893	-.360	0.528
LOVERING	1980	4.00	0.3628	0.321157	15.	72.7	-0.296	0.4471	0.155	0.418
LOVERING	1980	5.00	0.3056	0.221884	15.	77.1	-0.582	0.8634	0.121	0.321
LOVERING	1980	6.00	0.2233	0.074445	15.	81.2	-0.884	1.0261	-.031	0.243
LOVERING	1980	7.00	0.2883	0.170335	15.	83.8	-0.679	0.9355	-.246	0.182
LOVERING	1980	8.00	0.2253	0.069619	15.	85.3	-0.802	0.8933	-.321	0.134
LOVERING	1980	9.00	0.1462	0.010876	15.	86.7	-1.102	0.7252	-.312	0.097
LOVERING	1980	10.00	0.1703	0.021932	15.	86.6	-0.876	0.7123	-.352	0.068
LOVERING	1980	11.00	0.2782	0.070421	15.	86.1	-0.514	0.4692	-.412	0.045
LOVERING	1980	12.00	0.4360	0.095607	15.	86.6	-0.320	0.2195	0.166	0.029
LOVERING	1980	13.00	0.4761	0.095635	15.	85.9	-0.281	0.1762	-.660	0.019
LOVERING	1980	14.00	0.3578	0.063852	15.	85.2	-0.352	0.2386	-.495	0.012
LOVERING	1980	15.00	0.3625	0.136481	15.	83.6	-0.319	0.3137	-.611	0.008
LOVERING	1980	16.00	0.3905	0.270006	15.	81.3	-0.253	0.3261	-.692	0.006
LOVERING	1980	17.00	0.3487	0.067590	15.	80.4	-0.222	0.1582	-.806	0.004
LOVERING	1980	18.00	0.4125	0.102505	15.	79.8	-0.139	0.1036	-.579	0.004
LOVERING	1980	19.00	0.4201	0.067579	15.	79.5	-0.098	0.0580	-.303	0.003
LOVERING	1980	20.00	0.5330	0.294115	15.	79.1	-0.055	0.0547	-.317	0.003
LOVERING	1980	21.00	0.3375	0.094250	15.	79.3	-0.060	0.0521	-.300	0.002
LOVERING	1980	22.00	0.2263	0.072041	15.	82.4	-0.056	0.0627	0.262	0.002

LYSTER	1979	0.0	*******	********	6.	57.2	-0.019	0.0286	-.299	1.103
LYSTER	1979	1.00	*******	********	6.	51.5	-0.044	0.0506	-.502	1.280
LYSTER	1979	2.00	*******	********	6.	41.4	-0.089	0.0764	0.070	1.251
LYSTER	1979	3.00	26.3439	********	6.	22.5	0.037	0.1731	-.801	1.156
LYSTER	1979	4.00	-1.5347	********	6.	0.1	-0.461	0.8634	0.800	1.008
LYSTER	1979	5.00	-0.5456	0.800988	6.	22.9	-0.889	1.3284	0.794	0.870
LYSTER	1979	6.00	-0.8088	1.435936	6.	36.4	-0.397	0.5556	0.585	0.772
LYSTER	1979	7.00	-0.1962	0.024417	6.	37.4	-1.056	0.6914	0.528	0.687
LYSTER	1979	8.00	-0.0667	0.001989	6.	38.1	-1.954	1.1668	0.559	0.617
LYSTER	1979	9.00	-0.0479	0.000976	6.	38.9	-1.770	1.1648	0.708	0.583
LYSTER	1979	10.00	-0.0536	0.000887	6.	35.6	-1.580	0.6615	0.434	0.611
LYSTER	1979	11.00	-0.0618	0.001768	6.	28.9	-1.771	0.9016	-.752	0.717
LYSTER	1979	12.00	-0.0883	0.007227	6.	20.5	-1.240	0.9160	-.610	0.833
LYSTER	1979	13.00	-0.1534	0.024745	6.	13.5	-0.597	0.2285	-.322	0.892
LYSTER	1979	14.00	-0.1388	0.084034	6.	3.2	-0.577	0.2074	-.512	0.951
LYSTER	1979	15.00	-0.2007	********	6.	0.1	-0.327	0.0843	-.712	0.992
LYSTER	1979	16.00	-0.1801	2.967878	6.	0.2	-0.302	0.1462	0.495	1.017
LYSTER	1979	17.00	-0.1853	0.133169	6.	3.7	-0.258	0.0477	-.581	1.124
LYSTER	1979	18.00	-0.3371	0.393547	6.	7.4	-0.122	0.1540	-.588	1.285
LYSTER	1979	19.00	-0.1960	0.089457	6.	6.2	-0.177	0.0412	-.188	1.331
LYSTER	1979	20.00	-0.1614	0.090927	6.	4.1	-0.174	0.0574	-.643	1.321
LYSTER	1979	22.00	-0.1717	********	6.	0.0	-0.086	0.0323	0.924	1.012
LYSTER	1979	24.00	-0.1353	0.497760	6.	0.5	-0.060	0.0673	-.094	0.870
LYSTER	1979	26.00	-0.0547	0.005109	6.	6.1	-0.054	0.0127	0.413	0.631
LYSTER	1979	28.00	0.0036	0.000317	6.	14.5	-0.082	0.0656	0.149	0.433
LYSTER	1979	30.00	0.0559	0.003567	6.	23.1	-0.038	0.0190	-.052	0.329
LYSTER	1979	32.50	0.1833	0.020357	6.	31.8	-0.019	0.0084	0.534	0.213
LYSTER	1979	35.00	0.2098	0.016693	6.	42.6	-0.018	0.0061	-.859	0.148
LYSTER	1979	37.50	0.4569	0.049615	6.	74.7	-0.011	0.0048	0.732	0.075
LYSTER	1979	40.00	1.9159	********	6.	93.3	-0.004	0.0067	0.754	0.036

LYSTER	1980	0.0	*******	********	6.	0.0	0.012	0.0540	-.606	1.000
LYSTER	1980	1.00	*******	********	6.	0.4	0.003	0.0195	0.057	0.998
LYSTER	1980	2.00	*******	********	6.	3.3	0.004	0.0201	0.270	0.993
LYSTER	1980	3.00	*******	********	6.	13.1	-0.044	0.0535	0.073	0.985
LYSTER	1980	4.00	*******	********	6.	37.3	-0.211	0.4032	0.346	0.972
LYSTER	1980	5.00	-6.0559	********	6.	65.4	-0.316	0.3830	0.515	0.956
LYSTER	1980	6.00	-4.6928	********	6.	79.2	-0.300	0.3996	0.563	0.937
LYSTER	1980	7.00	-1.9563	1.747801	6.	74.1	-0.531	0.3376	0.919	0.917
LYSTER	1980	8.00	-0.4632	0.121133	6.	56.9	-1.692	1.1531	0.404	0.905
LYSTER	1980	9.00	-0.2455	0.013432	6.	45.2	-2.479	0.5037	-.339	0.912
LYSTER	1980	10.00	-0.2340	0.018654	6.	36.8	-2.001	0.5873	-.563	0.926
LYSTER	1980	11.00	-0.2490	0.030652	6.	25.2	-1.428	0.3016	0.001	0.935
LYSTER	1980	12.00	-0.2734	0.083697	6.	12.5	-0.998	0.2002	-.827	0.953
LYSTER	1980	13.00	-0.2894	0.250846	6.	5.0	-0.722	0.1559	-.022	0.969
LYSTER	1980	14.00	-0.3002	********	6.	0.0	-0.540	0.1855	-.221	0.998
LYSTER	1980	15.00	-0.3707	0.463381	6.	4.6	-0.342	0.1137	-.786	1.042
LYSTER	1980	16.00	-0.2910	0.129352	6.	9.5	-0.343	0.0776	0.222	1.086
LYSTER	1980	17.00	-0.2573	0.059608	6.	16.3	-0.312	0.1077	-.015	1.168
LYSTER	1980	18.00	-0.3031	0.060017	6.	24.4	-0.215	0.0924	-.398	1.319
LYSTER	1980	19.00	-0.3101	0.044690	6.	31.5	-0.173	0.0636	-.980	1.550
LYSTER	1980	20.00	-0.4134	0.279156	6.	32.2	-0.103	0.1208	-.641	1.789
LYSTER	1980	22.00	-0.2954	0.122725	6.	12.2	-0.080	0.0453	0.760	1.649
LYSTER	1980	24.00	-0.2326	0.166970	6.	4.9	-0.058	0.0222	0.327	1.582
LYSTER	1980	26.00	-0.1952	0.633849	6.	0.9	-0.036	0.0118	0.757	1.360
LYSTER	1980	28.00	-0.1075	1.267160	6.	0.1	-0.036	0.0084	0.083	1.187
LYSTER	1980	30.00	-0.0455	0.243209	6.	0.1	-0.040	0.0074	0.280	0.838
LYSTER	1980	32.50	0.0028	0.001675	6.	1.7	-0.024	0.0060	-.036	0.423
LYSTER	1980	35.00	0.1045	0.022813	6.	9.1	-0.017	0.0042	0.064	0.152
LYSTER	1980	37.50	0.3517	0.090024	6.	33.8	-0.011	0.0065	0.890	0.049
LYSTER	1980	40.00	0.7910	0.438263	6.	66.0	-0.007	0.0056	0.897	0.017

MASSAWIPPI	1979	0.0	0000000	00000000	12.	36.8	-0.336	0.5617	0.643	0.932
MASSAWIPPI	1979	1.00	-6.0310	00000000	12.	48.7	-0.201	0.2921	0.614	0.811
MASSAWIPPI	1979	2.00	-5.9349	00000000	12.	61.9	-0.117	0.0925	0.586	0.736
MASSAWIPPI	1979	3.00	0000000	00000000	12.	75.2	-0.030	0.1875	0.194	0.656
MASSAWIPPI	1979	4.00	-0.4176	0.545048	12.	86.8	-0.350	0.8337	0.434	0.571
MASSAWIPPI	1979	5.00	0.0112	0.000572	12.	93.4	-1.071	1.1827	0.764	0.487
MASSAWIPPI	1979	6.00	0.0978	0.041302	12.	93.3	-1.173	2.2019	0.293	0.415
MASSAWIPPI	1979	7.00	0.1069	0.015411	12.	85.0	-1.563	1.6430	0.380	0.357
MASSAWIPPI	1979	8.00	0.0737	0.006235	12.	72.6	-2.408	2.2205	0.152	0.312
MASSAWIPPI	1979	9.00	0.1004	0.011040	12.	63.7	-1.781	1.6443	-.226	0.278
MASSAWIPPI	1979	10.00	0.1937	0.025969	12.	60.8	-0.919	0.6935	-.254	0.246
MASSAWIPPI	1979	11.00	0.1881	0.025247	12.	61.0	-0.874	0.6699	-.077	0.218
MASSAWIPPI	1979	12.00	0.1266	0.014626	12.	64.9	-1.136	0.9730	-.695	0.194
MASSAWIPPI	1979	13.00	0.1721	0.048930	12.	69.1	-0.816	0.9768	-.539	0.164
MASSAWIPPI	1979	14.00	0.6676	0.285167	12.	70.4	-0.224	0.1712	0.417	0.130
MASSAWIPPI	1979	15.00	0.5576	0.174178	12.	71.5	-0.267	0.1902	-.492	0.103
MASSAWIPPI	1979	16.00	0.5319	0.046921	12.	71.9	-0.280	0.0996	0.017	0.080
MASSAWIPPI	1979	17.00	0.5365	0.027574	12.	71.7	-0.274	0.0666	0.083	0.063
MASSAWIPPI	1979	18.00	1.0041	0.368778	12.	71.0	-0.143	0.0817	-.096	0.049
MASSAWIPPI	1979	19.00	0.6137	0.052107	12.	69.9	-0.224	0.0700	-.682	0.038
MASSAWIPPI	1979	20.00	0.5003	0.056682	12.	68.9	-0.261	0.1106	-.666	0.030
MASSAWIPPI	1979	22.50	0.7439	1.220069	12.	68.8	-0.107	0.0377	-.476	0.016
MASSAWIPPI	1979	25.00	0.9110	0.068977	12.	68.9	-0.115	0.0239	-.350	0.009
MASSAWIPPI	1979	27.50	1.1388	0.165273	12.	67.8	-0.083	0.0242	-.305	0.005
MASSAWIPPI	1979	30.00	1.4338	0.330354	12.	65.6	-0.059	0.0200	-.846	0.002
MASSAWIPPI	1979	32.50	1.6294	0.476692	12.	64.5	-0.047	0.0170	-.791	0.001
MASSAWIPPI	1979	35.00	1.5330	0.248378	12.	64.4	-0.045	0.0108	-.700	0.001
MASSAWIPPI	1979	37.50	1.5225	0.298883	12.	64.9	-0.041	0.0116	-.608	0.000
MASSAWIPPI	1979	40.00	1.7575	0.635617	12.	65.6	-0.032	0.0126	-.682	0.000
MASSAWIPPI	1979	42.50	1.9803	0.688232	12.	66.5	-0.026	0.0093	-.775	0.000
MASSAWIPPI	1979	45.00	2.3550	0.561257	12.	67.6	-0.020	0.0049	-.401	0.000
MASSAWIPPI	1979	47.50	1.7018	0.192788	12.	68.5	-0.025	0.0042	0.276	0.000
MASSAWIPPI	1979	50.00	1.5935	0.229309	12.	69.7	-0.025	0.0057	-.052	0.000
MASSAWIPPI	1979	55.00	2.7565	2.884521	12.	73.6	-0.012	0.0069	-.225	0.000
MASSAWIPPI	1979	60.00	1.5714	0.423987	12.	75.4	-0.016	0.0059	-.217	0.000
MASSAWIPPI	1979	70.00	3.3235	00000000	12.	86.3	-0.003	0.0044	-.267	0.0
MASSAWIPPI	1979	80.00	0.6312	0.087621	12.	96.0	-0.006	0.0027	-.466	0.0

MASSAWIPPI	1980	0.0	0000000	00000000	11.	58.2	-0.096	0.1104	0.170	0.950
MASSAWIPPI	1980	1.00	0000000	00000000	11.	66.9	-0.047	0.1090	0.100	0.839
MASSAWIPPI	1980	2.00	-8.2375	00000000	11.	74.3	-0.117	0.1775	0.400	0.762
MASSAWIPPI	1980	3.00	-4.8723	00000000	11.	79.0	-0.098	0.1435	-.016	0.674
MASSAWIPPI	1980	4.00	-0.4896	0.800994	11.	79.7	-0.335	0.6234	0.320	0.575
MASSAWIPPI	1980	5.00	0.0364	0.002846	11.	77.5	-0.968	1.0920	0.527	0.474
MASSAWIPPI	1980	6.00	0.1019	0.014076	11.	73.0	-1.493	1.5530	0.427	0.384
MASSAWIPPI	1980	7.00	0.1123	0.010441	11.	65.3	-1.841	1.4792	0.421	0.312
MASSAWIPPI	1980	8.00	0.1110	0.009032	11.	56.4	-1.952	1.4373	-.119	0.258
MASSAWIPPI	1980	9.00	0.1232	0.011443	11.	50.5	-1.735	1.2886	-.472	0.211
MASSAWIPPI	1980	10.00	0.1648	0.014015	11.	48.6	-1.306	0.7846	-.156	0.167
MASSAWIPPI	1980	11.00	0.2694	0.046334	11.	48.5	-0.793	0.5576	-.187	0.129
MASSAWIPPI	1980	12.00	0.4057	0.053896	11.	49.1	-0.509	0.2373	-.405	0.099
MASSAWIPPI	1980	13.00	0.3707	0.061364	11.	51.2	-0.528	0.3058	-.365	0.074
MASSAWIPPI	1980	14.00	0.4849	0.311509	11.	53.3	-0.386	0.4209	-.521	0.055
MASSAWIPPI	1980	15.00	0.5017	0.199968	11.	55.0	-0.362	0.3001	-.448	0.040
MASSAWIPPI	1980	16.00	0.5657	0.200779	11.	56.0	-0.316	0.2308	-.446	0.028
MASSAWIPPI	1980	17.00	1.1919	0.305623	11.	56.1	-0.150	0.0562	-.316	0.019
MASSAWIPPI	1980	18.00	1.4272	0.971280	11.	56.1	-0.124	0.0780	0.246	0.013
MASSAWIPPI	1980	19.00	0.7105	0.085194	11.	55.7	-0.239	0.0725	0.332	0.009
MASSAWIPPI	1980	20.00	0.6611	0.092666	11.	55.2	-0.246	0.0894	0.007	0.007
MASSAWIPPI	1980	22.50	1.5000	1.947803	11.	54.6	-0.058	0.0291	-.592	0.003
MASSAWIPPI	1980	25.00	1.0376	0.322637	11.	53.4	-0.117	0.0543	-.466	0.001
MASSAWIPPI	1980	27.50	1.2303	0.376730	11.	50.7	-0.087	0.0346	-.786	0.001
MASSAWIPPI	1980	30.00	1.6450	0.527178	11.	48.3	-0.060	0.0185	-.646	0.000
MASSAWIPPI	1980	32.50	1.9553	0.847075	11.	47.2	-0.046	0.0158	-.422	0.000
MASSAWIPPI	1980	35.00	1.3686	0.439805	11.	46.4	-0.059	0.0210	-.095	0.000
MASSAWIPPI	1980	37.50	1.3305	0.383289	11.	45.2	-0.054	0.0173	-.444	0.000
MASSAWIPPI	1980	40.00	2.0654	2.672949	11.	43.6	-0.031	0.0219	-.702	0.000
MASSAWIPPI	1980	42.50	2.2565	1.252901	11.	42.8	-0.026	0.0090	-.221	0.000
MASSAWIPPI	1980	45.00	2.3129	1.205803	11.	41.6	-0.023	0.0070	0.612	0.000
MASSAWIPPI	1980	47.50	1.2474	0.278913	11.	38.6	-0.037	0.0067	-.519	0.000
MASSAWIPPI	1980	50.00	1.2364	0.311277	11.	35.4	-0.033	0.0061	-.608	0.0
MASSAWIPPI	1980	55.00	1.9214	2.308229	11.	28.6	-0.016	0.0103	-.370	0.0
MASSAWIPPI	1980	60.00	1.0182	0.383367	11.	25.0	-0.023	0.0069	-.611	0.0
MASSAWIPPI	1980	70.00	0000000	00000000	11.	31.5	-0.000	0.0077	0.186	0.0
MASSAWIPPI	1980	80.00	0.4872	0.259763	11.	30.8	-0.009	0.0084	-.328	0.0

NORTH	1979	0.0	-2.3217	00000000	10.	66.6	-0.800	1.5337	0.554	0.785
NORTH	1979	1.00	-1.6938	00000000	10.	67.8	-0.497	0.9606	0.563	0.689
NORTH	1979	2.00	-2.9081	00000000	10.	69.3	-0.146	0.2694	0.576	0.619
NORTH	1979	3.00	-2.1030	7.210323	10.	71.0	-0.078	0.0995	0.397	0.556
NORTH	1979	4.00	0.5378	0.436422	10.	72.9	-0.030	0.0360	0.466	0.493
NORTH	1979	5.00	1.6900	00000000	10.	75.0	-0.085	0.1868	0.600	0.433
NORTH	1979	6.00	1.1445	5.817746	10.	77.4	-0.202	0.4208	0.595	0.376
NORTH	1979	7.00	1.3436	4.019856	10.	80.3	-0.213	0.3130	0.844	0.325
NORTH	1979	8.00	2.1217	8.897922	10.	83.5	-0.147	0.2052	0.741	0.282
NORTH	1979	9.00	2.0040	00000000	10.	87.1	-0.158	0.2522	0.620	0.245
NORTH	1979	10.00	1.4974	4.749963	10.	90.6	-0.203	0.2931	0.501	0.216
NORTH	1979	11.00	0.2682	0.120229	10.	93.5	-1.002	1.2443	0.041	0.194
NORTH	1979	12.00	0.1688	0.053358	10.	94.6	-1.353	1.7416	-.003	0.178
NORTH	1979	13.00	0.1963	0.047861	10.	95.3	-0.973	1.0273	-.277	0.168
NORTH	1979	14.00	0.1636	0.038998	10.	95.2	-0.929	1.0520	-.660	0.162
NORTH	1979	15.00	0.1689	0.047557	10.	94.8	-0.740	0.8983	-.790	0.153
NORTH	1979	16.00	0.2316	0.026100	10.	94.3	-0.478	0.3168	-.828	0.139
NORTH	1979	17.00	0.4211	0.060463	10.	93.8	-0.240	0.1356	-.513	0.123
NORTH	1979	18.00	0.5037	0.086030	10.	93.5	-0.181	0.1023	-.547	0.108
NORTH	1979	19.00	0.5084	0.049767	10.	93.2	-0.161	0.0681	-.110	0.094
NORTH	1979	20.00	0.6001	0.146423	10.	93.2	-0.122	0.0760	-.586	0.082
NORTH	1979	22.00	0.8246	0.125805	10.	93.2	-0.071	0.0295	-.044	0.063
NORTH	1979	24.00	0.4737	0.025058	10.	93.6	-0.096	0.0305	-.709	0.047
NORTH	1979	26.00	0.3869	0.030590	10.	95.6	-0.096	0.0419	0.310	0.034
NORTH	1979	28.00	0.4402	0.143997	10.	96.8	-0.067	0.0567	0.527	0.025

NORTH	1980	0.0	0000000	00000000	19.	68.2	-0.235	0.4180	0.080	0.845
NORTH	1980	1.00	-6.6240	00000000	19.	69.7	-0.151	0.1499	0.185	0.671
NORTH	1980	2.00	-2.9554	00000000	19.	71.5	-0.131	0.1694	0.297	0.588
NORTH	1980	3.00	-0.3785	0.189888	19.	73.5	-0.116	0.1364	0.253	0.512
NORTH	1980	4.00	2.9200	7.132731	19.	75.7	-0.057	0.0510	0.182	0.441
NORTH	1980	5.00	3.5277	00000000	19.	78.3	-0.081	0.0983	0.184	0.375
NORTH	1980	6.00	1.7042	6.419692	19.	81.1	-0.204	0.3013	0.100	0.317
NORTH	1980	7.00	0.7821	1.385167	19.	83.8	-0.468	0.6929	-.146	0.267
NORTH	1980	8.00	0.5603	0.738144	19.	85.6	-0.635	0.9533	-.183	0.226
NORTH	1980	9.00	0.3855	0.171419	19.	86.2	-0.847	0.8820	-.352	0.192
NORTH	1980	10.00	0.2812	0.136280	19.	85.3	-1.023	1.2917	-.303	0.165
NORTH	1980	11.00	0.2152	0.041892	19.	83.9	-1.146	1.0338	-.627	0.143
NORTH	1980	12.00	0.2596	0.107016	19.	83.3	-0.834	1.0071	-.657	0.122
NORTH	1980	13.00	0.4224	0.083804	19.	85.3	-0.466	0.3083	-.531	0.101
NORTH	1980	14.00	0.4054	0.158987	19.	87.9	-0.433	0.4137	-.052	0.083
NORTH	1980	15.00	0.5370	0.195610	19.	89.3	-0.290	0.2332	-.179	0.069
NORTH	1980	16.00	0.5543	0.362348	19.	89.7	-0.246	0.2615	-.510	0.057
NORTH	1980	17.00	0.5910	0.965580	19.	89.3	-0.203	0.3320	-.442	0.046
NORTH	1980	18.00	0.5356	0.199452	19.	89.1	-0.200	0.1630	-.063	0.037
NORTH	1980	19.00	0.4659	0.109429	19.	89.0	-0.205	0.1412	-.070	0.030
NORTH	1980	20.00	0.5714	0.132364	19.	88.5	-0.149	0.0921	-.675	0.024
NORTH	1980	22.00	0.7658	0.226650	19.	88.4	-0.089	0.0543	0.339	0.015
NORTH	1980	24.00	0.4672	0.053072	19.	88.6	-0.116	0.0554	0.478	0.010
NORTH	1980	26.00	0.5913	0.169070	19.	89.4	-0.075	0.0506	0.689	0.006
NORTH	1980	28.00	0.9081	1.188478	19.	80.1	-0.030	0.0355	-.286	0.005

ORFORD	1979	0.0	*******	********	10.	32.7	-0.105	0.1460	0.003	1.094
ORFORD	1979	1.00	56.5866	********	10.	21.6	0.030	0.2063	0.186	1.117
ORFORD	1979	2.00	-3.0531	********	10.	7.1	-0.416	0.6587	0.163	1.065
ORFORD	1979	3.00	-3.2455	********	10.	0.7	-0.287	0.4513	0.807	0.981
ORFORD	1979	4.00	-2.5092	********	10.	24.4	-0.264	0.9973	0.623	0.882
ORFORD	1979	5.00	-1.0077	5.577980	10.	54.0	-0.446	1.0475	0.420	0.785
ORFORD	1979	6.00	-0.2728	0.087785	10.	66.5	-1.049	1.1609	0.642	0.694
ORFORD	1979	7.00	-0.0808	0.003652	10.	66.3	-2.244	1.8591	0.647	0.624
ORFORD	1979	8.00	-0.0481	0.000501	10.	61.5	-2.813	1.5161	0.607	0.599
ORFORD	1979	9.00	-0.0496	0.000352	10.	43.9	-2.700	0.8605	-.227	0.629
ORFORD	1979	10.00	-0.0715	0.002999	10.	20.4	-1.884	1.2136	-.782	0.691
ORFORD	1979	11.00	-0.0976	0.008391	10.	10.5	-1.180	0.5908	-.803	0.722
ORFORD	1979	12.00	-0.1175	0.015523	10.	7.1	-0.756	0.1663	0.320	0.714
ORFORD	1979	13.00	-0.1307	0.033474	10.	4.3	-0.547	0.1487	0.050	0.717
ORFORD	1979	14.00	-0.1994	0.174377	10.	2.2	-0.297	0.1771	-.925	0.736
ORFORD	1979	15.00	-0.1796	0.218491	10.	1.3	-0.268	0.0891	-.940	0.736
ORFORD	1979	16.00	-0.2012	0.376412	10.	1.0	-0.180	0.0538	-.799	0.717
ORFORD	1979	17.00	-0.1998	0.441657	10.	0.8	-0.130	0.0229	-.555	0.683
ORFORD	1979	18.00	-0.1540	0.291591	10.	0.7	-0.114	0.0263	0.027	0.642
ORFORD	1979	19.00	-0.1043	0.143008	10.	0.6	-0.106	0.0258	0.215	0.600
ORFORD	1979	20.00	-0.0651	0.056896	10.	0.5	-0.093	0.0139	-.297	0.560
ORFORD	1979	22.00	0.0282	0.036347	10.	0.4	-0.057	0.0123	-.790	0.467
ORFORD	1979	24.00	0.1657	0.827932	10.	0.4	-0.046	0.0066	-.670	0.358
ORFORD	1979	26.00	-0.3614	3.730170	10.	0.4	-0.035	0.0053	-.692	0.251
ORFORD	1979	28.00	0.6728	********	10.	0.4	-0.026	0.0057	0.505	0.162
ORFORD	1979	30.00	0.9719	********	10.	0.4	-0.022	0.0198	-.002	0.103
ORFORD	1979	32.50	0.6594	********	10.	0.4	-0.037	0.0581	-.113	0.058
ORFORD	1979	35.00	-0.6578	********	10.	0.4	0.046	0.1991	0.[illegible]7	0.030
ORFORD	1979	37.50	-0.3072	3.082496	10.	0.4	0.121	0.4275	0.069	0.015

ORFORD	1980	0.0	*******	********	17.	57.1	-0.044	0.1499	0.205	0.803
ORFORD	1980	1.00	*******	********	17.	59.5	-0.035	0.0650	0.075	0.736
ORFORD	1980	2.00	-9.8805	********	17.	62.6	-0.058	0.0430	-.379	0.678
ORFORD	1980	3.00	8.1961	********	17.	66.7	0.039	0.1151	0.178	0.626
ORFORD	1980	4.00	-0.6261	0.718871	17.	72.1	-0.253	0.3466	-.184	0.578
ORFORD	1980	5.00	-0.1463	0.028835	17.	78.9	-0.404	0.5025	-.147	0.535
ORFORD	1980	6.00	-0.0092	0.000002	17.	86.2	-0.988	1.0647	-.112	0.499
ORFORD	1980	7.00	0.0023	0.000099	17.	91.2	-1.948	1.5216	-.284	0.474
ORFORD	1980	8.00	0.0052	0.000127	17.	91.0	-1.888	1.3560	-.173	0.460
ORFORD	1980	9.00	0.0011	0.000048	17.	85.0	-1.760	1.0435	-.479	0.462
ORFORD	1980	10.00	-0.0061	0.000010	17.	73.9	-1.571	1.1136	-.782	0.482
ORFORD	1980	11.00	-0.0100	0.000000	17.	61.5	-1.136	0.8226	-.779	0.498
ORFORD	1980	12.00	-0.0099	0.000000	17.	49.3	-0.656	0.4343	-.798	0.498
ORFORD	1980	13.00	-0.0047	0.000010	17.	38.6	-0.429	0.2026	-.319	0.484
ORFORD	1980	14.00	-0.0028	0.000023	17.	28.3	-0.373	0.1874	-.719	0.475
ORFORD	1980	15.00	0.0035	0.000081	17.	20.4	-0.218	0.0944	-.907	0.464
ORFORD	1980	16.00	0.0055	0.000170	17.	14.5	-0.194	0.1115	-.441	0.452
ORFORD	1980	17.00	0.0045	0.000162	17.	9.9	-0.183	0.0820	-.724	0.443
ORFORD	1980	18.00	0.0083	0.000330	17.	6.7	-0.131	0.0467	-.561	0.433
ORFORD	1980	19.00	0.0080	0.000493	17.	4.2	-0.106	0.0388	-.619	0.428
ORFORD	1980	20.00	0.0046	0.000560	17.	2.5	-0.089	0.0359	-.467	0.432
ORFORD	1980	22.00	-0.0121	0.000036	17.	0.5	-0.062	0.0262	-.505	0.512
ORFORD	1980	24.00	-0.0536	1.827850	17.	0.0	-0.035	0.0135	-.609	1.220
ORFORD	1980	26.00	-0.1145	0.107131	17.	0.6	-0.027	0.0134	-.579	-.488
ORFORD	1980	28.00	-0.1818	0.095272	17.	1.9	-0.022	0.0110	-.779	-.121
ORFORD	1980	30.00	-0.2400	0.104926	17.	3.4	-0.019	0.0105	-.768	-.052
ORFORD	1980	32.50	-0.2686	0.092683	17.	4.5	-0.016	0.0061	-.851	-.024
ORFORD	1980	35.00	-0.3817	0.189719	17.	4.5	-0.009	0.0032	0.231	-.014
ORFORD	1980	37.50	-0.5785	0.617909	17.	4.7	-0.005	0.0040	-.065	-.008

STUKELY	1979	0.0	0000000	00000000	12.	0.5	-0.110	0.1655	0.253	1.010
STUKELY	1979	1.00	-9.3980	00000000	12.	0.3	-0.155	0.1652	0.479	0.988
STUKELY	1979	2.00	-3.2672	00000000	12.	5.0	-0.293	0.4283	0.491	0.939
STUKELY	1979	3.00	-2.0989	00000000	12.	18.6	-0.298	0.4735	0.470	0.868
STUKELY	1979	4.00	-1.0430	1.228915	12.	41.9	-0.367	0.3739	0.751	0.777
STUKELY	1979	5.00	-0.4279	0.795612	12.	65.5	-0.477	1.0137	0.469	0.673
STUKELY	1979	6.00	-0.0790	0.005278	12.	76.1	-1.040	1.0881	0.177	0.572
STUKELY	1979	7.00	-0.0009	0.000077	12.	73.9	-1.912	1.7415	0.433	0.479
STUKELY	1979	8.00	0.0153	0.000151	12.	71.3	-2.428	1.0758	0.744	0.414
STUKELY	1979	9.00	0.0227	0.000456	12.	66.1	-1.937	1.1857	0.174	0.367
STUKELY	1979	10.00	0.0210	0.000118	12.	63.6	-1.446	0.3898	-.656	0.389
STUKELY	1979	11.00	0.0071	0.000146	12.	67.0	-1.399	0.9245	-.724	0.413
STUKELY	1979	12.00	0.0063	0.000115	12.	71.6	-0.977	0.6017	-.617	0.419
STUKELY	1979	13.00	0.0138	0.000122	12.	78.2	-0.658	0.2824	-.740	0.398
STUKELY	1979	14.00	0.0419	0.000714	12.	85.5	-0.368	0.1829	-.124	0.350
STUKELY	1979	15.00	0.0976	0.001731	12.	87.0	-0.201	0.0742	-.187	0.301
STUKELY	1979	16.00	0.1812	0.015071	12.	86.0	-0.121	0.0763	-.386	0.255
STUKELY	1979	17.00	0.1656	0.019336	12.	86.0	-0.138	0.1080	-.187	0.209
STUKELY	1979	18.00	0.3653	0.027958	12.	88.2	-0.067	0.0290	0.157	0.168
STUKELY	1979	19.00	0.7373	7.229126	12.	89.1	-0.034	0.1212	-.020	0.135
STUKELY	1979	20.00	0.3160	0.042104	12.	89.8	-0.075	0.0466	-.269	0.109
STUKELY	1979	22.00	0.6361	0.158319	12.	93.2	-0.034	0.0210	-.124	0.070
STUKELY	1979	24.00	0.7259	0.086085	12.	93.6	-0.026	0.0100	-.143	0.046
STUKELY	1979	26.00	0.8072	0.148820	12.	94.6	-0.018	0.0086	-.155	0.032
STUKELY	1979	28.00	0.7226	0.091171	12.	94.9	-0.015	0.0063	-.053	0.023
STUKELY	1979	30.00	0.8452	0.318496	12.	95.0	-0.009	0.0056	-.346	0.019

STUKELY	1980	0.0	0000000	00000000	16.	43.4	-0.025	0.0629	-.370	0.871
STUKELY	1980	1.00	0000000	00000000	16.	47.1	-0.051	0.0478	0.046	0.754
STUKELY	1980	2.00	0000000	00000000	16.	51.7	-0.027	0.0647	0.009	0.659
STUKELY	1980	3.00	-0.4324	0.242843	16.	57.3	-0.276	0.3170	0.105	0.559
STUKELY	1980	4.00	0.1026	0.008563	16.	64.3	-0.553	0.4408	0.470	0.460
STUKELY	1980	5.00	0.2889	0.117240	16.	72.0	-0.553	0.6269	0.344	0.369
STUKELY	1980	6.00	0.1776	0.024329	16.	79.4	-1.148	0.9415	0.177	0.292
STUKELY	1980	7.00	0.1670	0.022842	16.	84.2	-1.286	1.0868	0.072	0.233
STUKELY	1980	8.00	0.1353	0.014371	16.	85.3	-1.477	1.2055	-.240	0.189
STUKELY	1980	9.00	0.1381	0.014902	16.	84.4	-1.289	1.0508	-.177	0.156
STUKELY	1980	10.00	0.1905	0.011757	16.	82.2	-0.803	0.4229	-.302	0.131
STUKELY	1980	11.00	0.1112	0.011531	16.	77.3	-1.051	0.9174	-.589	0.115
STUKELY	1980	12.00	0.0970	0.008088	16.	72.6	-0.947	0.7798	-.888	0.100
STUKELY	1980	13.00	0.1090	0.008838	16.	71.5	-0.737	0.5685	-.698	0.080
STUKELY	1980	14.00	0.1892	0.010129	16.	72.7	-0.412	0.1982	-.399	0.060
STUKELY	1980	15.00	0.3668	0.068492	16.	73.0	-0.208	0.1408	-.398	0.044
STUKELY	1980	16.00	0.5078	0.074408	16.	73.2	-0.146	0.0737	-.404	0.031
STUKELY	1980	17.00	0.6371	0.112965	16.	73.1	-0.114	0.0566	-.232	0.022
STUKELY	1980	18.00	0.8883	0.215966	16.	73.1	-0.080	0.0395	-.139	0.015
STUKELY	1980	19.00	1.0503	0.122032	16.	73.0	-0.066	0.0192	-.096	0.011
STUKELY	1980	20.00	1.4610	0.364450	16.	73.0	-0.045	0.0173	-.181	0.008
STUKELY	1980	22.00	2.0618	0.785405	16.	72.8	-0.029	0.0114	0.384	0.004
STUKELY	1980	24.00	2.0460	1.268007	16.	72.1	-0.024	0.0127	-.008	0.002
STUKELY	1980	26.00	2.0287	0.980594	16.	71.3	-0.019	0.0089	-.024	0.001
STUKELY	1980	28.00	1.6490	0.687396	16.	70.8	-0.018	0.0085	0.146	0.001
STUKELY	1980	30.00	1.7749	2.565661	16.	69.7	-0.011	0.0096	-.064	0.001

TROITE	1979	0.0	0.4592	0.934647	16.	58.3	5.304	10.8602	0.506	0.917
TROITE	1979	1.00	0.5845	2.145372	16.	58.1	1.643	4.0315	0.510	0.795
TROITE	1979	2.00	-0.4141	0.155093	16.	68.3	-1.070	1.0280	-.251	0.688
TROITE	1979	3.00	-0.1320	0.029582	16.	75.8	-0.950	1.3362	0.761	0.567
TROITE	1979	4.00	-0.0050	0.000019	16.	82.1	-2.897	2.3210	0.801	0.488
TROITE	1979	5.00	-0.0114	0.000000	16.	85.9	-5.978	3.0132	-.567	0.508
TROITE	1979	5.50	-0.0161	0.000012	16.	83.7	-5.118	3.0346	-.878	0.552
TROITE	1979	6.00	-0.0241	0.000074	16.	79.2	-2.696	1.6586	-.826	0.588
TROITE	1979	6.50	-0.0303	0.000190	16.	79.1	-1.876	1.2782	-.758	0.618
TROITE	1979	7.00	-0.0342	0.000239	16.	79.7	-1.410	0.8984	-.746	0.638
TROITE	1979	7.50	-0.0411	0.000380	16.	80.5	-0.904	0.5635	-.690	0.646
TROITE	1979	8.00	-0.0599	0.000286	16.	80.8	-0.439	0.1399	-.237	0.643
TROITE	1979	8.50	-0.0657	0.001691	16.	80.8	-0.323	0.2368	-.679	0.649
TROITE	1979	9.00	-0.0535	0.001931	16.	80.9	-0.351	0.3556	-.797	0.662
TROITE	1979	10.00	-0.0571	0.001363	16.	85.9	-0.193	0.1516	-.579	0.650
TROITE	1979	11.00	-0.0560	0.000841	16.	91.0	-0.099	0.0624	-.710	0.611
TROITE	1979	12.00	-0.0322	0.000160	16.	91.7	-0.065	0.0373	0.005	0.550
TROITE	1979	13.00	-0.0174	0.000043	16.	81.1	-0.038	0.0355	0.069	0.514

TROITE	1980	0.0	*******	********	16.	19.9	-0.106	0.2768	0.144	0.983
TROITE	1980	1.00	*******	********	16.	32.8	-0.066	0.1499	0.[illegible]	0.959
TROITE	1980	2.00	-2.5179	********	16.	54.3	-0.457	0.5846	0.041	0.912
TROITE	1980	3.00	-0.6978	0.903863	16.	78.0	-0.784	1.0793	0.029	0.830
TROITE	1980	4.00	-0.1049	0.003874	16.	91.9	-2.348	1.5365	0.517	0.716
TROITE	1980	5.00	-0.0309	0.000135	16.	94.1	-3.645	2.0541	0.427	0.615
TROITE	1980	5.50	-0.0226	0.000024	16.	91.5	-3.494	1.3947	0.318	0.584
TROITE	1980	6.00	-0.0197	0.000021	16.	85.0	-2.810	1.3587	-.256	0.568
TROITE	1980	6.50	-0.0183	0.000036	16.	75.9	-2.217	1.6548	-.540	0.560
TROITE	1980	7.00	-0.0177	0.000027	16.	69.9	-1.511	1.0634	-.465	0.550
TROITE	1980	7.50	-0.0218	0.000040	16.	70.6	-0.622	0.3319	-.529	0.544
TROITE	1980	8.00	-0.0199	0.000112	16.	77.4	-0.671	0.7380	-.645	0.554
TROITE	1980	8.50	-0.0194	0.000248	16.	86.8	-0.735	1.2874	-.684	0.579
TROITE	1980	9.00	-0.0202	0.000231	16.	91.0	-0.490	0.7620	-.728	0.577
TROITE	1980	10.00	-0.0015	0.000055	16.	90.2	-0.103	0.0854	0.130	0.478
TROITE	1980	11.00	0.0237	0.001500	16.	92.3	-0.086	0.0981	-.598	0.392
TROITE	1980	12.00	0.1195	0.002574	16.	93.0	-0.029	0.0111	-.481	0.305
TROITE	1980	13.00	0.4714	0.740078	16.	93.6	-0.007	0.0117	0.341	0.253

APPENDIX SIX

Rates of oxygen depletion measured in each stratum of the hypolimnion of the study lakes. The method of calculation is outlined in Chapter 12. The data are arranged in columns:

1. Lake Name.
2. Year of study.
3. Depth (m).
4. Rate of oxygen depletion (mg/L/day).
5. Variance in the rate of oxygen depletion.
6. Number of measured oxygen concentrations.

BROMPTON	1978	14.0	-0.02812	0.00194	6
BROMPTON	1978	16.0	-0.03066	0.00049	6
BROMPTON	1978	18.0	-0.02925	0.00049	6
BROMPTON	1978	20.0	-0.02874	0.00097	6
BROMPTON	1978	22.0	-0.02942	0.00123	5
BROMPTON	1978	24.0	-0.02837	0.00102	6
BROMPTON	1978	26.0	-0.02818	0.00041	5
BROMPTON	1978	28.0	-0.02829	0.00052	5
BROMPTON	1978	30.0	-0.02854	0.00030	6
BROMPTON	1978	32.5	-0.02786	0.00120	5
BROMPTON	1978	35.0	-0.02767	0.00100	6
BROMPTON	1978	37.5	-0.02710	0.00130	5
CENTRAL	1978	20.0	-0.03964	0.00427	7
CENTRAL	1978	30.0	-0.01763	0.00333	7
CENTRAL	1978	35.0	-0.01646	0.00396	7
CENTRAL	1978	40.0	-0.02539	0.00712	7
CENTRAL	1978	50.0	-0.01071	0.00316	7
CENTRAL	1978	70.0	-0.00968	0.00412	7
CENTRAL	1978	90.0	-0.00389	0.00482	7
LOVERING	1978	10.0	-0.07678	0.00288	7
LOVERING	1978	12.0	-0.07604	0.00289	7
LOVERING	1978	14.0	-0.07081	0.00360	8
LOVERING	1978	16.0	-0.07282	0.00399	8
LOVERING	1978	18.0	-0.07637	0.00301	8
LOVERING	1978	20.0	-0.07719	0.00321	8
LOVERING	1978	22.0	-0.08253	0.00559	5
LYSTER	1978	12.0	-0.01685	0.00166	7
LYSTER	1978	14.0	-0.01637	0.00479	7
LYSTER	1978	16.0	-0.00665	0.00335	7
LYSTER	1978	18.0	-0.00998	0.00349	7
LYSTER	1978	20.0	-0.01169	0.00278	7
LYSTER	1978	22.0	-0.00673	0.00080	6
LYSTER	1978	24.0	-0.01418	0.00270	7
LYSTER	1978	26.0	-0.01716	0.00383	6
LYSTER	1978	28.0	-0.01930	0.00140	6
LYSTER	1978	30.0	-0.01711	0.00372	7
LYSTER	1978	32.5	-0.02095	0.00409	6
LYSTER	1978	35.0	-0.02968	0.00272	7
LYSTER	1978	37.5	-0.02969	0.00493	6
LYSTER	1978	40.0	-0.03718	0.00847	7
STOKELY	1978	12.0	-0.03278	0.00153	5
STOKELY	1978	14.0	-0.02003	0.00177	5
STOKELY	1978	16.0	-0.02336	0.00306	5
STOKELY	1978	18.0	-0.02574	0.00213	5
STOKELY	1978	20.0	-0.02495	0.00193	5
STOKELY	1978	22.0	-0.02719	0.00228	5
STOKELY	1978	24.0	-0.02858	0.00235	5
STOKELY	1978	26.0	-0.02939	0.00255	5
STOKELY	1978	28.0	-0.03166	0.00242	5
STOKELY	1978	30.0	-0.02848	0.00207	4
BROMPTON	1979	12.0	-0.02294	0.00998	6
BROMPTON	1979	14.0	-0.03573	0.00188	6
BROMPTON	1979	16.0	-0.03462	0.00365	6
BROMPTON	1979	18.0	-0.03785	0.00327	6
BROMPTON	1979	20.0	-0.03571	0.00141	6
BROMPTON	1979	22.0	-0.03437	0.00259	6
BROMPTON	1979	24.0	-0.03526	0.00208	6
BROMPTON	1979	26.0	-0.03530	0.00142	6
BROMPTON	1979	28.0	-0.03525	0.00143	6
BROMPTON	1979	30.0	-0.03616	0.00215	6

BROMPTON	1979	32.5	-0.03750	0.00251	6
BROMPTON	1979	35.0	-0.03800	0.00170	6
BROMPTON	1979	37.5	-0.03752	0.00351	6
BROMPTON	1979	40.0	-0.03862	0.00446	4
CENTRAL	1979	20.0	-0.02958	0.00170	8
CENTRAL	1979	22.5	-0.02529	0.00163	8
CENTRAL	1979	25.0	-0.02274	0.00077	8
CENTRAL	1979	27.5	-0.01985	0.00066	8
CENTRAL	1979	30.0	-0.01541	0.00072	7
CENTRAL	1979	32.5	-0.01307	0.00284	6
CENTRAL	1979	35.0	-0.01185	0.00147	8
CENTRAL	1979	40.0	-0.01107	0.00137	8
CENTRAL	1979	45.0	-0.01118	0.00151	7
CENTRAL	1979	50.0	-0.01052	0.00097	8
CENTRAL	1979	60.0	-0.01057	0.00101	8
CENTRAL	1979	70.0	-0.01078	0.00100	8
CENTRAL	1979	80.0	-0.01202	0.00401	6
FITCH	1979	12.0	-0.09896	0.01236	6
FITCH	1979	13.0	-0.09283	0.01262	4
FITCH	1979	14.0	-0.12207	0.02166	5
FITCH	1979	16.0	-0.12702	0.01320	4
LOVERING	1979	10.0	-0.05860	0.00386	4
LOVERING	1979	12.0	-0.07450	0.00385	7
LOVERING	1979	14.0	-0.07201	0.00358	8
LOVERING	1979	15.0	-0.06686	0.00364	5
LOVERING	1979	16.0	-0.07322	0.00179	8
LOVERING	1979	17.0	-0.07434	0.00230	8
LOVERING	1979	18.0	-0.07788	0.00264	7
LOVERING	1979	19.0	-0.08208	0.00254	7
LOVERING	1979	20.0	-0.08211	0.00424	7
LOVERING	1979	22.0	-0.06755	0.01624	4
LYSTER	1979	12.0	-0.01623	0.00131	6
LYSTER	1979	14.0	-0.01745	0.00218	6
LYSTER	1979	16.0	-0.01569	0.00203	6
LYSTER	1979	18.0	-0.01723	0.00296	6
LYSTER	1979	20.0	-0.01622	0.00276	6
LYSTER	1979	22.0	-0.01742	0.00249	6
LYSTER	1979	24.0	-0.01479	0.00198	6
LYSTER	1979	26.0	-0.01596	0.00120	6
LYSTER	1979	28.0	-0.01556	0.00055	6
LYSTER	1979	30.0	-0.01638	0.00238	6
LYSTER	1979	32.5	-0.02057	0.00635	6
LYSTER	1979	35.0	-0.02131	0.00545	6
LYSTER	1979	37.5	-0.03216	0.00419	6
LYSTER	1979	40.0	-0.02459	0.01023	6
MAGOG	1979	12.0	-0.21842	0.00999	5
MAGOG	1979	13.0	-0.20363	0.01392	5
MAGOG	1979	14.0	-0.21600	0.01543	5
MAGOG	1979	15.0	-0.20397	0.02941	4
MAGOG	1979	16.0	-0.22113	0.01353	4
MASSAWIPPI	1979	15.0	-0.03278	0.00197	6
MASSAWIPPI	1979	20.0	-0.02869	0.00217	6
MASSAWIPPI	1979	22.5	-0.02488	0.00195	5
MASSAWIPPI	1979	25.0	-0.02426	0.00347	6
MASSAWIPPI	1979	27.5	-0.01934	0.00207	6
MASSAWIPPI	1979	30.0	-0.01631	0.00134	6
MASSAWIPPI	1979	32.5	-0.01542	0.00256	5
MASSAWIPPI	1979	35.0	-0.01401	0.00171	6
MASSAWIPPI	1979	40.0	-0.01208	0.00194	6
MASSAWIPPI	1979	45.0	-0.01144	0.00215	6

MASSAWIPPI	1979	50.0	-0.01061	0.00150	6
MASSAWIPPI	1979	60.0	-0.00916	0.00153	6
MASSAWIPPI	1979	70.0	-0.01039	0.00323	6
NORTH	1979	12.0	-0.07350	0.00466	5
NORTH	1979	14.0	-0.07880	0.00461	6
NORTH	1979	16.0	-0.07220	0.00460	7
NORTH	1979	18.0	-0.06236	0.00640	9
NORTH	1979	20.0	-0.06664	0.00473	9
NORTH	1979	22.0	-0.06710	0.00440	9
NORTH	1979	24.0	-0.06599	0.00441	9
NORTH	1979	26.0	-0.06896	0.00477	9
NORTH	1979	28.0	-0.06967	0.00541	9
ORFORD	1979	12.0	-0.00811	0.00297	6
ORFORD	1979	14.0	-0.00961	0.00311	6
ORFORD	1979	16.0	-0.01083	0.00187	6
ORFORD	1979	18.0	-0.00854	0.00181	6
ORFORD	1979	20.0	-0.00888	0.00355	6
ORFORD	1979	22.0	-0.01166	0.00165	6
ORFORD	1979	24.0	-0.01038	0.00172	5
ORFORD	1979	26.0	-0.01319	0.00327	6
ORFORD	1979	28.0	-0.01704	0.00473	6
ORFORD	1979	30.0	-0.02080	0.00147	6
ORFORD	1979	32.5	-0.01949	0.00345	6
ORFORD	1979	35.0	-0.03238	0.00387	6
ORFORD	1979	37.5	-0.03452	0.00103	6
STOKELY	1979	12.0	-0.02785	0.00190	7
STOKELY	1979	14.0	-0.02698	0.00054	7
STOKELY	1979	16.0	-0.02946	0.00108	7
STOKELY	1979	18.0	-0.02629	0.00103	7
STOKELY	1979	20.0	-0.02731	0.00081	7
STOKELY	1979	22.0	-0.02809	0.00150	7
STOKELY	1979	24.0	-0.02688	0.00153	7
STOKELY	1979	26.0	-0.02776	0.00164	7
STOKELY	1979	28.0	-0.02738	0.00135	7
STOKELY	1979	30.0	-0.02771	0.00168	7
TROITE	1979	7.0	-0.05357	0.01479	7
TROITE	1979	8.0	-0.06466	0.00983	7
TROITE	1979	9.0	-0.04363	0.01871	6
TROITE	1979	10.0	-0.06146	0.01519	7
TROITE	1979	11.0	-0.06581	0.01919	7
TROITE	1979	12.0	-0.06718	0.03397	5
BROMPTON	1980	14.0	-0.04163	0.00090	6
BROMPTON	1980	16.0	-0.04250	0.00173	12
BROMPTON	1980	18.0	-0.04252	0.00263	6
BROMPTON	1980	20.0	-0.04212	0.00188	11
BROMPTON	1980	22.0	-0.04439	0.00171	6
BROMPTON	1980	24.0	-0.04347	0.00111	11
BROMPTON	1980	26.0	-0.04421	0.00177	6
BROMPTON	1980	28.0	-0.04467	0.00134	7
BROMPTON	1980	30.0	-0.04413	0.00114	12
BROMPTON	1980	32.5	-0.04691	0.00088	7
BROMPTON	1980	35.0	-0.04689	0.00157	7
BROMPTON	1980	37.5	-0.04672	0.00106	12
CENTRAL	1980	20.0	-0.03269	0.00299	9
CENTRAL	1980	22.5	-0.03204	0.00339	7
CENTRAL	1980	25.0	-0.02791	0.00297	7
CENTRAL	1980	27.5	-0.02272	0.00173	9
CENTRAL	1980	30.0	-0.01997	0.00164	6
CENTRAL	1980	32.5	-0.02540	0.00281	4
CENTRAL	1980	35.0	-0.01395	0.00097	8

CENTRAL	1980	40.0	-0.01475	0.00158	7
CENTRAL	1980	45.0	-0.01375	0.00143	7
CENTRAL	1980	50.0	-0.01311	0.00136	9
CENTRAL	1980	60.0	-0.01301	0.00141	7
CENTRAL	1980	70.0	-0.01145	0.00085	9
FITCH	1980	12.0	-0.12892	0.00664	15
FITCH	1980	13.0	-0.15527	0.01030	15
FITCH	1980	14.0	-0.17111	0.01349	15
FITCH	1980	15.0	-0.16741	0.01553	11
FITCH	1980	16.0	-0.17187	0.01738	11
LITTLEBRPT	1980	10.0	-0.07624	0.00905	12
LITTLEBRPT	1980	11.0	-0.07518	0.00654	12
LITTLEBRPT	1980	12.0	-0.06745	0.00448	12
LITTLEBRPT	1980	13.0	-0.07101	0.00284	10
LITTLEBRPT	1980	14.0	-0.07890	0.00572	12
LITTLEBRPT	1980	15.0	-0.08639	0.00870	5
LITTLEBRPT	1980	16.0	-0.08969	0.01081	5
LOVERING	1980	14.0	-0.08807	0.00205	9
LOVERING	1980	15.0	-0.08865	0.00151	9
LOVERING	1980	16.0	-0.08942	0.00196	14
LOVERING	1980	17.0	-0.09309	0.00272	12
LOVERING	1980	18.0	-0.09455	0.00344	13
LOVERING	1980	19.0	-0.10083	0.00338	7
LOVERING	1980	20.0	-0.09833	0.00265	13
LOVERING	1980	22.0	-0.10106	0.00388	13
LYSTER	1980	14.0	-0.02950	0.01174	4
LYSTER	1980	16.0	-0.01817	0.00422	10
LYSTER	1980	20.0	-0.02771	0.00195	10
LYSTER	1980	24.0	-0.02395	0.00256	9
LYSTER	1980	26.0	-0.03808	0.00721	4
LYSTER	1980	30.0	-0.03125	0.00404	8
LYSTER	1980	32.5	-0.04322	0.01431	4
LYSTER	1980	35.0	-0.04663	0.01567	4
LYSTER	1980	37.5	-0.03604	0.00815	9
MAGOG	1980	11.0	-0.15885	0.04408	5
MAGOG	1980	12.0	-0.15695	0.01846	8
MAGOG	1980	13.0	-0.16624	0.01316	9
MAGOG	1980	14.0	-0.19090	0.01599	9
MAGOG	1980	15.0	-0.21779	0.01572	9
MAGOG	1980	16.0	-0.22487	0.02166	7
MASSAWIPPI	1980	15.0	-0.03519	0.00143	6
MASSAWIPPI	1980	17.5	-0.03566	0.00216	6
MASSAWIPPI	1980	20.0	-0.03135	0.00113	12
MASSAWIPPI	1980	22.5	-0.02793	0.00150	6
MASSAWIPPI	1980	25.0	-0.02145	0.00198	7
MASSAWIPPI	1980	27.5	-0.01873	0.00075	12
MASSAWIPPI	1980	30.0	-0.01807	0.00188	7
MASSAWIPPI	1980	35.0	-0.01563	0.00081	12
MASSAWIPPI	1980	40.0	-0.01524	0.00261	7
MASSAWIPPI	1980	45.0	-0.01523	0.00167	6
MASSAWIPPI	1980	50.0	-0.01413	0.00125	12
MASSAWIPPI	1980	60.0	-0.01630	0.00176	7
MASSAWIPPI	1980	70.0	-0.01598	0.00166	12
NORTH	1980	14.0	-0.07718	0.00317	7
NORTH	1980	16.0	-0.07957	0.00252	11
NORTH	1980	18.0	-0.08126	0.00225	11
NORTH	1980	20.0	-0.07963	0.00230	11
NORTH	1980	22.0	-0.08220	0.00277	7
NORTH	1980	24.0	-0.08303	0.00332	11
NORTH	1980	26.0	-0.09087	0.00137	7

NORTH	1980	28.0	-0.08777	0.00206	11
ORFORD	1980	12.0	-0.01253	0.01295	9
ORFORD	1980	14.0	-0.00330	0.00443	7
ORFORD	1980	16.0	-0.01496	0.00100	12
ORFORD	1980	18.0	-0.01502	0.00226	6
ORFORD	1980	20.0	-0.01816	0.00179	12
ORFORD	1980	22.0	-0.01557	0.00463	6
ORFORD	1980	24.0	-0.01829	0.00239	11
ORFORD	1980	26.0	-0.01918	0.00548	7
ORFORD	1980	28.0	-0.01927	0.00349	6
ORFORD	1980	30.0	-0.02367	0.00300	12
ORFORD	1980	32.5	-0.01712	0.00786	6
ORFORD	1980	35.0	-0.02901	0.00952	6
ORFORD	1980	37.5	-0.04637	0.00366	12
STUKELY	1980	14.0	-0.03275	0.00121	8
STUKELY	1980	16.0	-0.03255	0.00088	15
STUKELY	1980	18.0	-0.03397	0.00072	15
STUKELY	1980	20.0	-0.03430	0.00096	14
STUKELY	1980	22.0	-0.03464	0.00107	9
STUKELY	1980	24.0	-0.03646	0.00053	14
STUKELY	1980	26.0	-0.03761	0.00114	9
STUKELY	1980	28.0	-0.03870	0.00074	12
STUKELY	1980	30.0	-0.04146	0.00193	9
TROITE	1980	8.0	-0.05846	0.00791	10
TROITE	1980	9.0	-0.05389	0.00686	10
TROITE	1980	10.0	-0.07103	0.00488	11
TROITE	1980	11.0	-0.08975	0.00726	10
TROITE	1980	12.0	-0.10915	0.00886	11
TROITE	1980	13.0	-0.13194	0.00677	8

APPENDIX SEVEN

Summary of estimates of rates of oxygen depletion determined from oxygen concentrations or oxygen isopleths published in the literature. Methods used to calculate various parameters are outlined in Chapter 12. Data are arranged by columns:

1. Lake number.
2. Thickness of stratum.
3. Year of study.
4. Mean depth of lake (m).
5. Phosphorus concentration (ug/L).
6. Calculated retention of phosphorus (mg/m2/yr).
7. Areal water load (m/yr).
8. Depth below lake surface (m).
9. Lake area at upper boundary of the stratum (/10**4).
10. Lake area at lower boundary of the stratum (/10**4).
11. Mean summer temperature (celcius) of stratum.
12. Rate of oxygen depletion (mg/m3/day).
13. Standard error of the rate.

1 1 69 12.3 206 926 1.4 14 1028 0988 11.4 105 4.0
1 1 69 12.3 206 926 1.4 15 0988 0922 11.1 121 2.5
1 1 69 12.3 206 926 1.4 16 0922 0833 10.8 146 2.8
1 1 69 12.3 206 926 1.4 17 0833 0733 10.6 164 12.4
1 1 69 12.3 206 926 1.4 18 0733 0620 10.3 190 9.2
2 2 66 120 150 1140 2.7 9 2550 2400 15.0 164 16.3
2 2 66 120 150 1140 2.7 12 2300 1950 12.5 129 5.4
2 2 66 120 150 1140 2.7 15 1820 1450 11.3 164 7.7
2 2 66 120 150 1140 2.7 18 128 85 10.7 209 6.9
3 2 57 33 24.2 475 10.9 25 5740 5510 8.1 33.8 2.1
3 2 57 33 24.2 475 10.9 35 4375 4050 7.3 30.2 6.5
3 2 57 33 24.2 475 10.9 20 6310 6085 8.8 43.1 8.9
3 2 57 33 24.2 475 10.9 30 5225 4938 7.5 23.9 9.8
3 2 57 33 24.2 475 10.9 45 2900 2610 6.9 . .
4 2 58 33 24.3 477 10.9 25 5740 5510 8.1 17.9 3.2
4 2 58 33 24.3 477 10.9 35 4375 4050 7.3 13.4 4.1
4 2 58 33 24.3 477 10.9 20 6310 6085 8.8 23.6 3.1
4 2 58 33 24.3 477 10.9 60 0635 0300 6.5 67.4 6.3
4 2 58 33 24.3 477 10.9 55 1710 1375 6.6 45.9 11.6
5 2 76 17.8 6.9 108 7.3 10 147.6 134.7 7.9 17.4 2.3
5 2 76 17.8 6.9 108 7.3 15 117.9 107.3 6.2 21.5 3.07
5 2 76 17.8 6.9 108 7.3 20 92.2 83.2 5.5 18.6 1.67
5 2 76 17.8 6.9 108 7.3 30 53.5 46.6 4.7 16.8 1.72
5 2 76 17.8 6.9 108 7.3 35 36.0 29.8 4.5 20.9 1.20
6 2 66 . 21.6 411 10.2 20 134.0 132.2 9.0 25.2 1.48
6 2 66 . 21.6 411 10.2 30 116.8 115.2 6.5 21.7 2.19
6 2 66 . 21.6 411 10.2 40 107.5 104.1 5.4 20.4 2.90
6 2 66 . 21.6 411 10.2 60 050.0 046.6 4.7 20.8 1.52
6 2 66 . 21.6 411 10.2 70 000.6 000 4.5 . 3.43
7 2 67 . 23.8 453 10.2 20 134.0 132.2 8.2 22.1 1.80
7 2 67 . 23.8 453 10.2 30 116.8 115.2 7.0 20.4 0.98
7 2 67 . 23.8 453 10.2 40 107.5 104.1 5.7 17.5 1.03
7 2 67 . 23.8 453 10.2 60 50.0 46.6 4.8 20.2 1.04
7 2 67 . 23.8 453 10.2 70 00.6 0.0 4.7 . 3.85
8 2 69 . 26.5 505 10.2 20 134 132.2 9.1 25.0 0.52
8 2 69 . 26.5 505 10.2 30 116.8 115.2 7.1 24.5 0.80
8 2 69 . 26.5 505 10.2 40 107.5 104.1 6.1 20.5 1.00
8 2 69 . 26.5 505 10.2 60 050.0 046.6 5.2 15.5 .60
8 2 69 . 26.5 505 10.2 70 000.6 000.0 5.1 . 0.12
9 2 72 101 10.5 323 71.7 20 2240 2220 10.3 22.2 2.41
9 2 72 101 10.5 323 71.1 30 2140 2122 7.7 15.2 3.79
9 2 72 101 10.5 323 71.7 40 2044 2028 6.8 4.7 4.36
9 2 72 101 10.5 323 71.7 80 1748 1728 5.3 7.4 3.06
9 2 72 101 10.5 323 71.7 120 1221 1178 5.2 5.9 1.59
10 2 73 101 13.7 421 71.7 20 2240 2220 9.3 23.2 0.46
10 2 73 101 13.7 421 71.7 30 2140 2122 7.3 18.3 0.83
10 2 73 101 13.7 421 71.7 40 2044 2028 6.3 13.1 0.16
10 2 73 101 13.7 421 71.7 80 1748 1728 5.2 9.1 0.42
10 2 73 101 13.7 421 71.7 120 1221 1178 5.1 9.3 1.56
11 2 74 101 17.8 547 71.7 20 2240 2220 9.4 19.1 4.80
11 2 74 101 17.8 547 71.7 30 2140 2122 7.8 14.8 3.51
11 2 74 101 17.8 547 71.7 40 2044 2028 6.2 10.4 4.02
11 2 74 101 17.8 547 71.7 120 1221 1178 5.1 11.9 2.07
11 2 74 101 17.8 547 71.7 80 1748 1728 5.2 9.4 4.81
12 1 69 7.0 42 420 3.8 10.5 1550 1340 9.2 84.6 8.7
12 1 69 7.0 42 420 3.8 115 1340 1140 8.8 93.3 14.9
12 1 69 7.0 42 420 3.8 125 1140 0913 8.4 106 13.8
12 1 69 7.0 42 420 3.8 135 0913 0561 8.1 125 12.4
12 1 69 7.0 42 420 3.8 14.5 0561 0136 8.0 153 13.5
13 1 70 7.0 39 390 3.8 10.5 1550 1340 9.2 73.9 3.8

13 1 70 7.0 39 390 3.8 11.5 1340 1140 8.8 71.3 6.1
13 1 70 7.0 39 390 3.8 12.5 1140 0913 8.4 77.1 8.3
13 1 70 7.0 39 390 3.8 13.5 0913 0516 8.1 87.7 8.5
13 1 70 7.0 39 390 3.8 14.5 0561 0136 8.0 93.1 7.3
14 1 73 7.0 33 330 3.8 10.5 1550 1340 11.3 87.1 8.0
14 1 73 7.0 33 330 3.8 11.5 1340 1140 10.8 81.6 15.4
14 1 73 7.0 33 330 3.8 12.5 1140 0913 10.5 84 16.4
15 1 74 7.0 25 250 3.8 10.5 1550 1340 9.1 100 13.1
15 1 74 7.0 25 250 3.8 11.5 1340 1140 8.4 98.9 12.4
15 1 74 7.0 25 250 3.8 12.5 1140 0913 8.0 112 5.2
15 1 74 7.0 25 250 3.8 13.5 0913 0561 7.6 128 7.6
15 1 74 7.0 25 250 3.8 14.5 0561 0136 7.4 139 10.8
16 2 74 71 9.1 35 436 60 3353 3267 5.2 5.2 .61
16 2 74 71 9.1 35 436 70 2913 2828 4.8 5.4 .55
16 2 74 71 9.1 35 436 80 2492 2400 4.7 6.3 .25
16 2 74 71 9.1 35 436 100 1481 1372 4.6 7.6 1.12
16 2 74 71 9.1 35 436 120 0517 0456 4.4 10.4 1.3
17 2 65 18. 28 280 3.8 15 1228 1124 10.0 77.0 5.01
17 2 65 18 28 280 3.8 10 938 822 9.5 88.3 7.04
17 2 65 18 28 280 3.8 7.5 798 602 9.3 98.5 3.97
17 2 65 18 28 280 3.8 5.0 528 480 9.1 94.0 5.2
17 2 65 18 28 280 3.8 2.5 230 078 9.0 91.2 4.99
18 2 71 . 24 473 192 14 0127 0117 7.8 60 0.2
18 2 71 . 24 473 192 21 092.1 084.0 6.9 60 0.2
18 2 71 . 24 473 192 30 018.0 006.8 6.2 100 0.2
19 2 73 13.6 19 334 8.8 10 035.7 31.8 5.4 40.0 7.38
19 2 73 13.6 19 334 8.8 15 26.0 22.4 4.1 35.3 6.10
19 2 73 13.6 19 334 8.8 20 16.6 12.6 4.0 40.4 7.99
19 2 73 13.6 19 334 8.8 25 6.3 3.5 4.0 47.6 10.6
19 2 73 13.6 19 334 8.8 30 1.8 .88 4.0 51.8 10.5
20 2 73 13.9 12.5 131 4.0 10 45.5 40.1 6.3 22.5 7.31
20 2 73 13.9 12.5 131 4.0 15 33.9 30.8 5.0 24.4 8.97
20 2 73 13.9 12.5 131 4.0 20 26.1 21.7 4.0 29.7 7.92
20 2 73 13.9 12.5 131 4.0 25 14.0 10.1 4.0 35.3 6.36
20 2 73 13.9 12.5 131 4.0 30 06.2 4.0 4.0 35.9 6.22
21 1 69 9.2 3.9 22 1.8 15 27.6 23.7 9.4 . 10
21 1 69 9.2 3.9 22 1.8 18 13.9 09.2 9.2 . 10
21 1 69 9.2 3.9 22 1.8 19 09.2 05.57 9.2 . 10
21 1 69 9.2 3.9 22 1.8 20 5.57 3.48 9.2 . 10
22 1 69 2.4 7.0 94.2 5.7 7 .836 .657 7.7 71.5 10
22 1 69 2.4 7.0 94.2 5.7 10 .269 0 7.2 87.7 3
23 1 69 7.0 9.6 240 145 7 .478 .443 9.2 45.4 4.67
23 1 69 7.0 9.6 240 145 10 .370 .325 7.7 92.8 10.8
24 .91 68 . 10 298 88.5 7.3 7.60 6.00 8.50 57.7 4.07
24 .91 68 . 10 298 88.5 8.2 6.00 4.05 7.8 48.7 3.31
24 .91 68 . 10 298 88.5 9.1 4.05 2.52 7.0 46.8 4.89
24 .91 68 . 10 298 88.5 10 2.52 .80 6.7 50.7 6.75
25 .91 68 . 8.6 108 5.2 . 14.7 12.1 9.0 43.9 4.33
25 .91 68 . 8.6 108 5.2 . 12.1 10.4 7.8 43.9 2.28
25 .91 68 . 8.6 108 5.2 . 10.4 8.9 7.1 41.6 1.7
25 .91 68 . 8.6 108 5.2 . 8.9 7.1 6.6 39.8 6.27
25 .91 68 . 8.6 108 5.2 . 7.1 4.8 6.2 45.7 6.37
26 .91 68 . 9.6 181 10.0 . 21.4 19.9 9.7 54.4 4.27
26 .91 68 . 9.6 181 10.0 . 18.4 16.8 7.1 34.2 3.65
26 .91 68 . 9.6 181 10.0 . 15.4 14.2 6.2 22.6 5.04
26 .91 68 . 9.6 181 10.0 . 10.1 8.2 5.4 32.5 3.42
26 .91 68 . 9.6 181 10.0 . 2.6 .93 5.2 60.2 2.30
27 .91 68 . 12.1 290 16.8 . 15.6 14.0 7.8 34.0 3.25
27 .91 68 . 12.1 290 16.8 . 12.4 11.0 6.3 28.7 3.62
27 .91 68 . 12.1 290 16.8 . 11.0 9.7 5.9 23.5 1.12

27	.91	68	.	12.1	290	16.8	.	8.75	8.10	5.4	26.9	2.76
27	.91	68	.	12.1	290	16.8	.	6.90	5.00	5.2	37.9	6.74
29	2	69	.	7.0	198	28.5	.	76.0	65.0	7.6	32.3	4.21
29	2	69	.	7.0	198	28.5	.	65.0	55.0	6.8	37.7	4.59
29	2	69	.	7.0	198	28.5	.	55.0	43.0	6.2	51.6	3.16
29	2	69	.	7.0	198	28.5	.	43.0	25.5	6.0	63.8	5.75
29	2	69	.	7.0	198	28.5	.	25.5	1.0	5.8	82.9	12.7
30	2	69	.	7.7	165	13.0	.	90.0	77.5	9.4	43.8	7.1
30	2	69	.	7.7	165	13.0	.	77.5	62.5	8.9	52.6	6.2
30	2	69	.	7.7	165	13.0	.	62.5	42.0	8.5	55.4	5.1
30	2	69	.	7.7	165	13.0	.	42.0	23.0	8.3	64.8	8.5
30	2	69	.	7.7	165	13.0	.	23.0	1.0	7.9	69.6	10.7

APPENDIX EIGHT

Raw data used to calculate the relationship between the gradient in oxygen concentration and phosphorus concentration and Zu-Zmax that was presented in Chapter 9 (Equation 4). The data are arranged in columns as follows:

1. Lake name
2. dO2/dz value in mg O2/m4 calculated as outlined in Chapter 9.
3. Phosphorus concentration in ug/L
4. Mean depth of the lake in metres.
5. Zu-Zmax in metres.
6. Year of study.

The sources of the literature data used in this analysis are the same as those given in Chapter 8. Additional data from Lake Mendota from Stewart (1975) and data from Lake Okoboji (Jones and Bachman 1974).

JERRY	-334	19.0	13.6	26	1973
HARP	-320	13.9	12.5	31	1973
ESROM	-650	206.	12.3	9	1969
MENDOTA	-346	150.	12.0	14	1966
BLUEHILL	70	3.9	9.2	10	1969
YUDLE NORTH	-400	7.0	2.4	5	1969
MICHIN	-522	9.6	7.0	6	1969
HOWRE BUCHT	- 45	21.6	50.2	52	1966
HOWRE BUCHT	- 40	23.8	50.2	52	1967
HOWRE BUCHT	- 28	26.5	50.2	52	1969
SAMMAMISH	-315	28.0	18.0	17	1965
WEST OKOBOJI	-192	28.1	13.7	22	1973
WALENSEE	- 3	10.5	101.	125	1972
WALENSEE	- 30	13.7	101.	125	1973
WALENSEE	- 12	17.8	101.	125	1974
BROMPTON	44	7.0	11.9	30	1979
CENTRAL	121	10.5	46.3	86	1979
FITCH	-591	12.1	10.0	5	1979
MAGOG	-435	39.8	8.2	7	1979
LOVERING	-204	8.5	8.5	12	1979
LYSTER	78	5.1	19.2	38	1979
MASS	79	10.5	37.2	75	1979
NORTH	-248	10.1	15.4	20	1979
STUKELY	82	3.9	11.6	21	1979
TRUITE	-795	9.4	5.2	7	1979
BROMPTON	- 44	7.1	11.9	29	1980
CENTRAL	66	12.0	46.3	87	1980
FITCH	-580	15.9	10.0	5	1980
LITTLE BROMPTON	-252	7.9	6.6	8	1980

MAGOG	-229	59.2	8.2	5	1980
LOVERING	-309	8.7	8.5	12	1980
LYSTER	44	5.0	19.2	38	1980
MASSAWIPPI	14	10.9	37.2	75	1980
NORTH	-164	9.7	15.4	19	1980
STUKELY	51	4.7	11.6	21	1980
TRUITE	-355	8.5	5.2	6	1980

APPENDIX NINE

Literature data sets used to analyze the relationships of the AHOD with phosphorus concentration, secchi depth, primary productivity, lake depth, and hypolimnetic temperature. These data sets were used by Cornett and Rigler (1980). The units and symbols used in the tables are:

AHOD - areal hypolimnetic oxygen deficit (mg/m2/d)

P - phosphorus concnetration (ug/L)

Z - mean lake depth (m)

SECCHI - meanseechi depth (m)

ZH - mean thickness of the hypolimnion (m)

AH - area of the upper boundary of the hypolimnion (m2)

PP - areal pelagic primary productivity (g Carbon/m2/a)

TH - mean summer hypolimnetic temperature (C).

LAKE NAME	AHOD	P	Z	SECCHI	SOURCE
CALHOUN	1800	106	10.6	2.1	Rast and Lee (1978)
CANADARAGO	1050	50	7.7	1.8	
HARRIET	810	62	8.8	2.4	
EAST TWIN 72	600	80	5.0	1.6	
EAST TWIN 73	362	80	5.0	2.3	
EAST TWIN 74	300	80	5.0	1.9	
WEST TWIN 72	523	120	4.3	2.2	
WEST TWIN 73	558	110	4.3	2.8	
WEST TWIN 74	223	100	4.3	2.3	
WASHINGTON 66	690	66	33	1.2	
WASHINGTON 74	880	-	33	3.8	
STONEY	580	24	6.0	4.6	Nicholls (1975)
ESROM 69	1000	209	12.3	3.2	Hargrave (1971)
MENDOTA 65	979	150	12.	2.3	Stewart (1975)
HORWRE BUCHT 66	800	21.6	42.6	3.0	von Zimmerman (1969)
HORWRE BUCHT 67	514	23.8	42.6	3.0	
HORWRE BUCHT 69	740	26.5	42.6	3.0	
KAMLOOPS	230	8.9	71.	8.3	St. John (1976)
SAMMAMISH	500	31.	18.	3.3	Emery et al (1975)
ERIE (EASTERN)	613	16	24.4	4.0	Burns (1976)
ERIE (CENTRAL)	380	19	18.3	4.5	
WALENSEE 72	1200	17.3	101	4.7	von Zimmerman (1977)
WALENSEE 73	800	22.1	101	3.5	
WALENSEE 74	900	24.6	101	3.1	
GRAVENHURST BAY 69	530	42	7.6	2.6	Dillon et al (1978)
GRAVENHURST BAY 70	470	39	7.6	3.1	
GRAVENHURST BAY 73	320	33	7.6	3.2	

GRAVENHURST BAY 74	430	25	7.6	2.7	
GRAVENHURST BAY 75	250	20	7.6	3.9	
HARP	340	12.5	13.9	4.3	Nichols (1976)
JERRY	342	19	13.6	3.9	
SAMMAMISH	530	28	18.	3.3	Rast and Lee (1978)
OKOBOJI	833	30	11.9	5.9	Jones and Bachman (1974)
WASHINGTON 57	812	24.2	33.	2.2	Edmondson (1962)
WASHINGTON 58	820	24.3	33.	2.2	
WASHINGTON 62	710	57	33.	1.2	Edmondson (1966)
WASHINGTON 63	570	66	33.	1.0	
WASHINGTON 64	783	59.3	33.	1.0	
NELSON(MAIN)	180	5.0	11.6	-	Dillon et al (1978)
NELSON (NORTH)	150	5.0	9.8	-	
CLEARWATER	220	5.0	8.1	-	
CRANBERRY	60	9.7	3.5	5.4	Lasenby (1975)
GREEN	160	11.7	6.1	5.3	
TWELVE MILE	170	6.6	11.5	6.0	
EAGLE	180	7.4	7.9	6.2	
BOSHKUNG	190	5.9	23.4	6.4	
BOB	230	8.5	18.	5.9	
MOOSE	270	6.8	16.6	6.1	
PINE	270	10.5	7.4	5.5	
FOUR MILE	300	12.0	9.3	5.5	
HALIBURTON	310	5.2	19.6	6.3	
BEECH	360	9.2	9.8	4.9	
MAPLE	380	9.3	11.6	5.2	
HALLS	130	4.1	27.2	8.7	
OKATAINA	460	18.	45.5	11.0	Fish (1970)
ROTOMA	910	12.	38.2	10.6	

TIKITAPU	77	7.0	19	11.0	
OKAREKA	280	15.	18.4	7.4	
ROTAKAKAHI	650	25.	17.6	7.6	Stockner and
NGAPOURI	1060	50.	12.1	2.0	Northcote (1974)
OKARO	580	90.	11.1	2.5	
WOOD	650	293.	22.	2.5	
OSOYOOS	380	62.	26.	3.3	
SKAHA	1480	64.	21.	4.5	
ELA 239	260	3.5	10.6	4.0	Schindler (1971)
ELA 240	126	-	6.1	3.7	
ELA 305	241	5.0	15.1	7.3	
BLUEHILL SOUTH	111	-	9.2	5.9	Kerekes (1974)
MICHIN	224	-	7.0	4.2	
YUDLE NORTH	217	-	2.4	4.2	
LAWRENCE 68	66	-	5.9	5.3	Wetzel et al (1972)
ZURICHSEE	1800	-	50.	4.0	von Zimmerman (1975)
ZURICHSEE	1500	-	50.	5.1	
1	317	11.7	6.9	5.7	Deevey (1940)
2	354	11.	9.9	6.3	
3	307	8.4	11.1	5.8	
5	150	9.0	5.7	5.5	
9	194	12.	6.5	5.5	
11	188	10.	15.2	6.9	
12	182	14.	5.8	2.7	
14	236	7.0	8.7	7.4	
23	247	17.	6.6	3.8	
28	273	10.	5.1	3.8	
29	418	21.	6.7	2.6	
30	169	5.0	4.5	3.5	

31	276	5.0	8.4	5.5
32	252	11.	6.7	4.0
36	255	11.	8.8	6.1
39	119	14.	3.8	5.7
42	128	17	5.0	6.2
46	310	8.0	5.9	5.2
48	202	14.	3.9	4.0
49	184	8.0	4.2	4.0

DATA OF BIRGE AND JUDAY (1911)

LAKE NAME	ZH	AHOD	AH
BEASLEY 07	2.5	372	17e3
BEASLEY 09	2.5	500	17e3
ELKHART 06	10.9	689	58e4
LONG 07	6.1	891	20e4
LONG 09	4.3	550	20e4
OKAUCHEE 06	9.6	860	127e4
RAINBOW 07	7.3	640	32e4
RAINBOW 09	7.3	750	32e4
GREEN 06	30.3	1040	179e5
GENEVA 06	13.2	960	135e5
GENEVA 09	13.2	1036	135e5
MOUSE 07	3.2	424	125e3
NORTH (EAST) 06	7.3	702	82e4
NORTH (WEST) 06	6.3	516	276e3
NORTH (WEST) 07	6.3	695	276e3
NORTH (EAST) 07	7.3	728	818e3

AHOD AND PRIMARY PRODUCTIVITY DATA

LAKE NAME	AHOD	PP	ZH	TH	SOURCE
ELA 239	260	110	10.5	4.8	Schindler (1971)
ELA 240	126	101	2.1	7.4	and Reid et al
ELA 305	241	157	9.6	5.6	
KAMLOOPS	255	32	35.4	4.8	St. John (1976)
WASHINGTON 64	690	766	23.	7.5	Rast and Lee (1978)
WASHINGTON74	540	103	23.	7.5	
OLIN	428	136	7.2	5.8	
CONADARAGO	1010	189	1.7	13.7	
MENDOTA	797	1100	6.1	11.2	
SAMMAMISH	530	238	9.5	9.9	
EAST TWIN	300	474	1.0	9.8	
WEST TWIN	223	576	1.0	8.0	
OLIVER	569	123	7.1	7.9	Wetzel (1966)
MEMPHREMAGOG	851	180	46.3	4.6	Ross and Kalff (1975)
ERIE (EAST)	613	175	13.4	6.0	Burns and Ross (1972) and
ERIE (CENTRAL)	380	230	3.34	9.6	Vollenweider et al (1974)
HORWRE BUCHT	740	415	22.4	6.0	Bloesch et al (1977)
ESROM	653	200	5.14	10.6	Jonasson (1972)
MIRROR	146	78	1.8	7.5	Rich and Devol (1978)
LAWRENCE	66	43	1.9	9.5	Wetzel et al (1972)