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A Methodology to Estimate Global Climate Change Impacts on Lake and Stream Environmental Conditions and Fishery Resources with Application to Minnesota

by

H. G. Stefan, M. Hondzo, B. Sinokrot, X. Fang
University of Minnesota
St. Anthony Falls Hydraulic Laboratory
Minneapolis, Minnesota 55414

in cooperation with
J. G. Eaton, B. E. Goodno, K.E.F. Hokanson, J. H. McCormick
D. G. O'Brien, and J. A. Wisniewski
Environmental Research Laboratory
U. S. Environmental Protection Agency
Duluth, Minnesota

for

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ABSTRACT

The effects of global climate were projected on the distribution and growth potential of common freshwater fishes in 5 streams and 27 classes of lakes in Minnesota. The method developed for this analysis uses laboratory growth and mortality data, and a stream temperature–fish distribution database, to define temperature responses for 32 fish species. Sensitivity to depressed dissolved oxygen concentrations was derived from information presented in the U.S. EPA ambient water quality criteria document on oxygen. Stream and lake water temperatures and lake dissolved oxygen concentrations are simulated by one–dimensional, unsteady heat and oxygen transport models operating on a timestep of one day. Simulations are made for a 25–year historical period (1955–80) and projected steady–state future climate simulated by general circulation models assuming a doubling of atmospheric CO_2. Water temperature and dissolved oxygen (D.O.) concentrations simulated for streams and lakes are then compared to "critical" values for presence (survival) or "good" growth (time of exposure to temperatures permitting rapid growth) of a fish species or guild. The results project expected impacts on representative Minnesota streams, while the lake results represent a regional analysis for the state as a whole.

The following conclusions stand out among the many study results. In wide, essentially unshaded streams, global warming is expected to contribute to elimination of coldwater fishes and some coolwater fishes in many habitats where they were formerly present. Warmwater fishes will gain substantially more potential for good growth than existed previously. Coldwater fishes will have a chance for continued existence only in those streams with adequate shading by riparian trees.

Coldwater fishes will have the best chance to survive in deep lakes located in the northern half of the state, but there will be a loss in habitat for good growth. Warmwater fishes will gain habitat for good growth in virtually all types of lakes. Coolwater fishes will gain habitat enabling good growth in most types of lakes. Losses or gains in good growth potential due to global warming are projected to be larger in deep lakes than in shallow ones. The trophic state of the water body will also have an influence on the response of indigenous fishes to climate change. In shallow lakes, trophic state is projected to have little effect on the influence of global warming on habitat suitability for fishes. In deeper, seasonally stratified eutrophic lakes losses or gains of habitat for good growth are projected to be smaller than in oligotrophic lakes of the same size and depth. Lake size and depth are of importance as they affect seasonal stratification of water temperature and dissolved oxygen.

Dissolved oxygen limitations are more serious in eutrophic lakes than in oligotrophic lakes. They are also more apparent in deep lakes than in shallow ones. Climate change is projected to worsen availability of habitats for good growth due to oxygen limitations.

For the state as a whole, the potentital for good growth of lake dwelling, coolwater fishes is projected to increase by 20 percent and for warmwater fishes by 53 percent. Coldwater species will lose 40 percent of their habitat suitable for good growth. The total habitat for good growth of Minnesota lake fishes, regardless of guild designation, is projected to increase by 6 percent.

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Symbols and Acronyms and Their Definitions

(a) Thermal Habitat

SCB = Earliest Julian date when the lowest temperature in a stream or in a vertical lake temperature profile exceeds the upper 95% FTDMS[1] temperature. This is an avoidance temperature or distribution limit. Herein it is also referred to as survival temperature.

SCE = Latest Julian date when the lowest temperature in a stream or in a vertical lake temperature profile exceeds the survival temperature.

SCL = Total number of days when the lowest temperature in a stream or in a lake temperature profile exceeds the survival temperature = length of time that temperature exceeds 95% FTDMS limit (days).

GSB = Earliest Julian date when any stream temperature or any value in the vertical lake temperature profile exceeds the lower bound good growth temperature. This is the beginning date of the good growth period. Good growth is defined in Appendix A.

GSE = Latest Julian date when any stream temperature or any value in the vertical lake temperature profile exceeds the lower bound growth temperature. This is the end of the good growth period.

GSL = Total number of days when stream temperature or temperature at any depth in the lake temperature profile falls between the lower and upper bound growth temperature. This is the length of the good growth period = length of time that temperature is within the range of good growth values (days).

GZER = Total number of days when stream temperature or the lowest temperature in the lake temperature profile exceeds the upper bound growth temperature. This is the midsummer reduced growth potential and stress (or even death), period, which includes non–survival SCL = length of time that upper good growth limit is exceeded (days).

R = Ratio of GSL over GZER. Measures length of good growth period to length of the midsummer period of stress which includes reduced growth, and can include non–survival period (SCL). Non–survival makes this and other parameters irrelevant, of course.

ΣZ^*jd = Integration of depths over time for those depths (m) and times (days) where and when water temperatures are within the upper and lower good growth temperature limits. Integration begins at the first exceedance of the lower growth limit. This is the summation of possible good growth depths over growing season.

$\Sigma \frac{Z^*jd}{Zm^*GSL}$ = Previous integration normalized by maximum lake depth Zm and length of good growing season GSL. Indicates what fraction of the maximum depth would be available for good growth during the entire growing season in a lake. Range of values from 0 to 1.

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[1]FTDMS, see page ix, table (d).

(a) Thermal Habitat (Cont'd)

$\Sigma \frac{Vol*jd}{A_S}$ = Integration of volumes over time for those volumes (m3) and times (days) where and when water temperatures are within the upper and lower good growth temperature limits. Integration begins at the first exceedance of the lower growth limit. This is the summation of possible good growth volumes over growing season divided by surface area.

$\Sigma \frac{Vol*jd}{Vtot*GSL}$ = Previous integration normalized by average depth (Vtot/A) and length of growing season GSL. Indicates what fraction of average depth would be available for good growth during the entire growing season. Range of values from 0 to 1.

A_S = Lake surface water

jd = Timestep for integration (jd=1 day)

Z_m = Maximum lake depth.

V_{tot} = total lake volume

Z = Depth

(b) Dissolved Oxygen (D.O.) Limited Habitat

DOB = Earliest Julian date when DO at some depth in a vertical lake DO profile is lower than the DO survival limit for fish.

DOE = Latest Julian date when DO at some depth in a vertical lake DO profile is lower than the DO survival limit for fish.

DOL = Total days between earliest and latest date of DO limitation, i.e. DO at some depth in vertical lake DO profile is lower than the survival limit for fish.

VDO = Lake volume without DO limitation.

TL = Total length of simulation season (Mar 1 – Nov 30) = 275 days

z*jd = Integration of depths over time for those depths (m) and time (days) where and when DO at some depth in vertical lake DO profile is larger than the DO survival limit. Integration begins on March 1 and ends Nov. 30. This is the summation of depths without DO limitation over a season.

$\Sigma \frac{z*jd}{zm*TL}$ = Previous integration normalized by maximum lake depth and length of the entire season TL. Indicates what fraction of the maximum depth is above the DO limitation during the entire season. Range of values from 0 to 1.

$\Sigma \frac{VDO*jd}{As}$ = Integration of volumes over time for those volumes (m3) and time (days) where and when DO in vertical lake DO profile is larger than the DO survival limit. Integration begins on March 1 and ends Nov. 30. This is the summation of volumes without DO limitation over a season divided by surface area.

$\Sigma \frac{VDO*jd}{Vtot*TL}$ = Previous integration normalized by average depth (Vtot/As) and length of the entire season TL. Indicates that fractions of the total lake volume which is available without DO limitation during the entire season. Range of values from 0 to 1.

(c) Thermal and Dissolved Oxygen Limited Habitat

The parameter definitions are the same as for the thermal habitat, except that instead of maximum lake depth the depth at which dissolved oxygen (DO) equals the DO survival limit is taken to be the useful lake depth. Lake water temperatures and volumes below that depth are ignored.

NSB = Earliest Julian date when in the vertical lake profile either temperature or dissolved oxygen simultaneously do not meet the survival limits at any depth.

NSE = Latest Julian date when in the vertical lake profile temperature or dissolved oxygen simultaneously do not meet the survival limits at any depth.

NSL = Total number of days when in the vertical lake profile temperature or dissolved oxygen simultaneously do not meet the survival limits. Defines length of yearly period of no survival = length of time that fish distribution limits are not met.

GSB = Earliest Julian date when simultaneously any value of temperature exceeds the lower good growth bound in the vertical lake temperature profile and dissolved oxygen exceeds the dissolved oxygen limit in the dissolved oxygen profile.

GSE = Latest Julian date when simultaneously any value of temperature exceeds the lower good growth bound in the vertical lake temperature profile and dissolved oxygen exceeds the dissolved oxygen limit in the dissolved oxygen profile.

GSL = Total number of days when simultaneously any value of temperature is between the lower and upper good growth bound in the vertical lake temperature profile and dissolved oxygen exceeds the limit in the dissolved oxygen profile = length of the good growth season.

GZER = Total number of days when simultaneously the upper limit for good growth temperature and dissolved oxygen survival limits are exceeded by the lowest temperature and dissolved oxygen in the lake profile. This is the midsummer period of reduced growth potential, stress and possible death. It includes the NSL period.

R = Ratio of GSL over GZER. Measures length of good growth period to length of the midsummer period of stress which includes reduced growth, and can include non–survival period (NSL). Non–survival makes this and other parameters irrelevant, of course.

Σ z*jd = Integration of depths over time for those depths (m) and times (days) where and when water temperatures are within the upper and lower good growth temperature limits and dissolved oxygen is greater than survival limit. Integration begins at the first exceedance of the lower growth limit and dissolved oxygen survival limit. This is the summation of possible good growth depths over growing season.

(c) Thermal and Dissolved Oxygen Limited Habitat (Cont'd)

$\Sigma \frac{Z^{*}jd}{Zm^{*}GSL}$ = Preceding parameter normalized by maximum lake depth Zm and length of growing season GSL. Indicates what fraction of the maximum depth would be available for good growth during the entire growing season. Range of values from 0 to 1.

$\Sigma \frac{Vol^{*}jd}{A}$ = Integration of volumes over time for those volumes (m3) and times (days) where and when water temperatures are within the upper and lower good growth temperature limits and dissolved oxygen is greater than survival limit. Integration begins at the first exceedance of the lower good growth limit and dissolved oxygen survival limit. This is the summation of possible good growth volumes over a growing season.

$\Sigma \frac{Vol^{*}jd}{Vtot^{*}GSL}$ = Preceding parameter normalized by average depth ($Vtot/A_s$) and length of the good growth season GSL. Indicates what fraction of average depth would be available for good growth during the entire good growing season. Range of values from 0 to 1.

(d) Other Acronyms

FTDMS = Fish Temperature Database Management System (EPA/Environmental Research Laboratory, Duluth). See p. 4.
GCC = Global Climate Change.
GCM = Global Circulation Model.
GFDL = Geophysical Fluid Dynamics Laboratory, Princeton, University
GIS = Geographic Information System.
GISS = Goddard Institute for Space Studies.
MLFD = Minnesota Lake Fisheries Database (Minnesota Department of Natural Resources, Div. of Fisheries and EPA/ERLD).
OSU = Oregon State University
PAST = Period from 1955 to 1979.
UKMO = United Kingdom Model.
UUILT = Ultimate upper incipient lethal temperature.
UZNG = Upper zero net growth.

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1. INTRODUCTION

A 1979 report on carbon dioxide and climate by the U.S. National Academy of Sciences concluded that doubling ambient CO_2 concentrations could increase global mean air temperatures by 1.5 to 4.5°C in approximately the next half century. This "greenhouse effect" projection has been reinforced by the development of several general circulation models (GCM) of ocean atmosphere heat budgets and other analyses producing similar temperature change estimates (Bolin and Doos 1986). Recognition that such changes are occurring many times faster than the background rate and might have severe and unexpected consequences (Harrington 1987, Schneider 1989, NAS 1988, Houghton et al., 1989) has led to requests for information on causes, effects and mitigation or accommodation possibilities. One such request by the Senate Environment and Public Works Committee resulted in the 1988 EPA, OPPE and ORD report to Congress on "The Potential Effects of Global Climate Change on the United States."

To follow up on this report the University of Minnesota and the Environmental Research Laboratory–Duluth initiated a cooperative investigation to determine the impacts of global warming on lake and stream environmental conditions and concomitant fishery resources. The project has been underway for two years and has the long–range goal of providing a region by region analysis of the projected effects of climate change, associated with doubling atmospheric CO_2, on aquatic resources in the U.S. The program will also suggest resource management implications and response options to the expected changes.

Minnesota was selected as the pilot area because of the known quality and accessibility of historical weather data, water body physical characteristics data, and fishery resources databases. Minnesota's more than 10,000 lakes and many streams are the basis of a tourism industry which produces revenues on the same order as manufacturing or agriculture. Fishing is an important recreational activity in Minnesota. Because of its northern latitude, Minnesota is expected to be heavily influenced by global warming. The results of this analysis consist of changes projected for all the lakes of the state and for a cross section of state stream types. The models, databases, and assessment techniques employed can serve as templates for conducting analyses of impacts on other regions of the U.S.

The investigation is especially informative because fisheries responses are assessed in relation to a more detailed analysis of the effects of climate change on aquatic environmental conditions than has previously been attempted. The basic interactions which are considered are indicated in Fig. 1. The more detailed information flow is indicated in Fig. 2. Researchers at the University of Minnesota have conducted extensive investigations of the effects of external environmental conditions on the temperature, dissolved oxygen concentration, and productivity of aquatic ecosystems. As a consequence, deterministic, physics–based mathematical models are available

to perform simulations of surface water environmental conditions for various climate change scenarios.

Outputs from the water quality modeling are interfaced with temperature and dissolved oxygen sensitivity data for North American freshwater fishes. Habitat space for fish species is most often constrained by extreme temperatures and low dissolved oxygen concentrations. The EPA Duluth Environmental Research Laboratory has conducted tests and compiled data on these limiting factors from many sources. Empirical models relating distributions of 30 fish species to surface water temperatures are available. The importance of other factors interacting with climate change to influence species distributions will also be discussed.

Climate change impacts are measured in terms of habitat space available for survival and for growth throughout the ice–free season. All analyses and simulations are therefore made for the period from March 1 to November 30. Temperature and dissolved oxygen are considered as the two most significant water quality parameters influenced by climate change, and both control survival and growth of fishes. The deterioration of fish habitat for certain species of fishes and the improvement for others are assessed in terms of only these two parameters. The results indicate which fishes can be expected in 27 classes of lakes and five different stream habitats before and after climate change, as well as effects on potential production and yield. Not included in this study are secondary effects of climate change such as loss of food supply, invasion of predators, changes in flow regimes, etc.

2. FISH THERMAL AND DISSOLVED OXYGEN REQUIREMENTS

2.1. Concepts

Surface water temperatures within the United States limit the southern distributions of cold and coolwater stream fishes and northern distribution of warm water fishes. Changes in the distribution of thermal guilds with rising surface water temperatures is the most likely serious consequence of global warming. Increases in surface water temperature would be expected to cause guild succession from coldwater, to coolwater, to warmwater forms. Loss of habitat for cold and coolwater fishes may be a significant impact of climate change in the United States and may have its greatest impact at higher latitudes and altitudes. Warmwater fishes could tolerate modest increases in surface water temperatures.

Analysis of climate change impacts on fishes is based on a temperature classification scheme that recognizes three limits of thermal requirements for growth and survival and three patterns of gonadal development for temperate stenotherm (coldwater), temperate mesotherm (coolwater), and temperate eurytherm (warmwater) fishes (Hokanson, 1990). The empirical model relating fish distribution to water temperature is developed from stream data, but Hokanson et al. (1991) have proposed that the temperature regimen for a given thermal guild can also be used to describe the thermal niche within stratified water bodies.

In this study we forecast changes in thermal guilds because other niche requirements (i.e. available food and reproductive conditions, competitive or predatory relationships, etc.) are not well enough known or predictable for any given water body to determine the future presence or absence of individual fish species.

A second important aspect of the problem is the effect of climate change on dissolved oxygen. Not only do saturation values for D.O. vary with water temperature, but virtually all processes which add oxygen to water (reaeration, photosynthesis) or take dissolved oxygen out of the water (respiration, biochemical oxygen demand) are temperature dependent. Furthermore, dissolved oxygen distribution in a surface water body depends strongly on mixing characteristics. In lakes, these mixing characteristics may be affected by weather changes.

By late summer, downward warming and upward deoxygenation in the hypolimnion can be so extensive in eutrophic water bodies that the thermal limit to distribution of a cold or cool water species or guild and the dissolved oxygen limit to distribution may approach one another or overlap in major portions of the basin. The volume of suitable habitat is thus reduced or eliminated and fish must move to restricted zones or refugia that maintain adequately cool and oxygenated water or be eliminated. When these refuges are not available, or are too small to contain the number of

fish present, mortality rates exceed growth rates and attrition of population biomass of that species or thermal guild occurs. Coutant (1987) has documented such habitat reduction for striped bass in reservoirs and has projected range changes with climate change for this species along the east coast of the U.S. (Coutant, 1990). Changes in the temperature and dissolved oxygen profiles of water bodies with climate change projections are a basis for forecasting changes in the distribution or well–being of temperate climate fish fauna in lakes. Habitat space available to cold, cool, and warmwater fishes in any particular season can be measured from available depth contours of a lake or reservoir and from the predicted temperature and D.O. response of a water body to global climate change.

2.2. Fish Extinction Versus Invasion

In the analysis herein, only the upper temperature limit as it occurs in summer is used to estimate the geographic distribution of fishes in relation to surface water temperatures. There is also a lower temperature limit which occurs in winter that can be limiting. Warmwater fishes are especially sensitive to low winter temperatures, and evidence is mounting that fishes in other guilds may also be vulnerable (e.g. Johnson and Evans, 1990). Global climate change is predicted to raise most water temperatures in streams. Therefore, additional stress for fishes now present in a stream will likely occur in summer, but not in winter. For fishes known to inhabit a particular stream, it is therefore meaningful to explicitly examine the upper temperature limits in the summer to determine if extinction due to elevated temperatures is likely.

Fishes currently excluded in a stream reach may or may not invade if thermal conditions become acceptable. To determine if colonization is possible both summer and winter limits also need to be examined.

The lower temperature bound to be examined for winter is not necessarily a minimum tolerated temperature value since many species of fish survive at or near 0°C, but instead may be a combination of low temperature plus the duration of that temperature. For potential warmwater invader species winter conditions need to be examined. Invasion is much more difficult to project than elimination. Whether an invading species will succeed does not depend on water temperature and D.O. alone. Winter survival of warmwater fish depends upon body size, fat stores, and starvation time and duration. Where accessibility and connections of waterbodies are poor or insufficient, natural invasion may be so poor that stocking is necessary to establish warmwater fish species if that is desirable. Therefore, only colonization potential which is a function of temperature and D.O. will be assessed in this study.

2.3. Databases

Fish thermal requirements have been estimated utilizing both laboratory and field data. Hokanson et al. (1990a) described the development of a national database system containing discrete fish presence records spatially and temporally associated with water temperature records. The current Global Climate Change Information Management System (GCC/IMS) grew out of a historical database, the Fish Temperature Database Management System, FTDMS (Biesinger et al., 1979). The

original FTDMS database utilized data available through the early 1970's and had limited application to current project needs. The GCC database development began with the conversion and quality assurance of the original FTDMS data. Subsequent efforts have concentrated on the expansion of database content and the augmentation and refinement of the system's reporting and analytic capabilities. Data inclusion criteria and quality assurance measures have been established for the inclusion of a variety of fisheries and temperature data. Data sources included federal agencies such as the U.S. Geological Survey (USGS) and the Environmental Protection Agency (STORET), state agencies such as the Department of Natural Resources, and private museum and university collections.

The database file structures were redesigned prior to database expansion to take full advantage of contemporary hardware and software technology. The hierarchical data structure includes a sampling location file, a fish sample file, and a physical/chemical parameter file (temperature, D.O., etc.). A Geographic Information System (GIS) interface has assisted in the production of graphics output. Additionally, a menu–driven user interface was developed to improve the system's accessibility to researchers. All database files are contained in a dBase–compatible system. The principal hardware supporting the system is a Northgate 386 computer, running at 25mHz with 300 megabytes of disk storage.

The database management system was designed and developed to store and retrieve laboratory–derived fish thermal criteria for which literature citations are available. The laboratory database stores information on literature citations, test species, and thermal criteria values such as growth rates, lethal temperatures, and behavior and spawning trigger temperatures. The laboratory data is used to reinforce estimates of thermal distribution limits obtained from thermal regimen analysis. Comparisons of the two data types help define data gaps, indicate end–points useful as surrogates for thermal limit information, provide data for some species not adequately represented in the field database, and suggest additional laboratory experiments to fill the data gaps. Cross comparison adds confidence to the computed FTDMS values used.

2.4. Water Temperature Requirements of Fishes

2.4.1. *Fish presence summer temperature limits*

Analysis of data contained in the GCC/IMS included a temperature limit for fish presence or geographic distribution. The highest summer 95 percentile temperature value (a weekly mean temperature) for presence of each species of fish from the FTDMS database was selected as the maximum temperature value at which a fish species or guild would be expected in a water body (Fig. 3). This seemed appropriate (instead of the 100 percentile) in light of the wide geographic data distribution and the range of time–scales over which measurements had been made. Possible sources of error in the data base are measurement errors, fish presence due to refugia, and lack of temporal correspondence of fish and temperature records. The values obtained in this way also compare favorably with laboratory test results involving exposures of several days (e.g. FTDMS 95 percentile values are mostly 1° to 3°C lower than acute mortality temperatures (UUILT), but

comparable to upper zero net growth (UZNG) temperatures (USEPA, 1976). Herein the presence or absence of a fish species or guild will also be indicated by terms such as "survival" or "non–survival," although a direct relationship to mortality is not implied. The 95 percentile FTDMS value will be used exclusively as the limit between presence (survival) or absence (non–survival).

Table 1 gives the FTDMS distribution limit (maximum 95 percentile) temperatures for a number of fish species subdivided into guilds. Further information on the FTDMS database can be obtained from Hokanson et al. (1990a).

Because water temperatures corresponding to the southern boundary of the range of warmwater fishes (i.e. south of the U.S.) are not included in the database, the FTDMS 95th percentile values are known to be too low to reflect the upper thermal tolerance limits for these species (Fig. 3). These values are not important for the present analysis because surface water temperatures will not get this hot in the northcentral region of the U.S., particularly Minnesota, even under climate change conditions. A regression relationship between upper incipient lethal temperature and 95th percentile values for cool and coldwater fishes has been determined to provide the best estimate of FTDMS values for warmwater fish (guild mean = 33.1° C). Hokanson et al. (1991) provide an estimate of 35.3° C based on a 95 percent stream temperature and UZNG relationship.

2.4.2. *Fish growth thermal criteria*

In addition to using the ability to survive as a gross measure of climate change effect, a measure of growth potential was sought as a sublethal effect indicator. The arbitrarily chosen measure was the temperature range between the lower temperature at which 50% of maximum growth occurred and the EPA (1976) maximum temperature for prolonged exposure (see Appendix A for details of its derivation). This "good growth" temperature range could be calculated from growth rate experiments for several species in each guild, the values of which were averaged to obtain guild good growth values. Since the amount of time spent within this range could be expected to contribute heavily to production of a fish population, a comparison of this time before and after climate change should be a useful measure of relative effects on growth potential. The lower and upper good growth values used in this analysis are shown in Table 1. They are labelled "lower 50% growth limits" and "upper growth criteria" in Table 1.

2.5. Dissolved Oxygen Requirements of Fishes

Based on information in the USEPA dissolved oxygen criteria document, and on discussions with the author (Chapman, 1986) D.O. limits of 2.5 mg/ℓ for warmwater fishes and 3.0 mg/ℓ for coolwater and coldwater fishes were selected. It was the intention to select a value at which loss of populations would ultimately occur. These concentrations are expected to result in significant mortality among individuals exposed for only a few days. In contrast, EPA criteria levels intended to protect these guilds are 4 and 5 mg/ℓ, respectively. The procedure used for selecting D.O. levels for this study is given in Appendix B.

3. TEMPERATURE AND DISSOLVED OXYGEN MODELING OF LAKES AND STREAMS

3.1. Model Concepts and Development

To apply the temperature survival and growth information to lakes and streams under changed climate conditions, water temperatures and D.O. are simulated for lakes and streams for past weather and future climate scenarios.

A one–dimensional lake water quality model, which has been successfully applied for several years to simulate hydrothermal and kinetic processes in individual north–central U.S. lakes and for a variety of meteorological conditions (Ford and Stefan, 1980; Stefan et al., 1980; Riley and Stefan, 1988; Stefan, 1989; Gu and Stefan, 1990), was adapted to this study (Hondzo and Stefan, 1991a).

In this model a lake is described by a system of horizontal layers, each of which is well mixed. Vertical transport of heat is described by a diffusion equation in which the vertical diffusion coefficient Kz(z) is related to windspeed, lake area, and strength of stratification.

The vertical temperature profile in the lake is computed from a balance between incoming heat from solar and longwave radiation and the outflow of heat through convection and back radiation. The internal distribution of heat due to radiation adsorption inside the water is also taken into consideration. Details of model development and validation are provided elsewhere (Hondzo and Stefan, 1991a, 1991b).

To simulate stream temperatures, a model which solves the one–dimensional advective–dispersive heat transport equation with heat input from above through the water surface is applied. The model is a modified version of the finite difference implicit computer model MNSTREM which is capable of simulating a very dynamic stream temperature regime and was developed for EPA (Stefan et al., 1980). The stream is well–mixed in each cross section. The original model was expanded by Sinokrot and Stefan (1992a) to include seasonal heat flux into/out of the stream sediments, seasonal variable partial shading by trees on the streambanks, and partial wind sheltering. Applications for different streams and climate scenarios established "regional" temperature regimes of Minnesota streams (Stefan and Sinokrot, 1992b).

A regional dissolved oxygen (D.O.) model was developed and validated by Stefan and Fang (1992). The model solves the one–dimensional, unsteady D.O. transport equation. Sedimentary oxygen demand (SOD) and biochemical oxygen demand (BOD) as well as plant respiration are the oxygen sinks in the model, and rates are specified according to trophic status but variable with temperature. Reaeration and photosynthesis are the

sources of oxygen in the model. Oxygen depletion in the hypolimnion is controlled by depletion rates and vertical mixing which is simulated with vertical diffusion coefficients that depend on stratification and lake size. Lake morphometry and daily weather parameters are model inputs. Lake trophic status is specified by chlorophyll–*a* concentration, BOD (biochemical oxygen demand), and SOD (sedimentary oxygen demand).

3.2. Selection of Lakes and Streams for Modeling

Lakes and streams were selected utilizing two criteria: (a) representativeness and (b) availability of data.

Waterbodies in Minnesota were selected as representative of the upper northcentral U.S. from Minnesota's extensive data bases available through the Department of Natural Resources and the Minnesota Pollution Control Agency. Differences between waterbodies in adjacent ecoregions were found too small to justify further subdivisions on this basis. Instead, the state was divided into a northern part, roughly coinciding with three ecoregions, and a southern part, roughly coinciding with three other ecoregions (Figure 4) which also extend into Wisconsin, Iowa, and South Dakota. "Representative" lake meant either having values of key characteristics near the median as identified in a state report by the Minnesota Pollution Control Agency (Heiskary et al, 1988) or being near the far ends of the frequency distributions. The westernmost regions of the state were ignored because of this area's limited fisheries resources. The screening process also eliminated stream reaches and lakes in which fish distributions could be affected by pollutants instead of D.O. and water temperature.

To validate the methodology and computational procedures, state data bases of lakes and streams were screened to find those "representative" waterbodies which also have information on fish species present. In addition, it was necessary to have water temperature data, stream flow data, and D.O. data to validate the water temperature and D.O. model results. Dissolved oxygen was modeled only for lakes. For streams, it was assumed that the most valuable fisheries are in non–polluted reaches with sufficient D.O. Specific lakes selected initially are shown in Figure 4 and their characteristics summarized in Table 2. Selected stream locations are shown in Figure 5 and stream characteristics are summarized in Table 3. Documentation on "typical" streams could not be found, and it was therefore not possible to relate the selected stream widths, depths, flow rates, bank vegetation, etc., to any statistical parameters. However, the selected streams are representative of those with the most valuable fisheries resources; they also frequent recent fish surveys and occur in several different ecoregions. Stream size, flow rates and bank vegetation were also considered in the selection of representative streams.

3.3. Model Input Requirements – Meteorological Data

The lake and stream models are applied in daily timesteps with input of mean daily values for the following meteorological variables from March 1 to November 30: air temperature, dew point temperature, precipitation, wind speed, wind direction, sunshine percentage and solar radiation. Weather data files have been assembled for three main weather stations

(Minneapolis–St. Paul, MN, Duluth, MN, and Fargo, ND) for periods between 1955 and 1979. The EPA, Office of Program Planning and Evaluation, suggestion to use weather data up to 1988 was not followed because a warming trend existed in the 1980's (Jones et al., 1986; Kerr, 1989). The weather data were obtained from the National Center for Atmospheric Research (NCAR), the Midwestern Climate Center in Champaign, IL, and the files of the Soil Science Department (Professor D. G. Baker) at the University of Minnesota, St. Paul. Examples of seasonal distributions of weather parameters for the sites are given by Hondzo and Stefan (1991a).

3.4. Model Input Requirements—Lake and Stream Data

Lake morphometry is characterized by surface area vs. depth relationships and maximum depth as obtained from the Department of Natural Resources (DNR) maps. Secchi depth is an open water average value (May–November) as determined by the Minnesota Pollution Control Agency (MPCA, 1988) surveys. This value is used in radiation attenuation but also as a rough characterization of trophic status. Relationships between Secchi depth, total phosphorus, and mean summer chlorophyll–*a* levels in Minnesota lakes have been developed (Heiskary, 1988). The stream temperature model requires input data on stream morphology (cross–sectional area and surface width as a function of stream flow rate), stream hydrology (streamflow), and stream bank vegetation (percent shading and percent wind shelter). This information was generated by stream site visits, cross–sectional surveys, U.S. Geological Survey flow rate records, and stage–discharge relationships.

3.5. Water Temperature Model Calibrations and Validations

The calibration coefficients used in the original lake temperature model were for light attenuation, wind sheltering, and hypolimnetic eddy diffusivity. For the regional analysis, the attenuation coefficients were empirically related to Secchi depth, and wind sheltering and eddy diffusivity to surface area, wind speed and stratification stability (Hondzo and Stefan, 1991a). Simulations started with isothermal conditions (4° C) on March 1 and progressed in daily timesteps until November 30. Ice goes out of Minnesota lakes sometime between the end of March and the middle of May. With climate change, this date may advance by as much as a month. Dates of spring overturn vary with latitude and year. To allow for these variable conditions, a 4° C isothermal condition was maintained in the lake water temperature simulations until simulated water temperatures began to rise above 4° C. This method permitted the model to find its own date of spring overturn (4° C) and the simulated summer heating cycle started from that date. Model coefficients were kept at their initially specified value throughout the entire simulation period. Examples of model validation for lakes are given by Hondzo and Stefan (1991b). The lake model simulates onset of stratification, mixed layer depth, and water temperature with reasonable accuracy. Standard error between measurements and simulation was 1° C. This is mostly due to small differences in predicted thermocline depth. Water temperature data for lake model calibration came from past limnological surveys and consisted typically of measurements with accuracies of ± °0.1 to 0.2° C and 0.1 m for depth.

The stream temperature model was run with an initial 1° C temperature imposed on March 1 as an initial condition. Temperatures could drop or rise freely after that date but not below 0° C. The model was calibrated and validated using hourly and daily measurements over several three–week periods. Shading and wind sheltering by bank vegetation (trees) were used for calibration. Shading and wind sheltering were expressed as percentages of solar radiation and wind speed measured at the weather station. The sensitivity to these two parameters was shown to be quite different. Sensitivity to shading is high; sheltering has a much smaller effect (Sinokrot and Stefan, 1992a). Stream temperature data were obtained with recording equipment, except for the Straight River where an extensive USGS study provided the data. The standard error for stream water temperature simulations was 0.6° C (Sinokrot and Stefan, 1992b).

3.6. Dissolved Oxygen Model Calibration and Validation

The D.O. model for lakes was calibrated and validated with measurements by Osgood (1984, 1985) in seven Twin Cities Metropolitan area lakes for several specific years. Eleven seasonal sets of data, each consisting of five or more measured vertical D.O. profiles, were used. Standard errors for calibration used six sets of data ranging from 0.6 to 2.3 mg/ℓ with an average of 1.4 mg/ℓ . Standard errors for validation used five sets of data ranging from 1.2 to 2.3 mg/ℓ with an average of 1.9 mg/ℓ . The main cause of errors in the D.O. predictions were small (1 m or less) deviations in mixed layer depths. The main calibration parameter was sedimentary oxygen uptake (SOD) which was a function of trophic status. Photosynthetic oxygen production rate was also a calibration parameter. The model development and calibration procedures are described elsewhere (Fang and Stefan, 1991). Past and future climate conditions were simulated at daily time steps.

3.7. Model Simulations of Individual Lakes and Streams for Historical Weather

Quantifying past weather impact on lake and stream temperatures provides baseline information against which the future climate effects can be measured. Analysis or simulation of individual lake and stream responses to extreme historical climate conditions is considered to be a first step to understand potential thermal changes in inland lakes. A second step is to quantify historical climate impact on representative lakes and streams for a longer period, i.e., from 1955 to 1979. Different climate scenarios with unknown degrees of uncertainty can then be superimposed on this basis.

In the summer of 1988, the north central region of the United States experienced very hot and dry weather (the warmest in the 100–year global record of instrumentally recorded air temperatures, Kerr 1989). This year was therefore selected to represent a "warm climate" while 1971 was representative of a normal year. The effects of historical weather in these two years on temperatures and stratification in three lakes (Lake Calhoun, Lake Elmo, and Holland Lake) in the northcentral U.S. were simulated and the results published separately (Hondzo and Stefan, 1991b). The main findings were: mean seasonal epilimnetic water temperatures responded strongly to mean atmospheric changes; hypolimnetic temperatures were

dominated by mixing events in spring and by lake morphometries, and responded inconsistently to atmospheric changes; evaporative heat loss during the summer season increased about 40 percent; and conductive heat transfer had a small effect on heat budget changes.

Water temperature simulations were also performed for five lakes in southern and two in northern Minnesota (Table 2) for the historical, recorded weather time series from 1955–1989. Weekly simulated average water temperature time series for the epilimnion and hypolimnion for Lake Calhoun are given in Fig. 6 as an example of model output. Variations in water temperatures are caused by variable meteorological conditions. Only the period from April 1 to October 31 in each year is shown. Epilimnetic water temperatures are simulated between 1 and 2 m below the surface, and hypolimnetic water temperature are simulated 1.0 m above the bottom of the lake. Weekly averages of maximum and minimum for the entire period of simulation (1955–1988) are given in Fig. 7. Weekly water temperatures averaged over the entire period of record (1955–1988) can also be given as isotherms as shown in Fig. 8. This illustrates the long–term weekly water temperature distribution as a function of both season and depth. Average and maximum water temperature contours for the entire lake are given in Fig. 8. Values at the 95% or other level of confidence can also be chosen. Information shown in Figs. 7 and 8 can be used to project fish species presence and growth potential in a given waterbody, based on water temperature.

The stream temperature model was similarly applied with past weather conditions, and computed daily water temperatures were averaged weekly. A free–flowing river condition with no upstream reservoir influence or groundwater was assumed in this application. An example of a simulated water temperature time series is shown in Fig. 9; long term (1955–1979) weekly averages of simulated values are shown in Fig. 10. Twenty–five years of historical weather data from the mid–1950's to the late 1970's were used to simulate water temperatures in each of the five streams. Weather data were from Minneapolis/St. Paul, Minnesota, or Duluth, Minnesota, or Fargo, North Dakota, whichever was nearest. Details of the simulation procedures are described by Sinokrot and Stefan (1992b). The simulation model was calibrated for each of the five streams. Shading and wind sheltering were the calibration parameters.

3.8. Simulations of Future Climate Scenarios

Projected future long–term (25–year) average stream and lake temperatures were calculated after applying increments to the historical weather parameters. The increments were monthly additive or multiplicative values for air temperature, windspeed, relative humidity, and other weather parameters. The monthly incremental values were obtained from NOAA and had been derived from the outputs of four Global Circulation Models (GCM's) for doubling of CO_2 in the atmosphere (Hansen et al., 1983). The models were the Goddard Institute for Space Studies (GISS), Geophysical Fluid Dynamics Laboratory (GFDL), the United Kingdom (UKMO), and the Oregon State University (OSU) models. The stream water temperatures, for example, rose by model and stream specific averages from 2.6° C (OSU) to 8.9° C (UKMO) with a median near 3.6° C for most of the GISS and GFDL

simulations. In the stream analysis the average of the GISS, GFDL, and OSU model results are similar and will be referred to as "future," whereas the UKMO model results will be labelled "extreme future" (see e.g. Tables 6 and 7). Additional details are given by Sinokrot and Stefan (1992a).

Future lake temperatures were simulated for the $2xCO_2$ scenario with the GISS model and 27 classes of lakes based on size, depth, and trophic state in the south and the north as will be described in Section 5. Regional temperature characteristics of southern Minnesota lakes have been summarized by Hondzo and Stefan (1991a).

4. CLIMATE CHANGE IMPACT ANALYSIS FOR STREAMS

4.1. Application of Fish Temperature Criteria

Fish distribution (survival) and growth temperature criteria were applied to simulated daily water temperatures for the five streams shown in Fig. 5 and listed in Table 3. An example of a simulated time series of stream water temperatures during a season and a set of survival and growth temperature criteria for one species of fish is shown in Fig. 11. Four particular dates are defined by the intersects. GSB and GSE mark the beginning and end of the good growth season, SCB and SCE the beginning and end of non–survivable temperatures, respectively. These parameters were determined for each of the fish species in Table 1 and the three guilds (cold, cool and warm). Also determined were other parameters: e.g. SCL = length of time that 95 percentile FTDMS fish temperature distribution limits (herein also called survival limits) are exceeded; GSL = length of time that water temperature is within the range of good growth limits (Appendix A); GZER = length of time that water temperature exceeds the upper good growth limit (Appendix A). During the period designated by GZER, growth is much reduced. GZER is therefore a period of low growth and/or stress including uninhabitable temperatures (SCL).

During the period designated by GZER, population biomass gain tends to be reduced below that of good growth due to direct thermal stress on individuals and subsequent deaths (Hokanson, 1990b), as well as due to bioenergetically induced increased energy demands for survival with weight loss of individuals and indirect enhanced vulnerability to disease, the combination of which is the loss of population biomass as the more thermally intolerant individuals are eliminated (McCormick et al., 1972). As a consequence, when trying to evaluate the relative suitability of one set of environmental conditions to another, in terms of production potential, it is necessary not only to compare the GSL's of the two but also to incorporate the effects of exposure to temperatures in exceedance of the good growth range. To achieve this, a ratio (R) was developed which divides the GSL by the GZER.* A value R=1 indicates that the good growth period and the stress period are of equal length. A very large value of R indicates a long growth period relative to the stress period, and R $\approx$ 0 indicates that the good growth period is totally overshadowed by the length of the stress period. The comparisons between expected growth potential of fish after global climate change (GCC) in particular habitats to that before GCC can now be achieved by comparing R ratios between the two times, i.e. R before

*One day was added to GSL and GZER to prevent the quotient from becoming zero or infinite when no days of GSL or GZER were extant. The (one) added day is considered an acceptable error for these evaluations since it avoids a ridiculous calculated value at the expense of only a small and consistent error for the purpose of obtaining a relative comparison.

may = 3.2 while R for the same habitat after GISS warming may = 0.5; 3.2 – 0.5 = 2.7 or post GISS warming would be expected to have an 84% reduction in relative growth potential.

This consideration is not necessary for temperatures below 50 percent maximum growth because growth occurs at temperatures below the good growth range, but without the stress experienced at temperatures above the good growth range.

In table 4, the three parameters considered most significant are given for fish guilds in all five representative streams and for five climate conditions. To relate future to past climate conditions, differences between future and past values of SCL*, GSL*, and R are presented. Under existing conditions the good growth season length varies with fish guild and stream temperature as expected. In cold streams such as the straight river the GSL values are 120, 60 and 8 days for cold–, cool– and warmwater fishes, respectively. In the warmer Mississippi River, the values are 73, 130 and 118, respectively. The most favorable R ratios are, at present, for coolwater fishes in the cooler smaller streams, and for warmwater fishes in the warmer Mississippi River. Results in Table 4 also indicate that as the climate changes, the length of the good growth season is shortened for coldwater fish and lengthened for coolwater and warmwater fishes.

R–values indicate poorer habitat conditions for coldwater fishes in all streams, and for coolwater fishes in the Mississippi. These relationships are even more extreme under the UKMO climate scenario.

An analysis by fish guilds gives only a very rough idea of fish habitat. Therefore, a breakdown of the parameters by fish species is given in Tables 5a through 5e. Variations within guilds are apparent, e.g. between Northern Pike and Yellow Perch in Table 5e.

A complete simulation output for streams is given in Appendix C.

An interpretation of the numbers in Tables 4 and 5 was made in Tables 6 and 7 by indicating (in shading) uninhabitable conditions and by listing the length of the good growth season (GSL) in days. Uninhabitable conditions are considered to exist when the upper 95% FTDMS limit is exceeded by more than seven days (SCL larger than 7 days).

Table 6 gives an overview of the GSL values for the five streams, three fish guilds and past, future, and extreme future climate conditions. "Extreme future" habitat conditions are based on the most extreme SCL or GSL–value usually associated with the UKMO climate scenario. Future habitat values are those excluding the extreme parameter value and are the average of the GISS, GFDL and OSU model results. The numerical values in Tables 6 and 7 give the length of the good growth season GSL. Uninhabitable conditions are identified by shaded boxes. The streams are arranged, more or less, from coldest to warmest. The habitat classification given in Table 6 for guilds is broken down by individual species in Table 7.

*See footnote on previous page.

In Table 7 as previously in Table 5 all fish species in the database are listed. This is not meant to imply that all species listed are present in every stream. Those which have been observed are listed by the frequency observations (e.g. 5/22) in the first column under the heading OBS. For the Mississippi River fish species reported are shown by an asterisk because the frequency of observations is not known

It needs to be clarified or recalled here that the parameters SCL, GSL and R as defined earlier in this section are not of equal significance. SCL is a parameter directly related to the FTDMS database which is presumably broad enough to integrate all phenomena important to fish presence in a stream such as reproduction, food supply, winter survival, upper lethal temperatures, etc. FTDMS also covers a broad segment of the geographic range in which a species is present.

GSL values, on the other hand, are derived from growth rate curves for individual species. This is a data source totally different from the FTDMS data base. GSL designates the length of the period when the potential for growth is high (better than 50% of the maximum), but there is poor or restricted growth even where GSL approaches 0. GSL is used as a relative measure of the change in the growth potential of the species or guilds of fishes within a waterbody with climate change.

For future climate scenarios, the percentage of shading is varied because stream temperatures are sensitive to this parameter as will be discussed in section 4.3.

Tables 6 and 7 indicate that:

(1) Coldwater fish are predicted to be all but eliminated from free flowing streams in Minnesota by GCC, except for those in the north which have and can maintain strong shading (40% or better).

(2) Coolwater fish will be eliminated from the central reach of the Mississippi River (Anoka, MN, area), but will find improved growth potential in colder streams with more shading. The extreme climate scenario predicts that even coolwater fish will be eliminated from all but the most shaded stream.

(3) Under future conditions, warmwater fish will have slightly improved growth conditions in the Mississippi River, and much improved growth conditions in the smaller streams.

4.2. Time Scales and Variability

4.2.1. *Seven–day water temperature averages*

A most important consideration for the fish habitat interpretation is the time scale at which the water temperatures are simulated or measured. Figure 11 and Tables 4 to 7 are for daily water temperatures simulated with daily average weather parameters as model input.

It is well–known that stream water temperatures have diurnal fluctuations which can amount to several °C and are related to stream

depth (Song et al., 1973). In this study such short–term variations at the time scale of hours have been ignored because it is assumed that fish can, within limits, "integrate" temperature effects over such short periods (i.e. they can resist short–term temperature peaks if the average temperature is not excessive). In fact fish can "integrate" temperature effects over periods of more then one day, and up to 4 to 7 days (Hokanson, Biesinger, Goodno, 1991). To determine how such long–term integration would affect the fish interpretations, computations of fish parameters have been repeated for the coldest (Straight) and the warmest (Mississippi) river with 7–day sliding average values instead of daily water temperature values. Simulations using sliding averages of water temperatures resulted in only small changes of the values for SCL, GSL and GZER. The maximum differences for SCL, GSL and GZER were seven days, ten days and eleven days, respectively. The average differences were on the order of two days for SCL and GSL and one day for GZER. No consistent pattern was found. The reason for the relatively moderate changes is that the water temperature time series is a 25–year average and therefore already a relatively smooth curve as shown, for example, in Fig. 10. Averaging over seven days only farther smoothes the already smoothed curve.

4.2.2. *Variability from year to year*

Another aspect of time variable stream temperatures is the variation from year to year. A twenty–five year average is a reliable indicator of mean conditions in the past and the future but individual years can produce stream temperatures much different from the mean as illustrated in Fig. 10. Fish temperature criteria were therefore also applied to exceptionally high and low stream temperatures. These were obtained by adding σ (σ = the standard deviation of stream temperatures calculated as a 25–year daily average) to the previously used 25–year mean stream temperatures.

These extreme temperatures have a probability of occurrence on the order of once in six years which is a sufficient frequency to have a lasting impact on fish species distributions. The fish habitat variables SCL, GSL and R for these high (ave. + std. dev.) and low (ave.–std. dev.) stream temperatures are shown in Tables 8a and 8b for guilds. Values of the fish parameters are markedly different from those in Tables 4 and 5. The values are measures of the growth potential in extreme years and indicate that growth conditions in extreme years are markedly different from average years. If these extreme temperatures were retained to indicate the presence or absence of a species or guild through survival and growth potential values, one would obtain the fish presence summaries in Tables 9a to 9e. Fish species actually observed in these streams have been marked in Table 9 by frequency of observation, e.g. 5/21, or by a star. A star means that at least one fish of the indicated species was present during three or less surveys.

One interpretation of the results in Table 9 is that infrequent (1 in 6 years) high water temperatures eliminate a number of species which would survive in average years (e.g. in the Baptism River and the Clearwater River, Table 9b and 9c). In a relatively warm stream such as the

Mississippi River even some coolwater species are eliminated in exceptional years (unless they find refuges to survive (Table 9e)). On the other hand exceptionally warm years enhance growth potential of coolwater and warmwater fish in cold streams by 50 percent and more. Conversely, exceptionally cool years virtually eliminate good summer growth potential of warmwater fishes in cool streams such as the Straight River (Table 9a) and the Clearwater River (Table 9c). While these effects can be qualitatively anticipated, the data in Tables 9a to 9e provide a quantitative estimate of these effects. The analysis is for summer conditions. Winter effects, although important, are not included.

4.3. Sensitivity to Shading and Flow

Changes in *bank vegetation* through reduction in shading, may have a drastic effect on stream temperatures and indigenous fishes. Simulations and analyses were therefore conducted for reduced shading by trees and reduced stream flow. The results of the no–shading or shading reduction analyses are added in Tables 7a to 7d. "No shading" means that 100 percent of the incident solar radiation is applied.

The results in Table 7 indicate that if in addition to climate change trees along the banks of Minnesota streams are eliminated, cold and coolwater fish will be severely impacted:

(1) Coldwater fish will be eliminated in nearly all free flowing streams. They will find adequate water temperatures only near sources of groundwater inputs or coldwater releases from hypolimnia of deep reservoirs.

(2) All coolwater fishes will be threatened or eliminated in the southern region of the state and some will even be threatened in the north.

(3) The species distribution in streams will become more similar to that in the mainstem of the Mississippi River.

Changes in *stream flow* are also very likely to occur with climate change. Stream temperatures in free flowing long streams will not be much affected by flowrate changes as shown in Table 10. Streams most strongly affected by flow rate changes will be the coldwater reaches, either natural ones or downstream from reservoir outlets. The analysis in this paper is only for free flowing streams.

5. REGIONALIZATION OF CLIMATE CHANGE IMPACT ANALYSIS FOR LAKES

5.1. Minnesota Lake Fisheries Database

The Minnesota Department of Natural Resources has developed a Minnesota Lake Fisheries Database, MLFD, which contains fisheries survey and physical and chemical parameter information for 3002 Minnesota lakes. This database currently has been used to produce lake physical parameter statistics essential to the definition of a lake classification system used in the lake modeling effort of this project. The database was made available by Dennis Schupp at the DNR Office in Brainerd, Minnesota, who has extensively reviewed and quality assured the data. The database contains information on lakes in Minnesota with permanent (non–winterkill) fish populations.

The MLFD system has been expanded to incorporate additional lake information from other data sources including USGS, state DNR offices, and the Minnesota Pollution Control Agency. A statistical analysis of Minnesota lakes in the MLFD in terms of three key physical parameters (surface area, depth and Secchi depth) led to frequency distributions which were then used to classify the lakes into three ranges of surface area, maximum depth, and Secchi depth as shown in Table 11. These represent typical conditions in 27 classes of lakes in each of the north and south regions of the state. Geographic location indexing capability has been added to the database system by incorporating latitude and longitude values from the USGS Geographic Names Information System (GNIS). The geographic distribution of all the 3002 lakes is given in Fig. 12a and is subdivided into the specified ranges of key parameters in Fig. 12b. Frequency distributions of lake surface areas, depths, and Secchi depths were developed by EPA/ERLD and are reproduced by Hondzo and Stefan (1991a).

The MLFD was also used to provide current fish species distribution data in Minnesota lakes. A breakdown into 27 lake classes is given in Table 12. These fishes comprise the majority of the sport or commercial species and some of the forage species in the state's lakes.

5.2. Temperature and D.O. Impact by Latitude, Lake Size, Lake Depth, and Trophic Status

Regional simulations were made for the 27 classes of lakes based on Table 11 separately for southern and northern Minnesota. A validated, one–dimensional, unsteady lake water quality model was linked to global climate model output in order to quantify potential thermal changes in inland lakes due to climate change. Water temperatures and D.O. were simulated on a daily time base for past weather conditions, 1955–1979 and the $2xCO_2$ GISS model climate scenario. Weather data were from the

nearest of three weather stations (Minneapolis/St. Paul, MN, Duluth, MN, Fargo, N.D.). Hondzo and Stefan (1991a) describe the results of the water temperature simulations in the 27 lake classes for southern Minnesota and point out the key parameters to which water temperatures are most sensitive. The conclusions of that substudy (Hondzo and Stefan, 1991a) are as follows:

(a) Simulated epilimnetic temperatures are predominantly related to weather and secondarily to lake morphometry. Weekly averaged epilimnetic temperatures are raised by climate change for all lake classes on average by 3° C, compared to a 4.4° C air temperature increase by the climate change. Maximum daily differences in water temperatures of 7.2 and 4.9° C are calculated for April and September. The seasonal maxima of epilimnetic temperatures are raised only by 2.0° C with climate change.

(b) Hypolimnetic temperatures are strongly influenced by lake morphometry, mixing events in spring, and only secondarily by summer weather phenomena. The highest near bottom temperatures are calculated for large, shallow, eutrophic lakes. After climate change, hypolimnetic water temperatures are projected to be as follows: shallow lakes, warmer on average by 3.1° C; large–area medium–depth lakes, warmer by 2.0° C; deep lakes, cooler by 1.1° C; small–area, medium depth lakes, cooler by 1.7° C.

(c) Simulated evaporative heat and water losses increase by about 30 percent for the $2xCO_2$ GISS climate scenario. Evaporative water losses increased by about 0.3 m, making the total seasonal evaporative water loss 1.2 m.

(d) Net heat flux through the lake surface increases with the changed climatic conditions. The largest difference in cumulative net heat flux is on the order of 100,000 kcal m^{-2} and occurs in April and September with climate change.

(e) With climate change, lakes stratify earlier, and overturn later in the season. Length of the seasonal stratification period is increased by 40 to 60 days. Simulated mixed layer depths decrease in the spring and summer, and increase in the fall.

(f) Climate change causes greater stratification stability in spring and summer. In fall lakes are driven faster towards isothermal conditions.

Samples of simulated temperature structures in southern Minnesota lakes of medium (13 m maximum) depth and surface areas varying from 10 to 1.7 and 0.2 km^2 are shown in Fig. 13a. The effect of maximum depths ranging from 4 to 13 to 24 m for lakes of 1.7 km^2 surface are illustrated in Fig. 13b. Bands of isotherms in increments of 2° C are shown, beginning at +4° C in spring and ranging up to 30° C in summer.

The regional D.O. model and its results are described by Stefan and Fang (1992). The D.O. model simulation results showed great sensitivity to sedimentary oxygen demand and vertical mixing. Examples of D.O. isopleths are shown in Fig. 14a for large, medium size, and small eutrophic lakes of 13 m depth in southern Minnesota which are essentially polymictic

and able to maintain D.O. levels on the order of 1 to 2 mg/ℓ near the bottom. In Fig. 14a the top row gives simulated D.O.'s under past climate conditions, and the bottom row those simulated for the $2xCO_2$ GISS climate scenario. Some deterioration of D.O.'s with climate change is noticeable near the lake bottom. In deep lakes which are dimictic, the D.O. distribution is much different from shallow lakes. Figure 14b shows isopleths for deep, medium deep, and shallow lakes of 1.7 km^2 surface area maximum depth before (top) and after (bottom) climate change. Hypolimnetic oxygen depletion is very apparent. This will force fish into more shallow depths where temperature can be a problem.

5.3. Application of Combined Temperature and D.O. Requirements by Fish to Simulated Lake Temperature and D.O. Profiles

Data files and processing were developed which provide for storage and utilization of lake temperature simulation outputs. Separate files per simulation specify average and standard deviation values of temperature profiles over 25 years of record. To integrate simulation output data with fish guild temperature criteria a user interface was developed. Similarly, dissolved oxygen (D.O.) concentration profiles were simulated for all 27 lake classes under 25 years of past weather and the $2xCO_2$ GISS climate scenario. The D.O. stratification and the depths of low or depleted oxygen in the hypolimnion were thus documented (Fang and Stefan, 1991). Examples of the water temperature and dissolved oxygen structures indicated by isotherms and isopleths were shown in Figs. 13 and 14.

Fish survival and growth temperature criteria were applied to simulated daily water temperature. Figure 15 shows schematically how this was done. Three isotherms were singled out for each fish guild. The same could have been done for individual species. They designate the survival temperature, the upper good growth temperature limit and the lower good growth temperature limit, respectively. Similarly the isopleth which designates the critical D.O. survival value is shown. Between these lines, three habitats can be identified:

(1) uninhabitable space when temperature is above or D.O. is below the survival limit,

(2) good growth habitat if temperature is between the upper and lower growth limits and D.O. is above the survival limit, and

(3) restricted growth habitat if temperature is above the upper good growth limit but below the survival limit, if temperature is below the lower good growth limit, and if D.O. is above critical.

Graphical presentations of these three habitats in 27 lake classes are shown for each of the three fish guilds (cold, cool, and warm) in Figures 16, 17, and 18, respectively, for past climate and the GISS climate scenario. On each figure simulated past and future habitat distributions are presented side by side. Three habitats are identified: (1) uninhabitable, (2) good growth, and (3) restricted growth. Habitat areas are plotted against depth and time, and represent 25–year average values. A few specifications apparent in these graphs deserve an explanation:

- When uninhabitable conditions extend over the entire depth of a lake for more than seven days such as shown e.g. in Fig. 16a, then the fishguild for which the graph is drawn cannot live in that lake.

- A narrow layer of inhabitable lake volume between temperature and D.O. limited habitat such as shown e.g. in Fig. 16c (left) indicates that only a small habitat space for that fishguild is available during certain periods of the summer season.

- A good growth habitat compressed below the water surface by a D.O. deficient hypolimnion, such as shown e.g. in Fig. 18c, indicates that the fishguild (warmwater) fishes can live and do well in shallow area of such a lake.

Southern Minnesota eutrophic lakes are shown because they are and will probably remain the most commonly found type of lake in southern Minnesota unless land use changes drastically. Oligotrophic lakes are shown only for northern Minnesota where they are more abundant.

To quantify the information in Figs. 16, 17, and 18 for easier comparison and interpretation, a number of parameters similar to those for streams were selected and their values calculated. Four dates were defined as shown in Fig. 15. GSB and GSE mark the beginning and the end of the good growth season, NSB and NSE the beginning and end of non–survival at any depth in the lake, respectively. These parameters were determined for each of the three fish guilds and past and future climate scenarios in Tables 13 and 14, respectively. Differences are given in Table 15.

Also determined were three other parameters to identify non–survival conditions, good growth conditions and restricted growth conditions. NSL = total number of days where in the vertical lake profile temperature and dissolved oxygen do not meet the survival conditions. GSL = total number of days when in the vertical lake profile any value of temperature is between the lower and upper growth bound and dissolved oxygen is sufficient for survival. GZER = total number of days when in the vertical lake profile the temperature is above the upper good growth bound and below the 95% FTDMS limit, and dissolved oxygen exceeds the survival criterion at all depths. This is the restricted growth season length.

The foregoing parameters measure durations of significant conditions. They are all in units of time (days). Since water quality varies with depth, depth is a most important parameter of lakes (but not of streams which are usually well–mixed); four additional parameters related to growth potential were defined. Each represents a depth or vertical distance integrated over time and its numerical value is also given in Tables 13, 14 and 15. z*jd basically measures the vertical height of the layer in which good fish growth is possible and sums that value over time (units of m×days). In the next column, designated $z*jd/z_m*GSL$, this value is referenced to the maximum lake depth z_m and the length of the growing season GSL. In addition to being the thickness of the layer in which significant growth can take place,

its volume is of equal interest. These volumes were calculated daily and integrated over time. To make these values independent of the surface areas A_S of the lakes the result was divided by A_S. The values reported under $Vol*jd/A_S$ are therefore the total time×volume integral per unit surface area to provide a size independent value for relative comparisons. In the next column the result is referenced to mean lake depth V_{tot}/A_S and length of the growing season GSL and reported under $(Vol*jd)/(V_{tot}*GS_L)$. A list of definitions of all these parameters is given at the beginning of this manuscript (pp. v to ix).

5.4. Application of Fish Temperature and D.O. Requirements, Individually

The combined effect of temperature T and dissolved oxygen (D.O.) on fish habitat in a stratified lake has been likened to the jaws of a 'vice' because temperature limits the habitat volume from above, and D.O. limits it from below, restricting fish to a progressively diminishing space, as the climate warms.

Prior to the analysis of the combined T plus D.O. effect, each was investigated individually. The results are shown in Appendices E and F. Because temperature effect is reported in exactly the same format as used above, comparisons are therefore relatively easy. It can be seen that in southern Minnesota, the temperature effect alone presents a serious limitation only to cold and coolwater fishes in non–stratifying shallow lakes.

The D.O. limitation alone is illustrated in Figs. 17 an 18 by the dark shaded area rising from the lake bottom. Numerical parameters calculated for these and other similar D.O. limitation curves are defined also at the beginning of this report and shown in Appendix F. These parameters give essentially the beginning, the end, and the length of the season during which there is insufficient D.O. concentration in the lake (DOB, DOE and DOL, respectively, see p. vii). They also give the integrals of lake depth z*jd and lake volume $V_{DO}*jd/A_S$ (measured from the water surface down) where D.O. is sufficient. As in the case of water temperature these values are referenced in separate columns to maximum lake depth z_m; however, unlike temperature, the time is referenced to total length of the simulated season (TL) rather than the growing season (GSL). Since TL is the same for all lakes (March 1 to November 30), but GSL is not, lakes can be compared better among each other if TL is used.

To illustrate how fish habitat can be gained or lost, Fig. 19 gives examples of domains of survival or growth vs. depth and time for a few cases. The shifts in depth as well as time are noteworthy. The differences due to lake depth can be seen by comparing Figs. 19a and 19b.

5.5. Interpretation of Results for Three Fishguilds

Figures 16, 17, and 18 give graphic examples of fish habitats in eutrophic southern and oligotrophic northern Minnesota lakes:

Characteristics of fish habitats in all 27 classes of southern Minnesota lakes are *quantified* in Tables 13, 14 and 15. This information is given not only for eutrophic lakes, which are the majority of lakes in southern Minnesota, but also for mesotrophic and even oligotrophic lakes. The information in Tables 13, 14 and 15 allows quantification of the qualitative interpretations of Figs. 16, 17, and 18.

Distribution of fishes. Temperature and dissolved oxygen levels are prime factors in limiting distribution of fishes. The presence of a fish guild is measured by the parameter NSL (see p. viii). Table 13 gives the earliest and latest dates (Julian days) when either temperature or D.O. do not meet the survival criteria at all depths in a lake. These are listed as NSB and NSE, respectively. The time between these dates is called NSL and measures the length of the period during which the lake is not a suitable habitat. NSL is different from the lengths of the periods SCL and DOL, when either temperature is limiting from the surface to the bottom of the lake or D.O. is limiting from the bottom to the surface, respectively. These values and their derivation are given in more detail in Appendices E and F where temperature and D.O. simulations are treated separately.

Since fish can avoid untenable conditions, a limitation at only some depths is not considered fatal. Fish will be absent from a lake as a whole if at all depths there is either a temperature or a D.O. survival limitation. If that occurs, the length of the period of time during which conditions everywhere in the lake become unsuitable for fish because either temperature is too high or D.O. is too low, is called NSL. In this study, if NSL exceeds seven days, survival of fish is considered impossible without refugia.

Growth potential can be assessed by knowing (1) the length of the good growth season (GSL) and (2) the time integrated volume of the lake's water that lies within those thermal limits that provide for good growth, Vol^*jd/A_s.

Changes, due to climate change, of the numerical values of these fish distribution and growth parameters can be obtained from Tables 13, 14, and 15 and indicate the following:

(1) *Coldwater fish* currently have only a remote chance to survive southern Minnesota summers, and only in lakes which have a deep seasonal thermocline. Such lakes have to be both large and deep and are rare in southern Minnesota (3/771). Shallow lakes have too high temperatures due to frequent mixing and small lakes have too much oxygen depletion due to lack of mixing. This simulation result is in agreement with results of fish surveys given in Table 12, which indicates only a single lake with lake trout and only three with lake whitefish. It should be emphasized again that this analysis is intended to indicate the potential D.O. and temperature habitat for fishes and not what species are actually there.

Climate scenarios for the future indicate that conditions for coldwater fish degenerate so that their potential for survival in southern Minnesota lakes becomes zero.

For northern Minnesota, the simulations indicate that temperature and D.O. conditions are suitable for coldwater fishes in all classes of lakes. For lakes of shallow (4 m) and medium (13m) depth, and for all small and medium size eutrophic and mesotrophic lakes, this result is the opposite of what was found for southern Minnesota lakes. This strong contrast between southern and northern lakes under present climate conditions for cold water fish is reflected also in the actual fish survey data in Table 12. The transition from southern to northern conditions is, however, undoubtedly more gradual than reflected by the separation line shown in Fig. 12a.

After climate change, the simulations for northern Minnesota predict a reduction in coldwater fish habitat (Table 14). Shallow lakes, large lakes of medium depth, and small lakes of medium depth will no longer support coldwater fishes except when they are eutrophic. These lakes are essentially all well–mixed. Coldwater fishes are predicted to find habitat in all deep, shallow eutrophic, and medium size (1.7 km^2), and medium depth (13m) lakes.

The length of the good growth season (GSL) for coldwater fish in northern Minnesota lakes will increase in deep oligotrophic lakes and decrease or remain the same in deep eutrophic lakes. It will decrease slightly in lakes of medium depth and size. There will also be an increase in the midsummer stress period (GZER) for coldwater fishes in these lakes. The increase will be from 0 to 65 days.

(2) *Coolwater fish* in southern Minnesota lakes find good growth conditions in the epilimnetic waters of all deep stratified lakes, and also in the shallow polymictic lakes. Growth potential based on temperature and D.O. is better for coolwater fishes than warm or coldwater fishes in southern Minnesota lakes.

Climate change will reduce the habitat volume for good growth of coolwater fishes moderately. Losses due to increase in D.O. demand will be somewhat compensated for by a lengthened growth season. This trend appears to be largely independent of lake size or depth (Fig. 16).

Coolwater fishes which at present can survive in all of the 27 classes of lakes will continue to do so.

In the south their good growth season will start 23 to 30 days earlier and end only a few days (3 to 10) later. The total good growth season will lengthen between 26 and 40 days. It is presently between 131 and 137 days long. There are only moderate differences (0 to 12 days) in these numbers due to lake size, or lake depth. The largest differences (1 to 27 days) are due to trophic status.

The mid–summer season of reduced growth will lengthen for shallow lakes.

Time integrated volumes of good growth habitat in southern Minnesota lakes will increase by no more than 16 percent for any class of lake. Changes will be the largest in lakes that are well–mixed, i.e. in shallow lakes and large lakes of medium depths. In lakes with seasonal stratification, i.e. deep lakes and medium depth lakes with medium or small surface area, volume of good growth habitat will increase by no more than 10 percent and may decrease by 6 percent.

According to the simulations, coolwater fishes should presently find suitable habitat conditions in all northern Minnesota lakes. The length of the good growth season in the north is, however, from 29 to 42 days shorter than in the south. After climate change, it will be lengthened by 29 to 41 days, i.e. it will become in the north as it is presently in the south. There is currently no midsummer reduced growth or stress period (GZER=0), and this is not expected to change after the predicted warming. Time integrated good growth volumes are anticipated to increase from 9% to 35%

(3) *Warmwater fish* currently find good growth conditions in the surface (epilimnetic) waters of southern Minnesota lakes but have to contend with a smaller volume of good growth habitat and a shorter season than the coolwater fishes. Warmwater fishes are frequent inhabitants of southern Minnesota lakes. After climate change, warmwater fish will continue to find a temperature and D.O. habitat in which they can survive in all lake classes. The simulated good growth volumes are more or less unchanged but are more confined to the surface waters. The good growth season is longer and is forecast to begin 18 to 25 days earlier and to end 12 to 17 days later. Its total length will increase by 31 to 42 days from the present 103 to 108 days for all 27 lake classes.

Time integrated growth volume will increase from between 9 and 40 percent. The largest increase (31 to 40 percent) will be for the shallow lakes, and the smallest (9 to 21 percent) for the deep lakes. Eutrophic lakes will have increases of between 31 to 37 percent if they are shallow, 17 to 28 percent if they are of medium depth and 9 to 15 percent if they are deep.

Warmwater fishes presently find suitable temperature and D.O. conditions in northern Minnesota lakes but have a short season for good growth (GSL), only 55 to 62 days. After climate change, this will increase dramatically by 42 to 54 days. The length of the good growth season length will then remain between 102 to 111 days. This is nearly identical to the present conditions in southern Minnesota lakes. Time integrated volumes for good growth of warmwater fish will increase dramatically by 66 to 92%!

(4) Overall one sees an improvement in survival and growth conditions for cool or warmwater fishes in Minnesota lakes. However, coldwater fishes currently have little space for survival in southern Minnesota, and this condition will only become worse with GCC, so as to reduce their habitat in the north as well.

The impact of climate change, simulated by the $2xCO_2$ GISS scenario, on fishes in Minnesota lakes appears to be appreciable, if water temperature and dissolved oxygen criteria for summer conditions are applied. Winter conditions, food availability, and hydrologic budgets need further investigations.

5.6. Interpretation of Results by Lake Types

In the preceding section the projected effects of GCC have been presented in terms of their effect on three fish guilds (cold–, cool–, and warmwater fishes). Another way to interpret the results is to examine how

different lake classes will be affected, for example, comparing cool– and warmwater fishes as they may be affected in different types of lakes (Table 15). From this, it can be noted that after climate change cool– and warmwater fishes will do slightly better in well–mixed (polymictic) lakes, i.e. shallow and larger lakes. This difference is the result of the temperature/D.O. squeeze which allows fish to do well in well–aerated shallow water. Lake depth, lake size and trophic status are the three lake parameters which have been used as independent variables in this study. The effects of these three parameters on simulation results and fish projections can be summarized as follows:

5.6.1. Lake depth

For maximum depths up to 24 m, and probably beyond, the good growth potential measured by water volume per unit surface area increases with lake depth if surface area and trophic status are kept constant. For example, the increases for small, eutrophic southern lakes are in proportions of 133 to 412 to 633 (mdays) as maximum lake depth increases from 4m to 13m to 24m, respectively. This behavior is documented for conditions before and after GCC. The losses or gains in good growth potential due to GCC are larger in deep lakes than in shallow ones.

5.6.2. Lake size

In shallow lakes which are usually well–mixed or polymictic lakes, good growth potential decreases slightly (of the order of 10%) as lake surface area increases. For deep (24m max. depth) lakes the trend is opposite and more pronounced (Table 13). After GCC this trend is maintained, although weakened.

5.6.3. Trophic status

The effect of trophic status in shallow lakes is small as the adversity of eutrophication tends to be compensated for by mixing during the open water season. Good growth potential is nearly the same in oligotrophic and eutrophic shallow lakes which tend to be well–mixed. In deep lakes, which have a seasonal stratification and are dimictic, oligotrophy is usually associated with higher growth potential. This trend continues after GCC. The largest losses in good growth volume due to GCC appear to occur for coldwater fish in eutrophic lakes; the largest gains are for coolwater and warmwater fishes in oligotrophic lakes of otherwise similar size and depth.

5.7. Assessment of Total Regional Impact of GCC on Fishes

The total regional impact of climate change on the presence and growth potential of the three fish guilds in Minnesota lakes is assessed, of course, with all the assumptions enumerated in the preceding sections. The total regional impact is determined from the parameters for each of the 27 lake classes in Tables 13, 14, and 15. These parameters are multiplied by the relative frequency of lakes in each class. The frequency is expressed by the number, or surface area, or volume of lakes in each class. The total number of lakes in the lake database used is 771 for southern Minnesota

and 2231 for northern Minnesota. The total is 3002 lakes. The total lake volumes are 5.6 and 18.7 billion m^3 in southern and northern Minnesota, respectively, for a total of 24.3 billion m^3. Surface areas are 1.42 and 3.58 billion m^2, respectively, for a total of 5.0 billion m^2.

A breakdown by classes is given in Table 16 for the south and the north separately, and the state as a whole. Combining information from Table 13, 14, and 15 with information from Table 16 produces the weighted average parameter values given in Table 17 for past and future climates, respectively. The weight factors applied to each class are the fractions of, alternatively, the total number of lakes, the total surface area or the total volume of lakes in each class. The summary is as follows:

(1) *Coldwater fishes* could according to the simulations at present be supported under *average* climate conditions in only deep, clear lakes (1.8 percent) in southern Minnesota. Coldwater fish have only rarely been reported in those lakes (Table 12) because of weather fluctuations from year to year and considerable length of the restricted growth/stress season for coldwater fish in summer. After climate change, survival conditions for coldwater fish in southern Minnesota lakes would be worsened and no coldwater fish habitat will remain.

For northern Minnesota lakes where coldwater fish find suitable summer habitat in many lakes, a major loss (41%) of good growth habitat is projected. Since virtually all (96%) of the good growth coldwater fish habitat is in the north, this loss is substantial.

(2) *Coolwater fishes* currently could survive in all of the southern and northern Minnesota lakes under *average* climate conditions of the past (1955–1979), according to the simulation. They will also be able to survive under the future climate of the $2xCO_2$ GISS scenario. The good growth season will be lengthened from 134 to 166 days in the south (Tables 13c and 14c) and from 100 to 135 days in the north (Tables 13d and 14d). In lakes of both the north and the south, temperature and dissolved oxygen conditions for good growth of coolwater fishes is expected to be available at some depth at all times between May 13 and September 22. The time integrated water volume in which good growth of coolwater fish is possible in all Minnesota lakes will increase by 20 percent (Table 17c). The increase will be greater in the north (25%) (Table 17b) than in the south (8%) (Table 17a).

(3) *Warmwater fishes* currently find habitat in virtually all southern Minnesota lakes, and will continue to be so under the $2xCO_2$ GISS climate scenario. The growth season will lengthen from an average of 106 to 142 days in the south (Tables 13e and 14e) and from an average 71 to 115 days in the north (Tables 13f and 14f). The time integrated good growth volume will increase by 53 percent for the entire state (Table 17c), much more in the north (71%) than in the south (21%)(Table 17a). Under past climate conditions the total time integrated good growth volume for warmwater fishes was 1364 billion m^3 days in the 3002 lakes or 60% of that for cool water fishes. After climate change, it will be 2086 billion m^3 days or 77% of that for coolwater fishes (Table 17c).

(4) Overall, climate change will increase the good growth potential of cool and warmwater fish in most Minnesota lakes and reduce the good growth potential for coldwater fishes in many Minnesota lakes. For all of Minnesota, the time–integrated lake volumes for good growth prior to climate change were calculated to be roughly in proportions of 9:10:6 for cold–, cool–, and warmwater fish, respectively. After climate change, the proportions are projected to be 5:12:9. The total integrated volume is increased by 6 percent by climate change. Most of that increase is in the north, but at the expense of the highly valued and more nationally exceptional coldwater fishes.

(5) Growth potential of fishes in many water bodies is increased by the temperature rise which causes a lengthening of the growing season, but it is curtailed by the increased dissolved oxygen demands. A summary of the time integrated water volumes in which good growth is possible is given by lake classes in Table 18. The largest gains in growth volumes are for cool– and warmwater fishes in the most common classes of lakes. Statewide over 80% of the good growth volume increases for coolwater and warmwater fish occur in only eight classes of lakes:

- Medium deep (13m) mesotrophic and eutrophic lakes of medium (1.7 km^2) or large 10 (km^2) surface area (958 lakes). These account for 44% of the increase.

- Deep (24m) mesotrophic or oligotrophic lakes of medium or large surface area (287 lakes). These account for 36% of the increase.

The largest losses in good growth potential for coldwater fish occur in almost the same categories of lakes as the gains in growth potential for coolwater and warmwater fishes.

It is of considerable interest to relate the simulated time integrated good growth volumes to actual fish productivity or fisheries yields potential. The word potential is used here because actual productivities and yields will depend on much more than water temperature and dissolved oxygen, e.g. food availability, predation, reproduction, winter conditions etc. Development of a fish productivity model, e.g. based on energetics is beyond the scope of this study.

Growth rates during the good growth period are considerably higher than during the restricted growth period. If the growth rate versus temperature curve in Appendix A can be approximated by straight lines, the ratio of the average good growth rate to the average restricted growth rate is 3 to 1. For nonlinear functions, the ratio is likely to be larger than 3 to 1. Therefore if the lake volume in which good growth potential exists is raised by a certain percentage, the increase in fish growth potential and potential fisheries yields is increased by a larger percentage, depending on length of total good and reduced growth season, shape of the good growth versus temperature curve, and length of the midsummer stress period.

5.8. Sensitivity to Lake Volume Changes

Water budgets of lakes and hence lake stages will most likely also be affected by climate change. An investigation of watershed runoff and other components of a lake water budget was beyond the scope of this study. The evaporative waterloss from lake before and after climate change was calculated as a by–product of the energy budget of lakes. Evaporation was found to be increased by about 0.3 m by climate change. Other elements of the water budget require information on watershed morphometry, soil and land use characteristics and groundwater, to name but a few. Since the retrieval of such information, as well as water budget modeling, is a significant task and affected by some uncertainty, water temperature and dissolved oxygen were simulated in this study with the assumption that lake stages would remain unchanged. If minor changes (± 1m) do occur, the results will not be dramatically changed. If larger changes must be anticipated, interpolations between the simulation results provided herein for lakes of different depths and surface areas can provide an estimate. Surely a study of lake water budgets is needed sooner or later.

6. VALIDATION OF PROJECTIONS FOR FISH PRESENCE

Projections of fish presence and growth potential under future climate scenarios are difficult if not impossible to validate, but fish surveys can be compared with simulation results for past climate conditions. Tables 7a to 7e provide such comparisons. It can be seen that agreement is very reasonable. Exceptions for coldwater fishes are found in the Baptism River for brook trout (1/7 i.e. caught in 1 of 7 surveys), and Zumbro for rainbow trout (4/50). In the Mississippi River, white sucker was observed where simulations indicated that it could not be present. Those are the only three disagreements for streams. All other observations agree with model predictions. This is considered satisfactory. In addition, the trout observations may be the result of stocking or immigration from cooler tributaries since fish presence and temperature data points are not necessarily same time, same place, matches.

If Tables 12 and 18 for lakes are compared, it is found that there is good agreement between observations and projections from simulations, but also a few disagreements. In 759 out of 771 southern Minnesota lakes coldwater fish were predicted to be absent; however, the following were observed in those lakes: 1 lake with lake trout, 2 lakes with whitefish, and 40 lakes with lake herring (cisco). The presence of lake trout and whitefish in 3 of 759 lakes does not invalidate the model. The cases of lake herring are of more concern but cannot be further evaluated from guild data because FTDMS temperature criteria for lake herring are not known. Lake herring are, however, the most thermally tolerant of the coldwater guild; thus, their presence where their guild is predicted to be absent, could be considered more of a confirmation of the validity of the method than a refutation.

Possible reasons for some disagreement between simulated and actually observed coldwater fish presence include the following:

(1) Fish collections may not have covered the same time period as the simulations (1955–1979).

(2) The water temperature criterion for fish presence or absence is subjectively chosen to be the upper 95% FTDMS temperature value. Fish can resist stressful temperatures for a time and still not be lost from the system, i.e. lethal temperatures are 2–3°C higher than the distribution limits; and are time of exposure dependent.

(3) This temperature criterion is applied to the maximum of water temperatures averaged over 25 years. It is conceivable that fish presence and distribution is in response to water temperatures which occur less frequently.

(4) Stocking of streams and lakes with game fish species biases fish survey results.

(5) Fish refuges are in areas of cooler tributary stream entrances, groundwater inflows/springs, or downstream from reservoir outlets. These can provide cooler, more local habitats than found in the remainder of the streams.

(6) Migration in streams with tributaries.

(7) Different thermal critical (i.e. UZNG) may give different predictions of fish distribution limits than used herein.

(8) Extremes of tolerance within a guild would be expected to be most imprecisely predicted. Lake Herring, of the coldwater guild, are nearest to the coolwater guild in thermal tolerance; smallmouth bass, of the warmwater guild are nearest to the coolwater guild. Both are examples of species that would be expected to be most imprecisely predicted by use of criteria applicable to a guild as a whole.

It has been shown that the model used herein is reasonable to determine fish presence. The model can probably be somewhat refined by incorporating water temperature fluctuations in addition to long–term averages. It is conceivable that fish presence or absence is in response to water temperature and D.O. conditions which occur at intervals of several years rather than in response to 25–year average conditions. As shown herein, the use of 25–year average temperatures leads to good predictions of fish presence for past conditions. It is extrapolated that it will do that also for future climate conditions. The authors believe that the uncertainty in climate scenarios is greater than that of the fish response model to temperature and D.O.

7. CONCLUSIONS

7.1. Methodology

(1) Two of the primary water quality variables which limit fish habitat and growth potential are temperature and dissolved oxygen.

(2) Numerical models which can simulate long (25–year) time–series of water temperatures in streams and water temperature and dissolved oxygen in lakes have been developed.

(3) Input data required by the simulation models are stream and lake morphometric characteristics, daily weather data and specifications of trophic status.

(4) The sensitivity of fishes to environmental temperature and D.O. conditions, and parameters which are meaningful to characterize fish habitat have been derived from field and laboratory data banks. The parameters used herein define water temperature and dissolved oxygen values for (a) survival, (b) good growth potential, and (c) restricted growth potential for different species or guilds of fishes. No claim is made that definition of the parameters used herein is optimal. The parameters used are, however, founded on large databases and sound theoretical concepts and are considered to be meaningful and useful.

(5) Fish survival and growth parameters can be determined for long–time series of simulated water temperatures and dissolved oxygen under both past and future climate conditions. Interpretation of these computed parameters indicates (a) which fish species or guilds will be threatened with extinction, (b) which will become potential invaders, and (c) whether or not the growth potential of a given species or guild is likely to increase or decrease.

(6) Further analysis of the survival and growth potential parameters indicates which lake and stream characteristics cause most or least change for fishes and leads to the identification of management options for the mitigation of or adaptation to undesirable effects.

7.2. Climate Change Impacts on Fish Resources in Minnesota Streams

(a) Coldwater fish will be all but eliminated from free flowing streams, except those in the north which have and can maintain strong shading (40% or better). Streams with significant groundwater input or fed by water releases from deep reservoirs can continue to sustain coldwater fish if the streams maintain shading and if the cool reservoir and/or groundwater releases can be maintained.

(b) Coolwater fish will be eliminated from the Mississippi River in its central Minnesota reach (Anoka, MN and below), but will find improved growth potential in cold streams if they are to retain or gain adequate shading. The extreme climate scenario (UKMO) predicts that even coolwater fish will be eliminated from all but the most shaded streams. Certain species or all of the coolwater fishes will also be eliminated from a great many streams if riparian vegetation is lost. This is the case for the southern streams, such as the Zumbro River, as well as for the more northerly Straight River, which will lose walleye and yellow perch.

(c) Warmwater fishes will have unchanged growth conditions in the Mississippi River and improved ones in more shaded streams.

(d) If riparian shading trees are lost, species habitation in southern Minnesota streams will become similar to that currently found in the mainstem of the Mississippi River, which is a warmwater fishery. Riparian vegetation is vulnerable to loss as the potential for agriculture is moved northward due to global climate change. With intensive agriculture possibly advancing into areas now too cool for agriculture, demands for plowing up to the banks of streams and rivers now running through forested lands will increase and shading can be expected to diminish.

7.3. Climate Change Impacts on Fish Resources in Minnesota Lakes

(a) Coldwater fish will be eliminated in southern Minnesota lakes and will be greatly reduced in northern Minnesota lakes.

(b) Coolwater fish will see an increase in growth potential. The greatest statewide impact will be in medium deep and deep lakes of medium and large surface area.

(c) Warmwater fish will find increased growth potential in all types of lakes, particularly in those now occupied by coolwater fishes.

(d) The factor which mostly limits growth potential as measured by time integrated volumes is absence of adequate dissolved oxygen at lake depths where temperatures are suitable. Lake water volumes in which D.O. is limiting are projected to increase significantly after climate change (see e.g. Figs. 17a and 17b, and 18a and 18b).

(e) Increases in actual growth potentials and fisheries yields will be larger than indicated by the increases in lake volumes in which good growth is predicted. This is because growth outside the good growth temperature range, not at reduced rates, and net losses in summer do not take place except at the upper extreme (see attachment #5, Appendix A). It is temperatures of this upper extreme that are most damaging to production potential. All that has been gained during the preceding good growth period could, if time and temperature above that range are too long or too high, result in an annual net loss rather than net gains. (Overwintering at northern latitudes is also a period when weight losses are incurred by many species.)

(f) Total habitat for good fish growth in Minnesota lakes will increase by 6%. Warmwater and coolwater species will experience all of the gain. Coldwater species will loose 40% of their habitat for good growth.

(g) It is also important to recognize that it is in part the unique nature of the cold and cool water fisheries of Minnesota that make it particularly attractive to recreational fishermen from other parts of the country where warmwater fisheries may be even better.

8. RESOURCE MANAGEMENT IMPLICATIONS

8.1. Streams

(a) Climate change threatens coldwater fishes and fishing in Minnesota streams but not as much by the rise in air temperatures as by the potential loss in riparian cover. Loss in shading by riparian trees would eliminate not only the coldwater fish but also threaten extinction of some of the coolwater species in all free–flowing stream sections. Water temperatures are appropriate for these species only near groundwater sources and reservoir outlets. Saving the riparian trees or replacing them now with trees which can grow in warmer climates is therefore recommended for all stream reaches with valuable cold and coolwater fish resources.

(b) Flow rates in streams are not a major factor in determining stream temperatures. Therefore change in flow rate will not significantly modify the response of stream temperature to climate warming.

(c) Where coldwater habitats are lost due to warming, and cool and warmwater fish habitats are expanded, DNR assisted introduction of appropriate species may be advantageous to more fully capitalize on the new types of habitats that are inevitably created.

8.2. Lakes

(a) *Coolwater fishes* are highly desirable sport fishes in southern Minnesota. Their potential good growth season is predicted to lengthen by 32 days or 24 percent, yet the time integrated water volume for good growth is increased by only 8 percent. The factor which limits additional lake volume for good growth is lack of dissolved oxygen. Artificial aeration of lake metalimnia without destruction of the thermocline has the potential to increase coolwater fish growth further after climate warming, but may be economically applicable only to selected lakes. Controlling eutrophication may be a better option for other situations.

(b) Trophic state does not seem to be a consistent factor influencing loss of coldwater growth potential and gain in *coolwater and warmwater fish* growth potential. In shallow lakes the trophic state seems fairly inconsequential for growth potential changes due to GCC. Therefore current effects to curb cultural eutrophication of such lakes in Minnesota will have a relatively minor effect on the consequences of global climate change for fishes.

(c) In deep lakes which typically show seasonal stratification, oligotrophic conditions are associated with smaller losses of good growth volumes for coldwater fishes (Table 15b) and larger gains of good growth volumes for coolwater and warmwater fishes (Tables 15c to 15f). Therefore curbing cultural eutrophication of deep lakes will be beneficial.

(d) In general, if other attributes of water quality and habitat are maintained, the productivity of warmwater and coolwater fisheries of the state should increase. This would provide the state with an opportunity to promote these resources (perhaps to economical advantage) for residents and visitors (tourists) while such resources may be declining in other regions of the U.S. The type of fishery will, however, become more similar to that in more southern states.

(e) The increased habitat for warmwater fishes may provide an opportunity for the judicious introduction of additional valued warmwater species.

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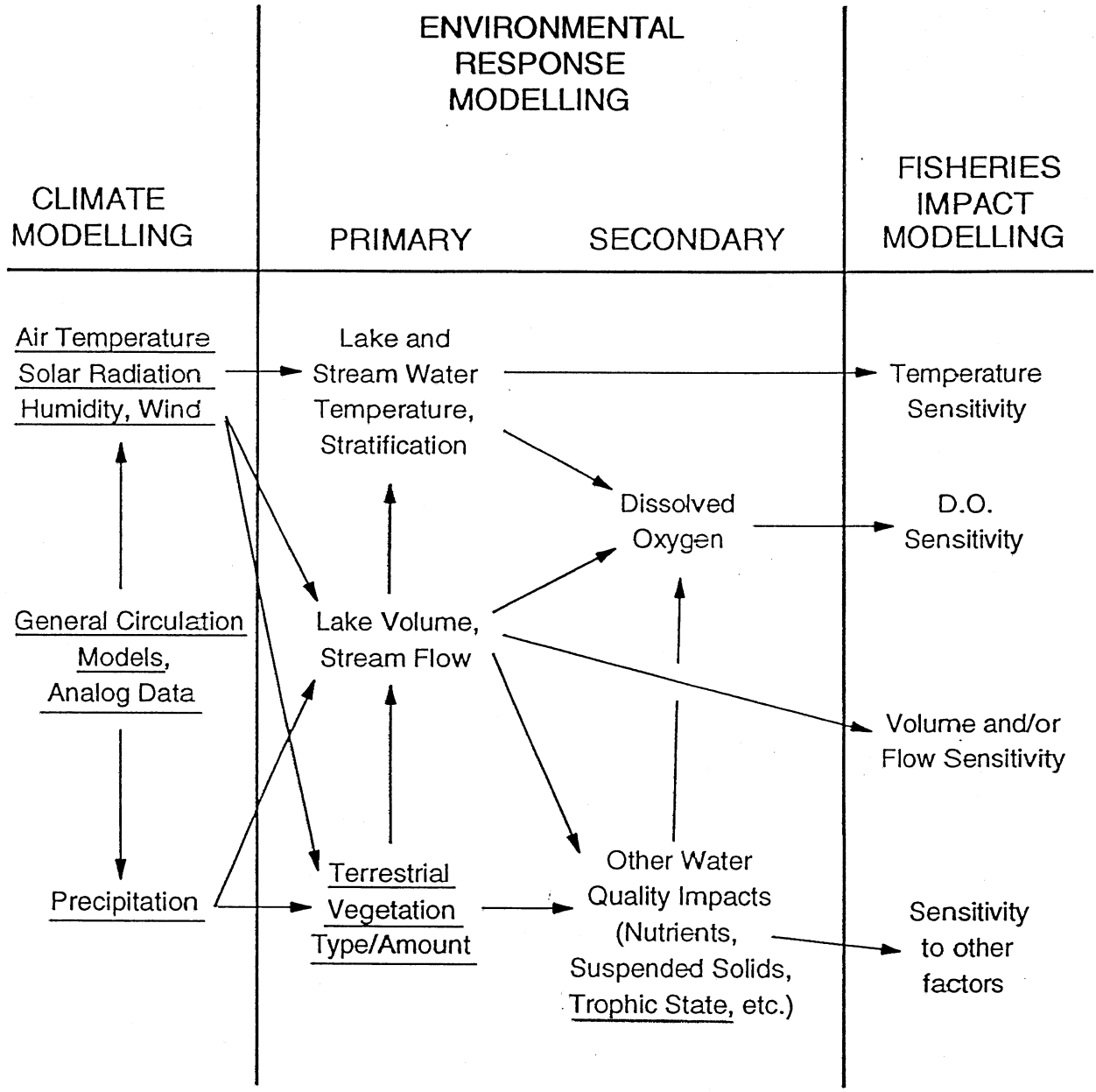
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Figure 1. Flow of information between modeling components of the climate change impact analysis leading to fisheries responses.

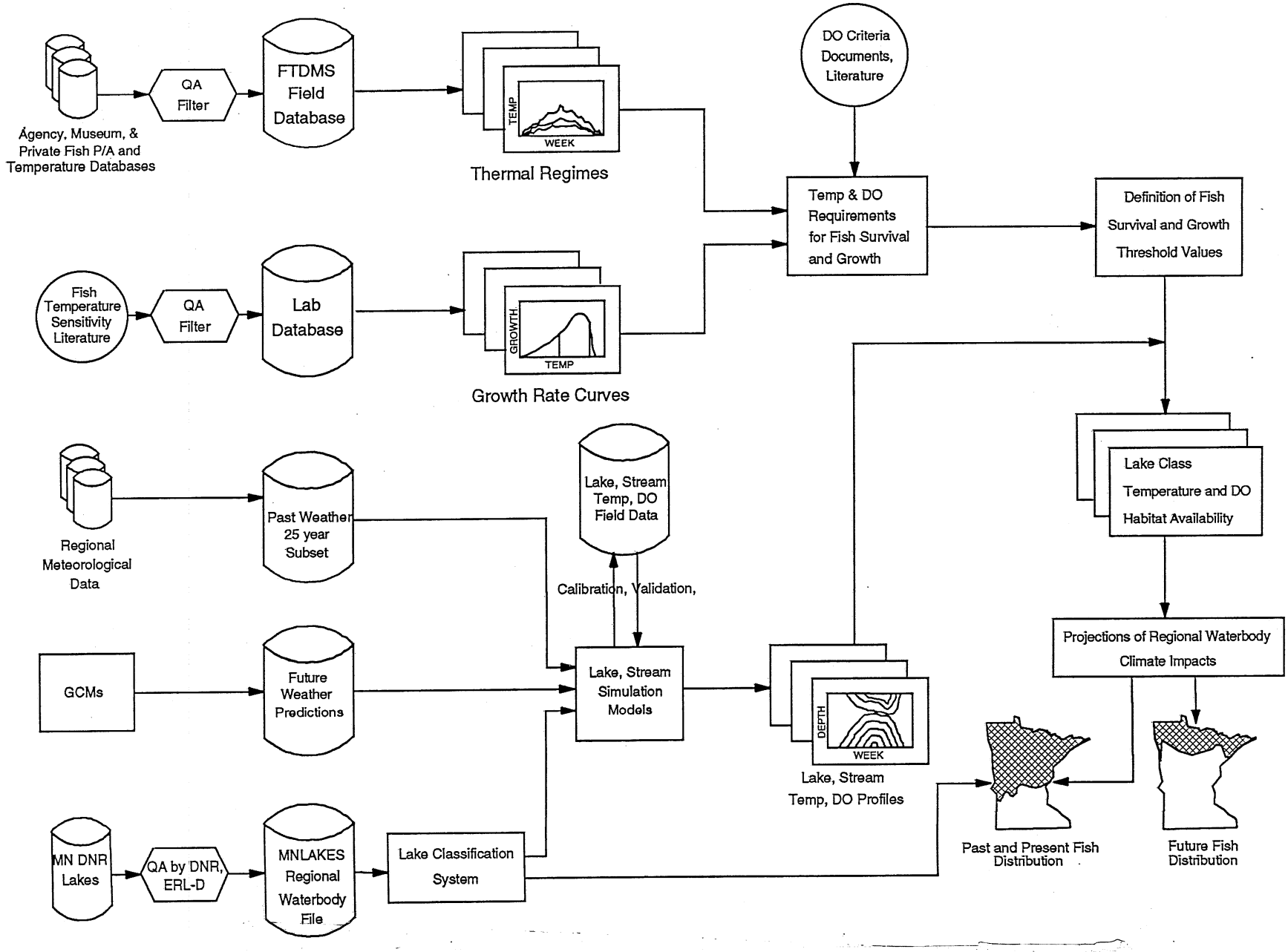


Figure 2. Regional global warming fisheries impact analysis flow chart.

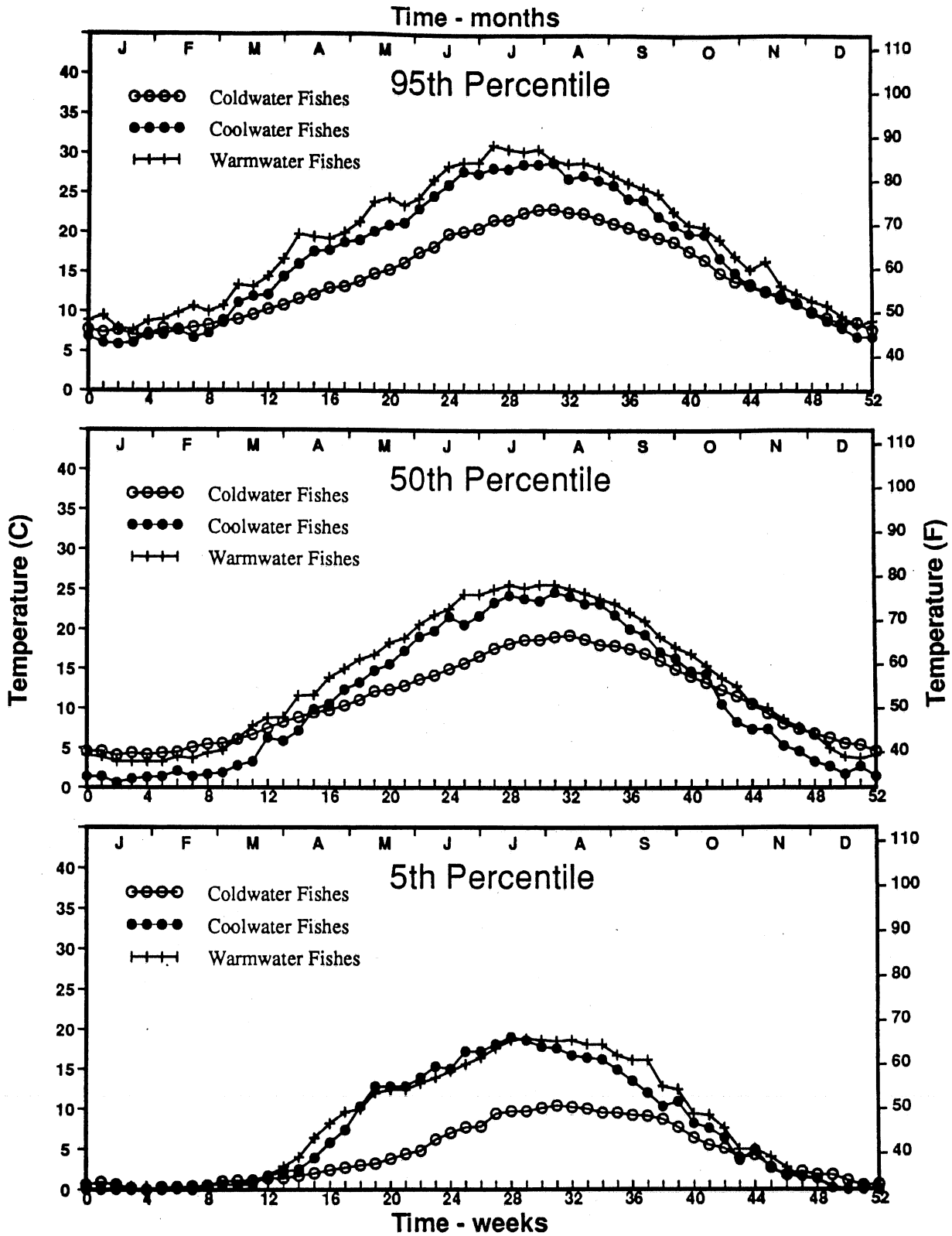
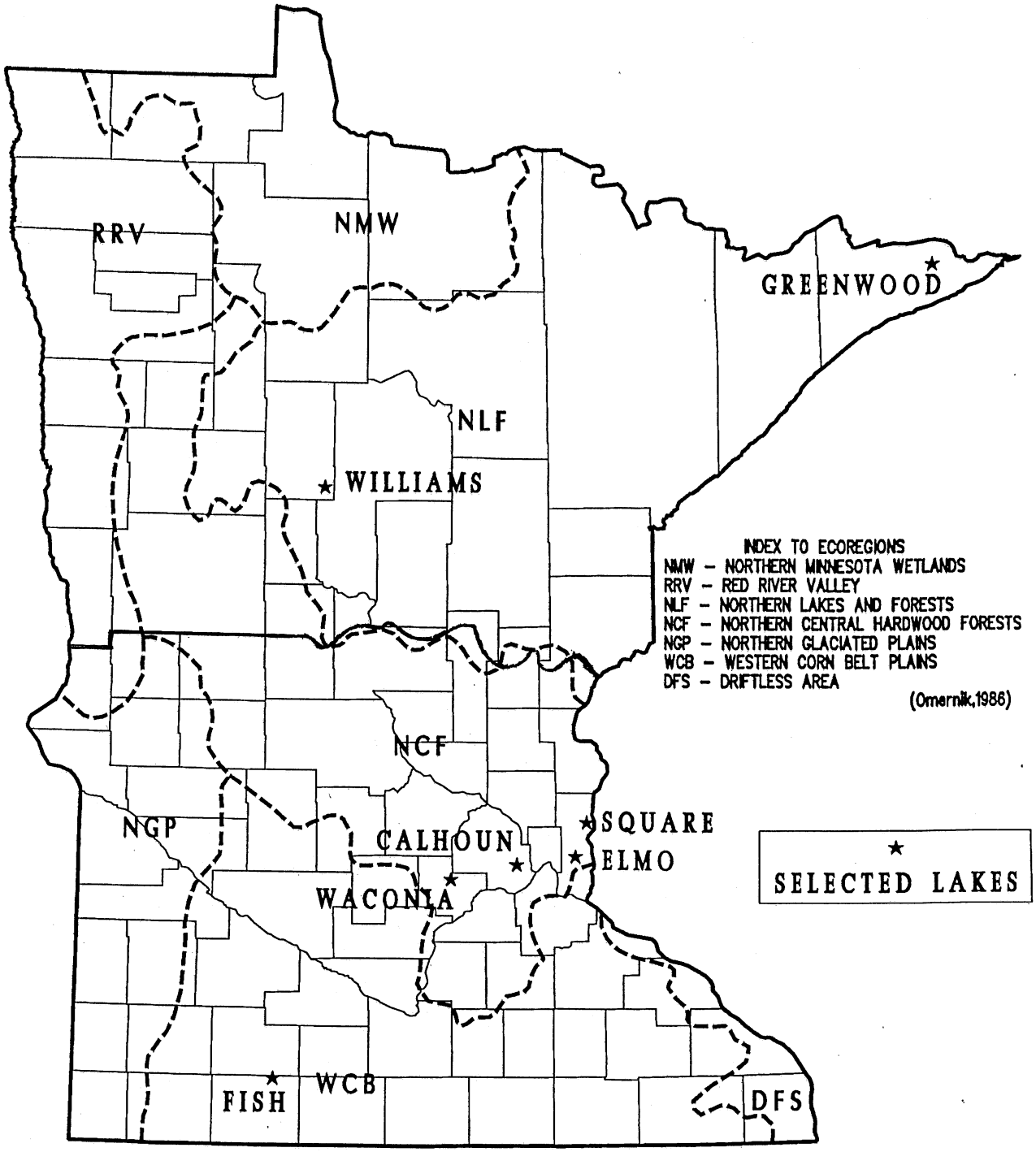


Figure 3. Seasonal temperature regimes among fish thermal guilds for the 5th, 50th and 95th percentile of occurrence of weekly mean temperature (°C) in the FTDMS database (from Hokanson et al. 1991).



MINNESOTA SELECTED LAKES

Figure 4. North and south regions selected for study. Locations of seven selected lakes. Ecoregion boundaries are also shown for reference.

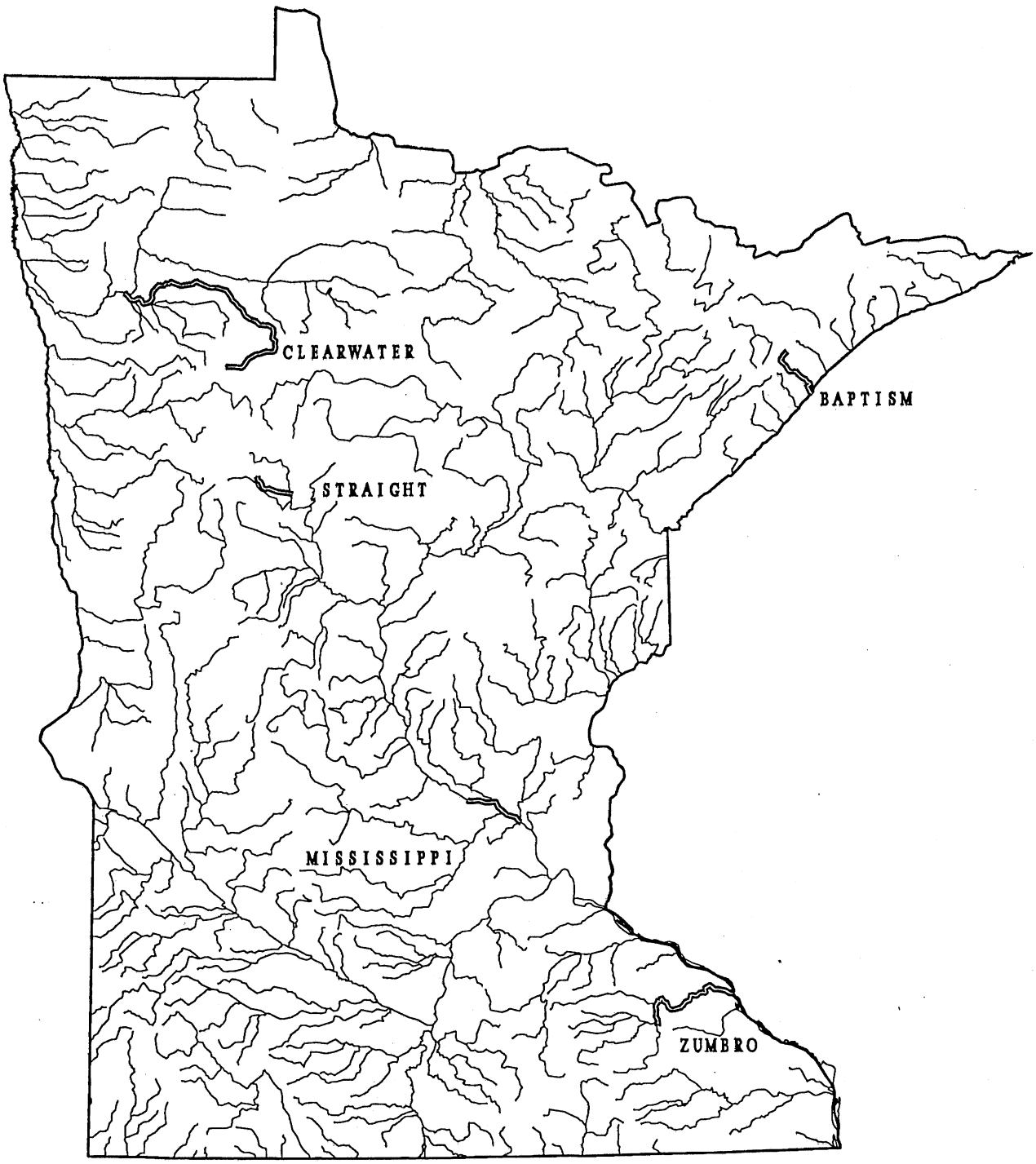


Figure 5. Location of selected streams.

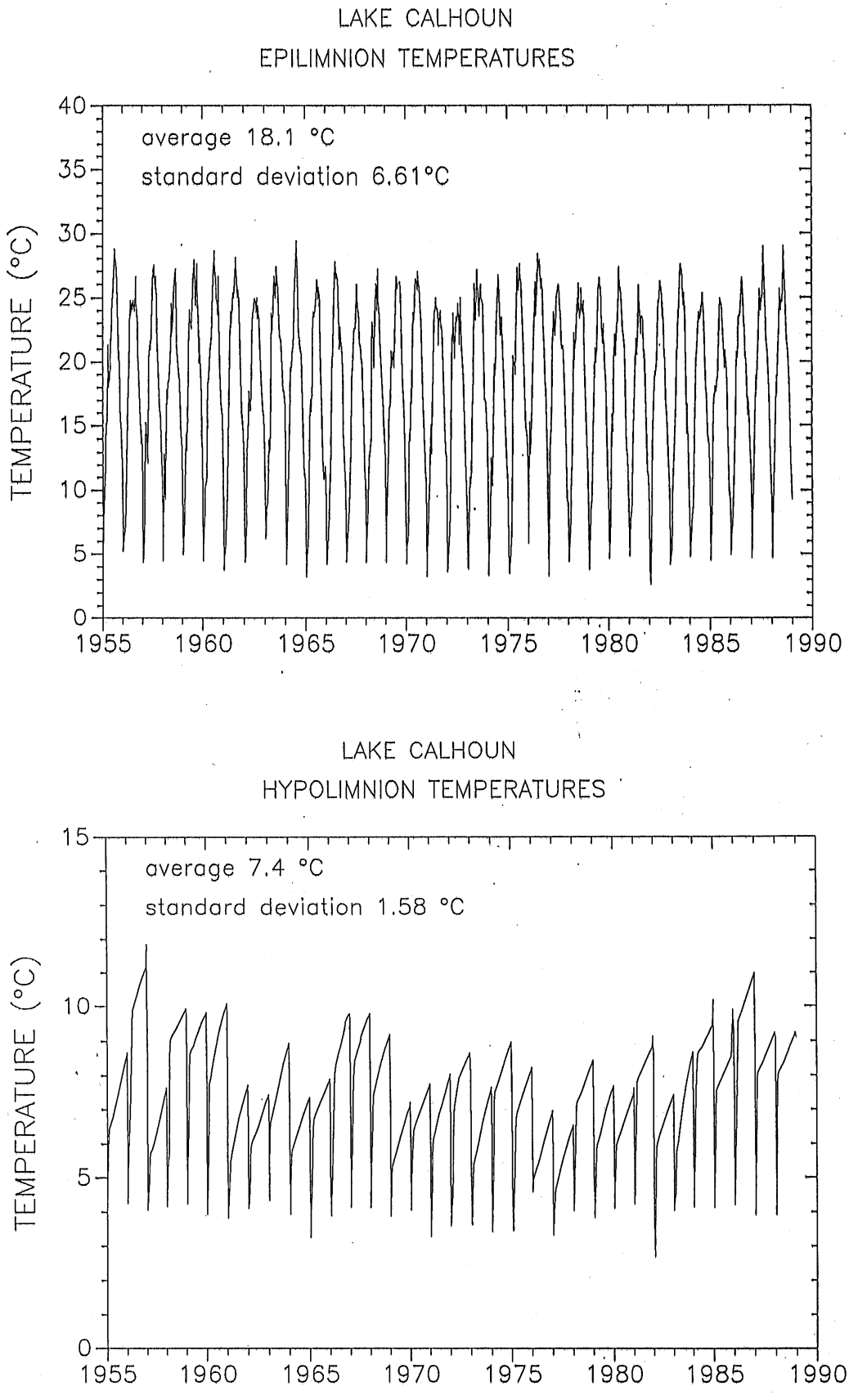
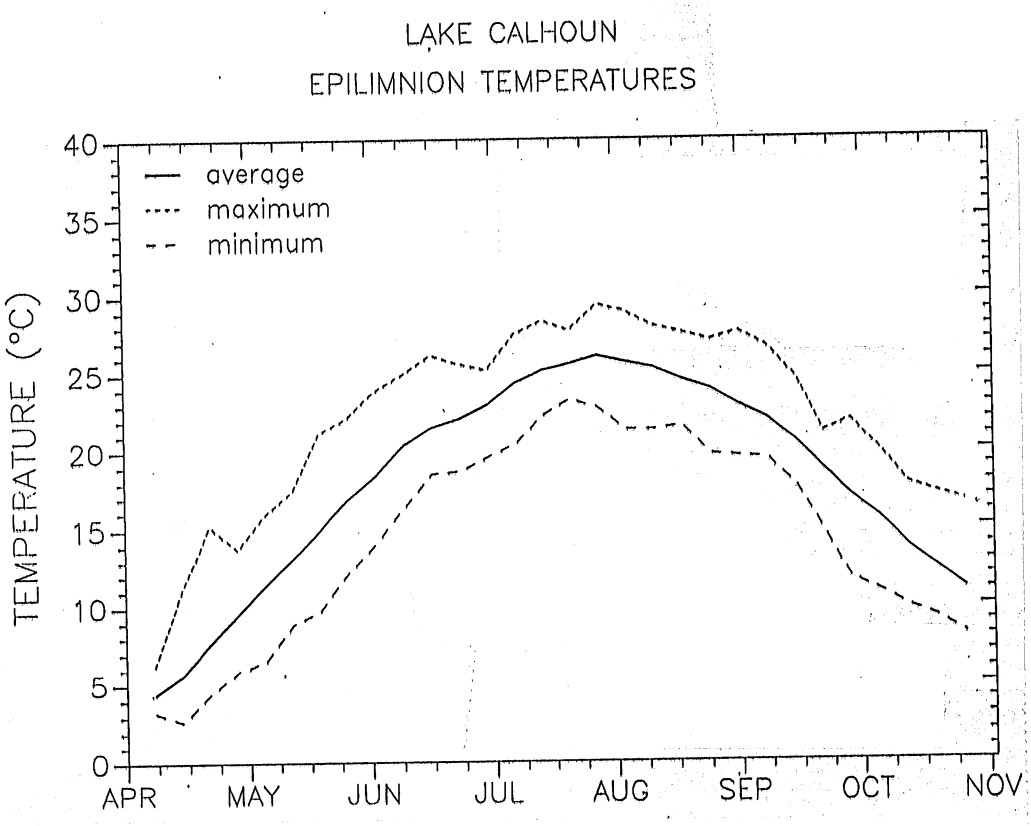


Figure 6. Water temperature time series simulated for Lake Calhoun (1955–1988).



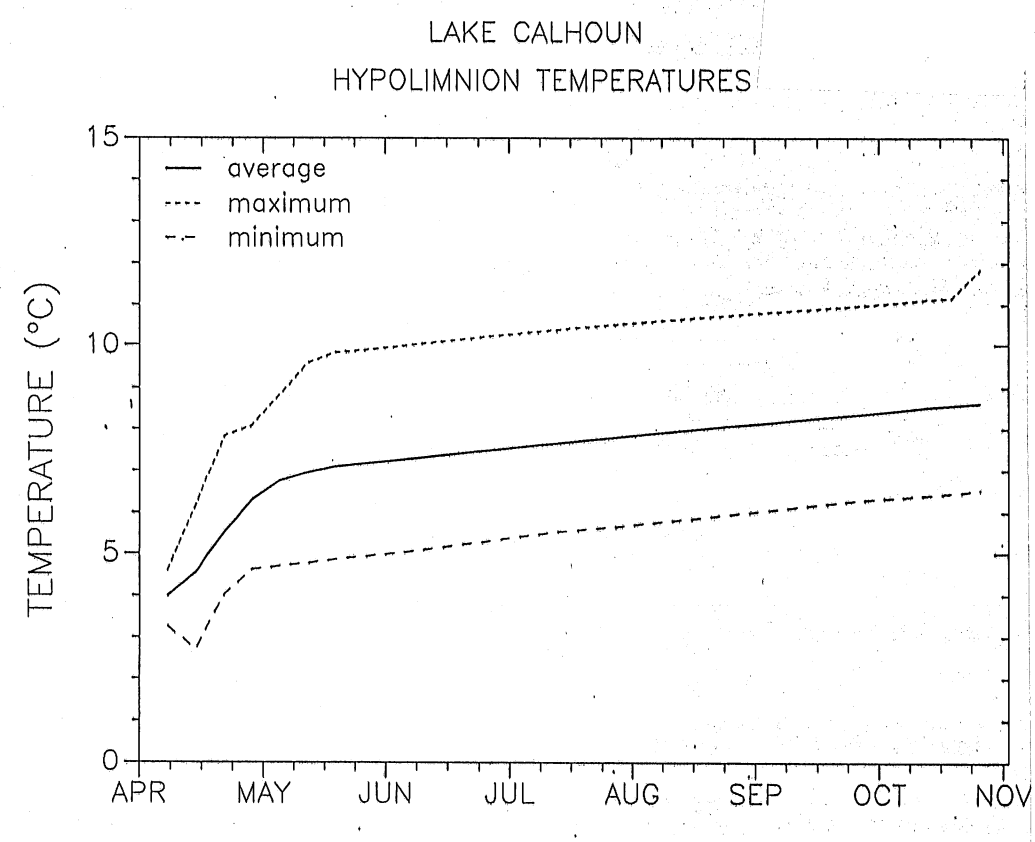


Figure 7. Weekly average temperatures in Lake Calhoun (1955–1988).

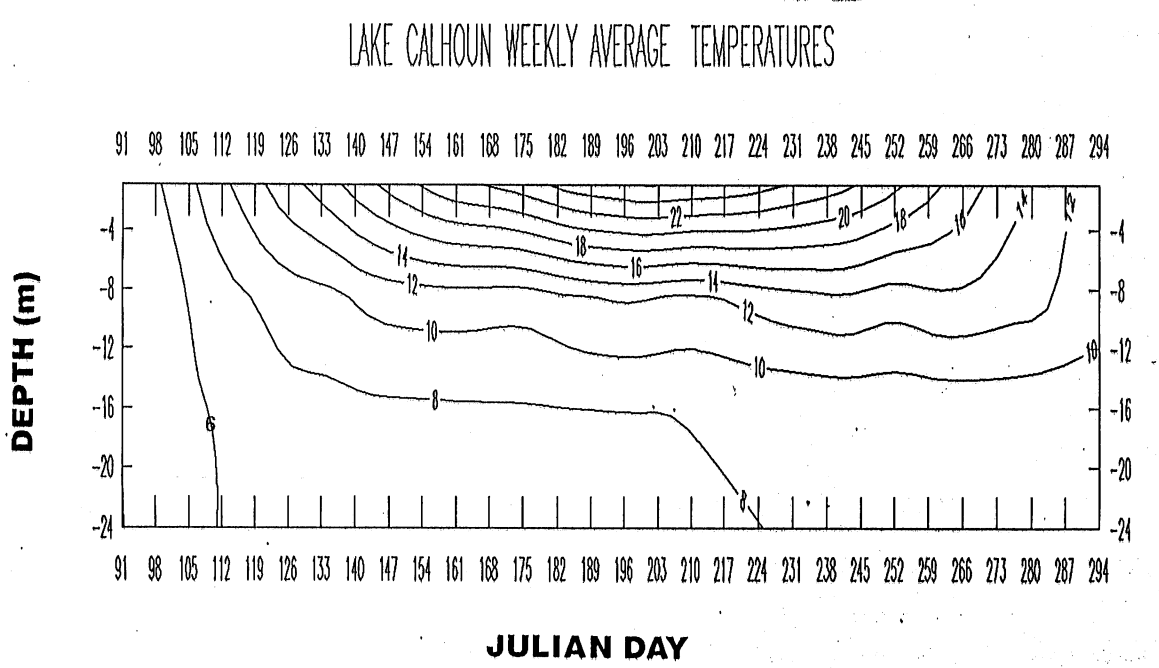


Figure 8. Weekly average isotherms in Lake Calhoun (1955–1988).

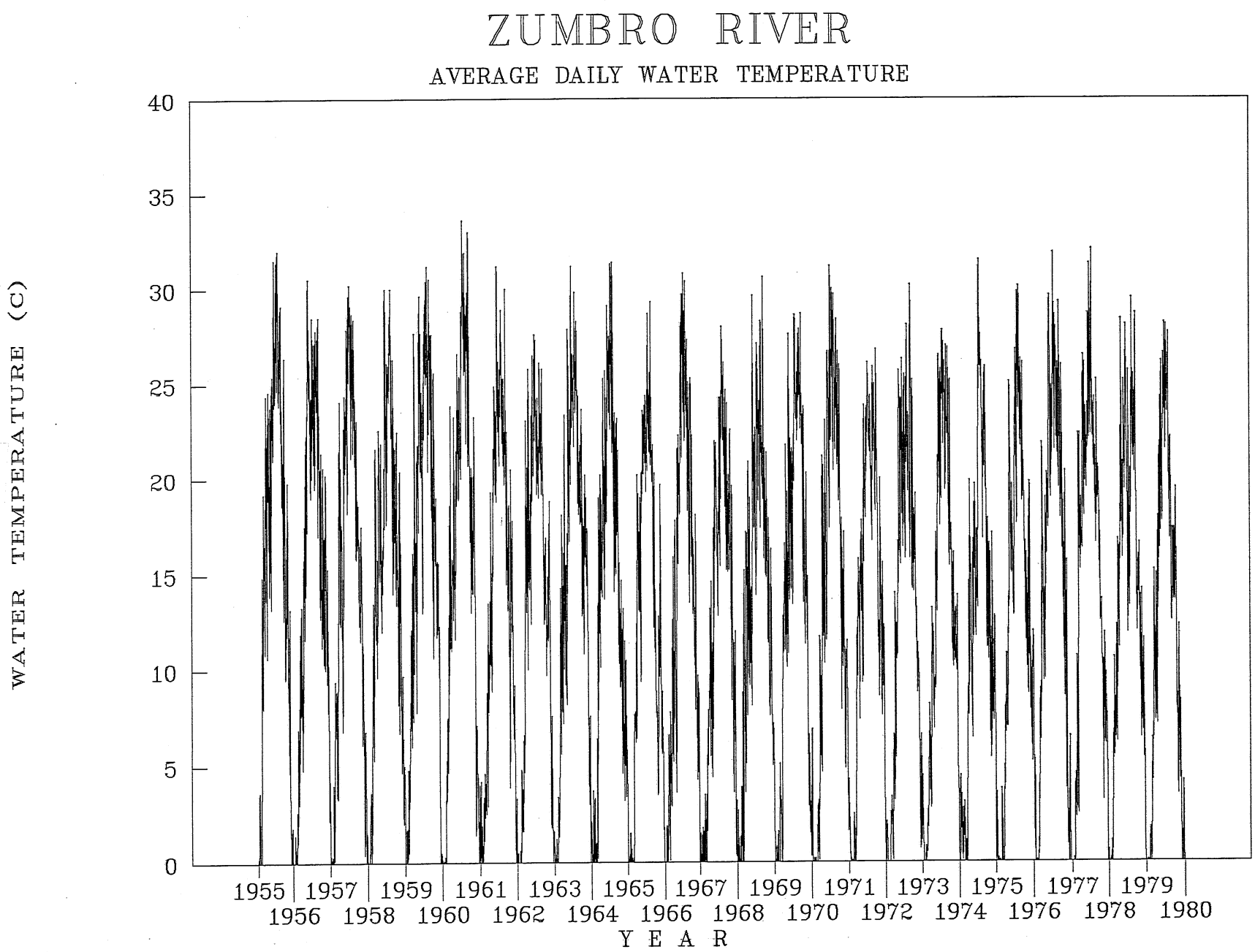


Figure 9. Water temperature time series simulated for the Zumbro River (1955–1979).

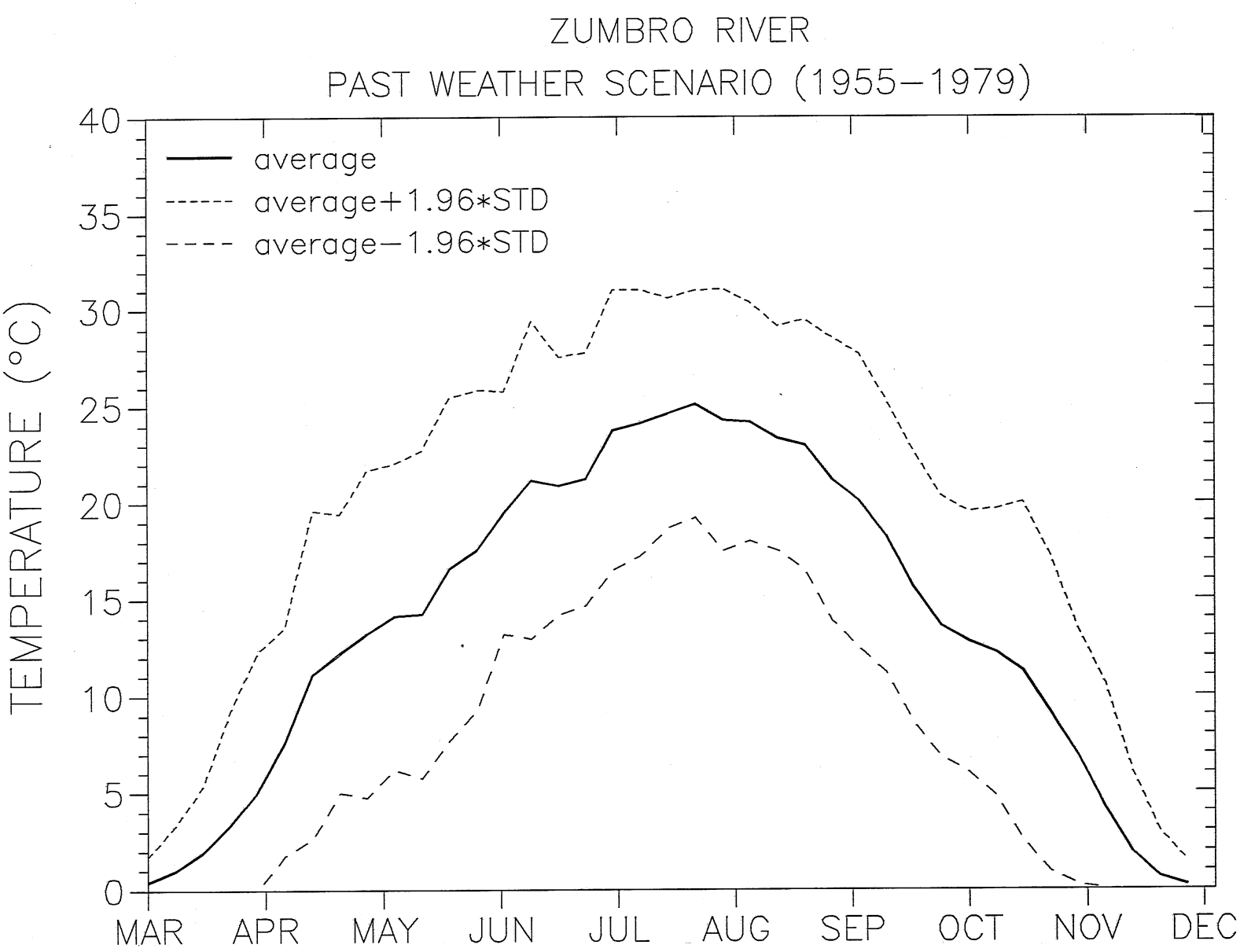


Figure 10. Weekly average temperatures in Zumbro River (1955–1979).

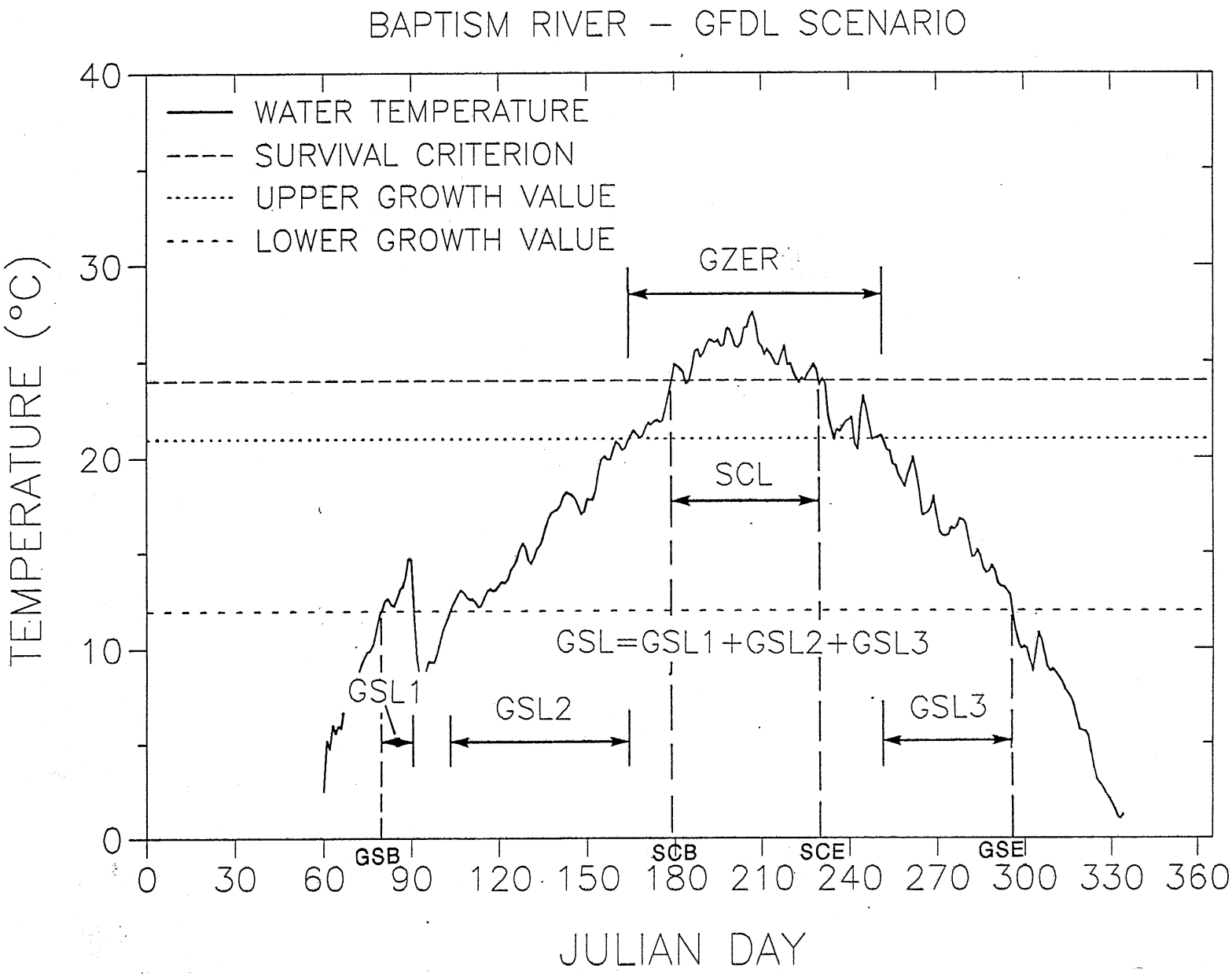


Figure 11. Example graph for fish survival and growth parameters (numbers are examples only). For acronyms see pp. v to xi.

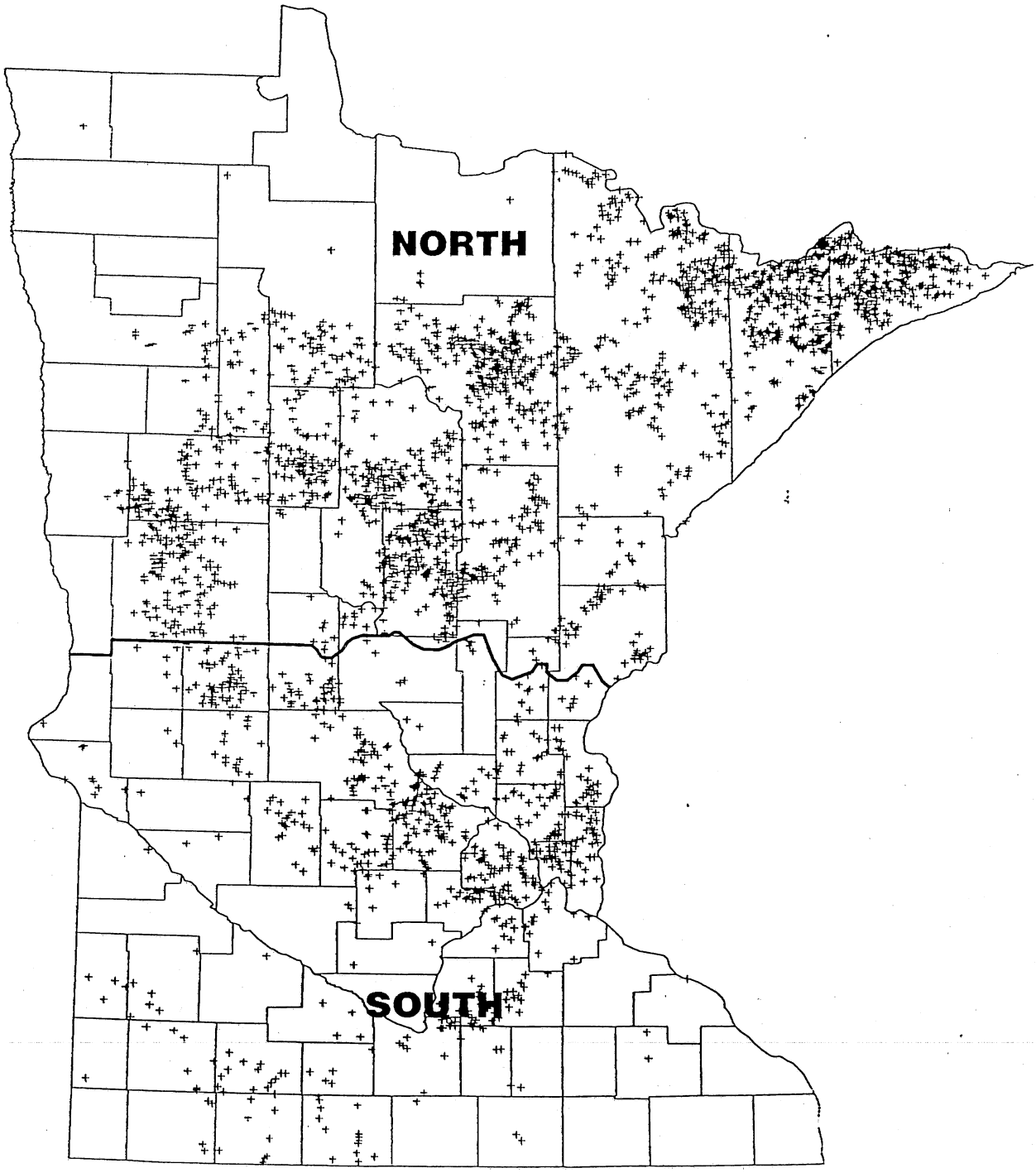


Fig. 12a. Regional boundaries and geographic distribution of lakes in MLFD database.

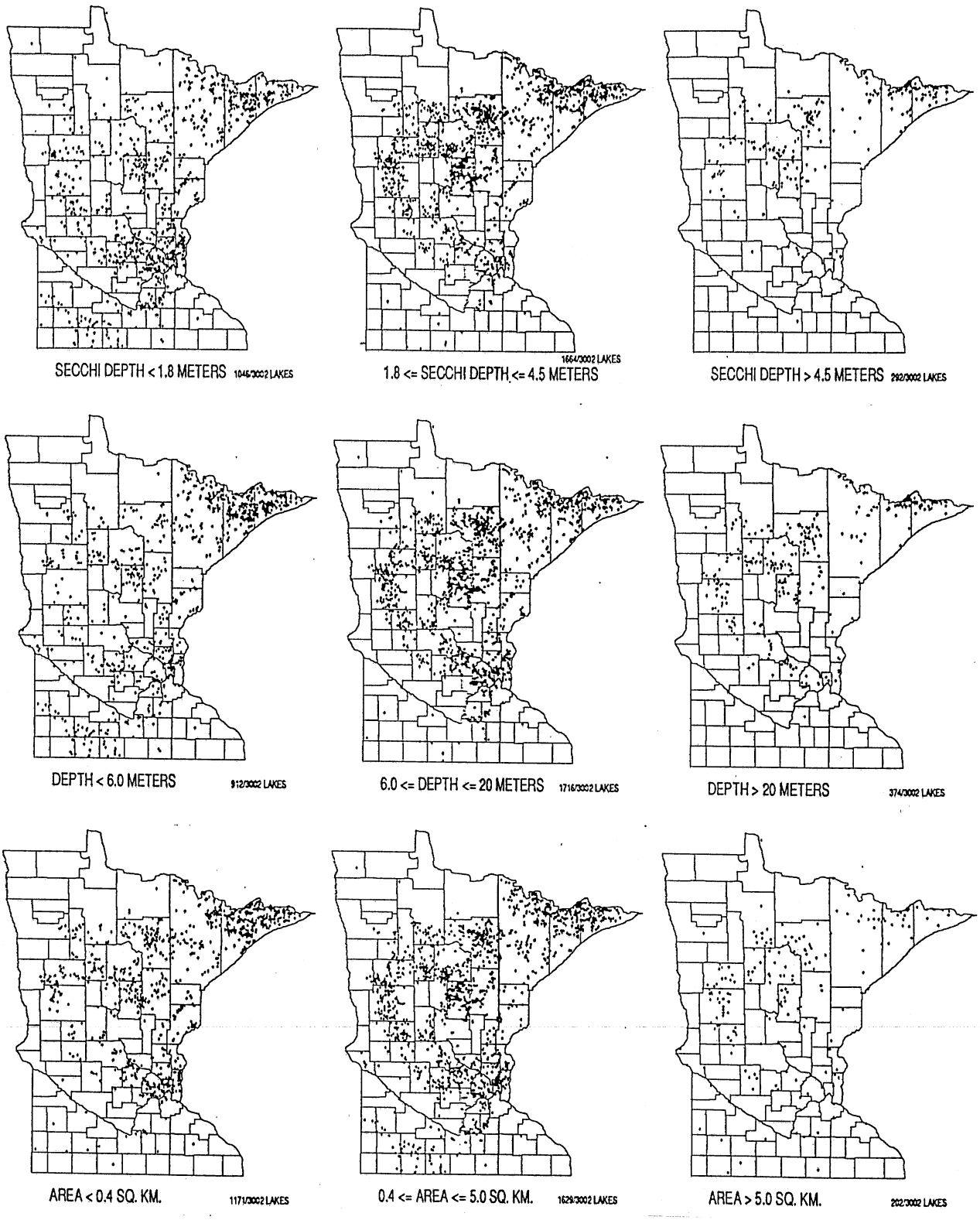


Fig. 12b. Geographic distribution of lakes based on key physical parameters. Rows show secchi depth, maximum depth and surface area, respectively.

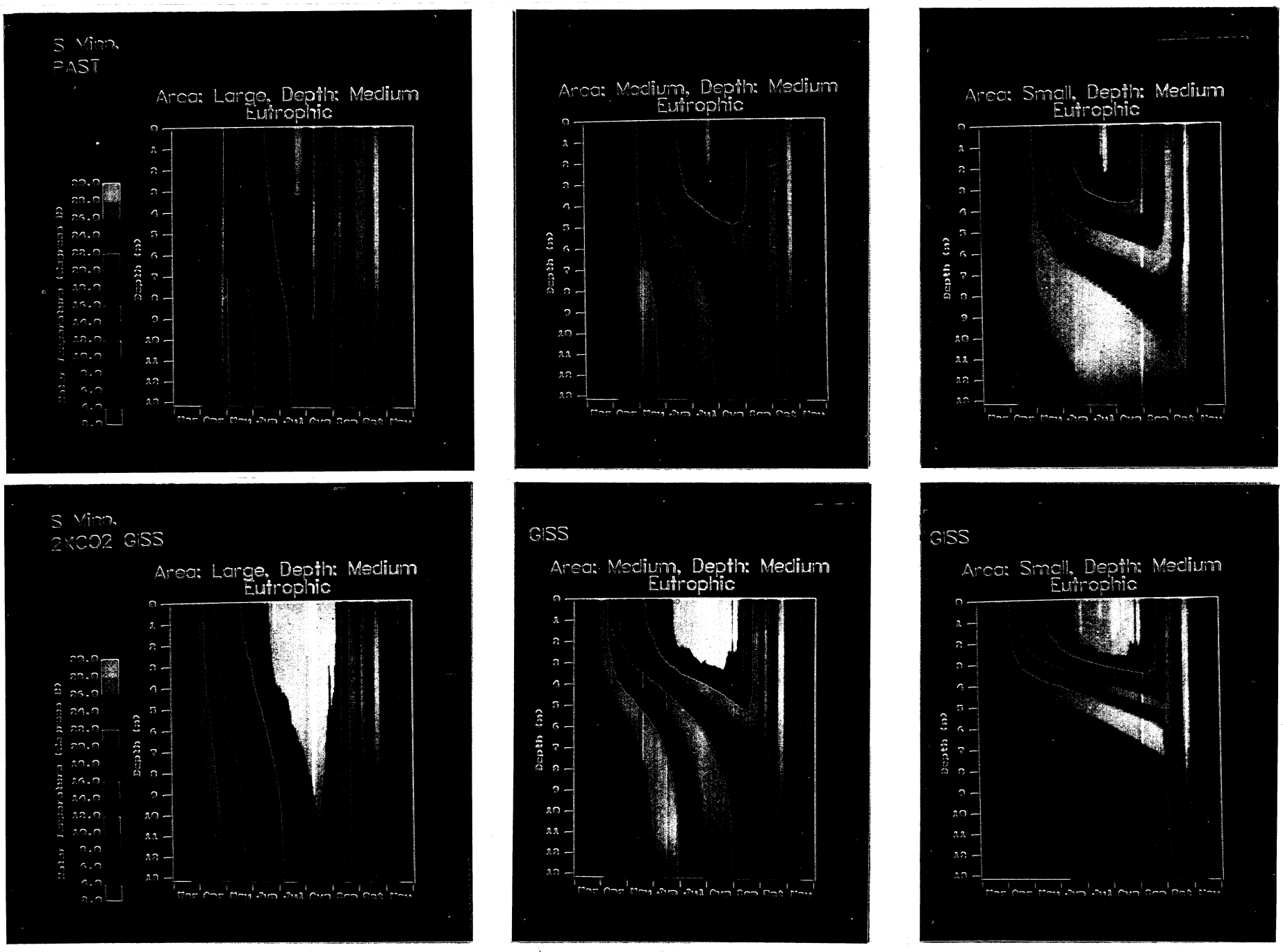


Figure 13a. Simulated temperature (isotherm) structure in three medium deep (13 m maximum depth) lakes of large (10 km^2), medium (1.7 km^2) and small (0.2 km^2) surface area. Isotherm bands are in increments of 2° C. Simulated water temperatures are for past climate (1955–79) (top) and the $2XCO_2$ GISS climate scenario (bottom).

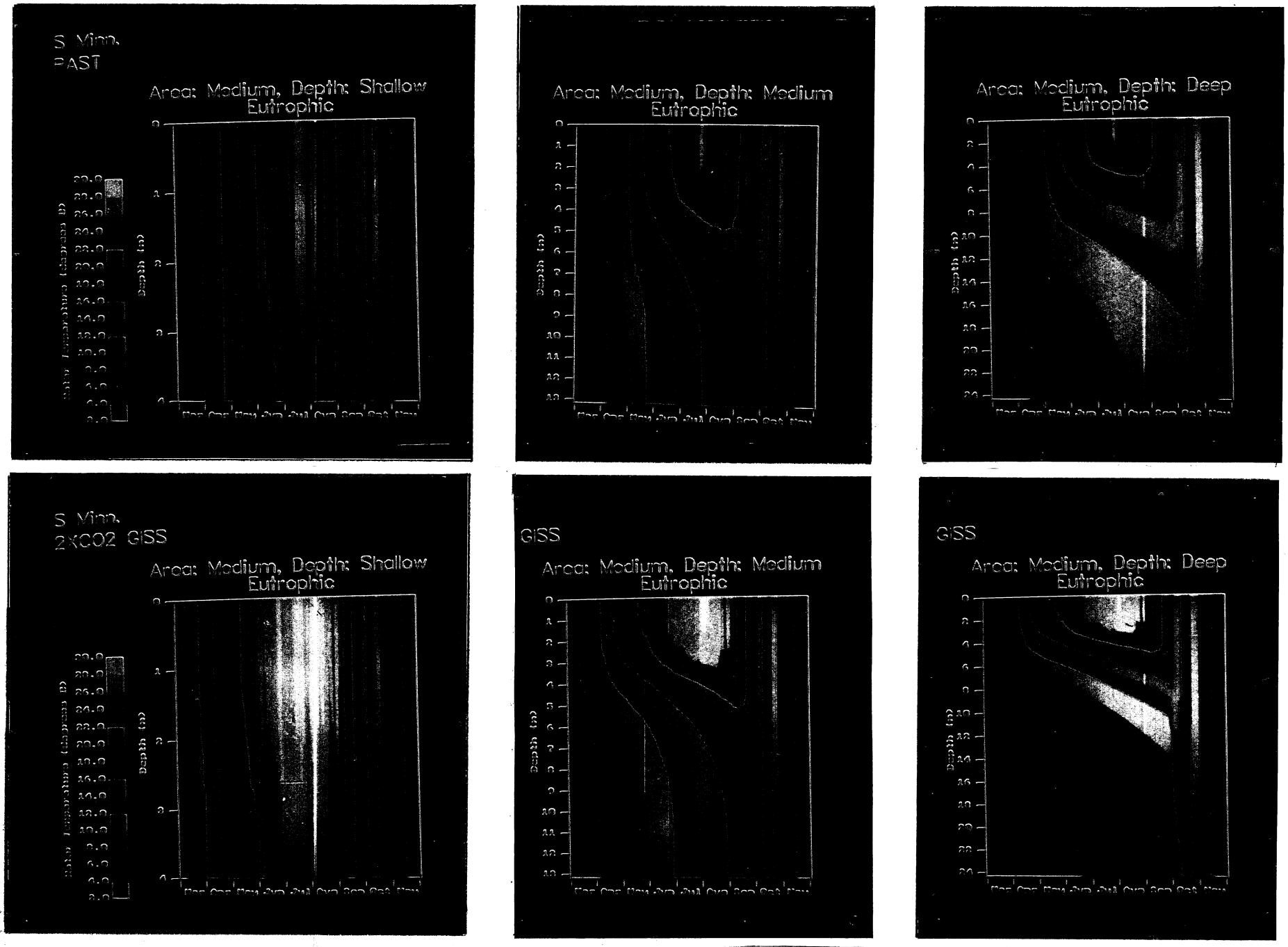


Figure 13b. Simulated temperature (isotherm) structure in three medium area (1.7 km^2) lakes of different maximum depths: shallow (4 m), medium (13 m) and deep (24 m). Isotherm bands are in increments of 2° C. Simulated water temperatures are for past climate (1955–79) (top) and the $2XCO_2$ GISS climate scenario (bottom).

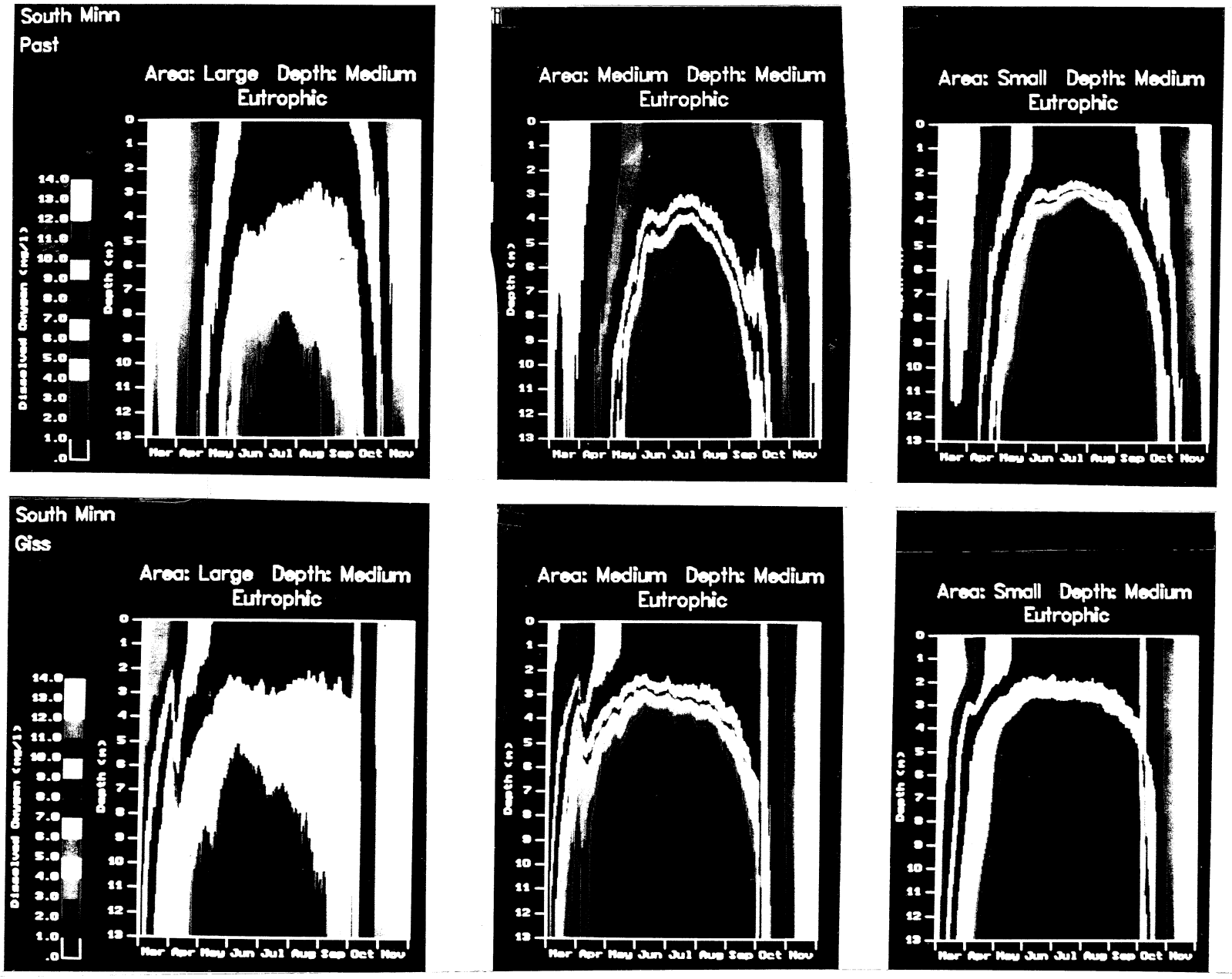


Figure 14a. Simulated dissolved oxygen isopleths in three medium deep (13 m maximum depth) lakes of large (10 km^2), medium (1.7 km^2) and small (0.2 km^2) surface area. Isopleth bands are in increments of 1mg/l. Simulated dissolved oxygen values are for past climate (1955–79) (top) and the $2XCO_2$ GISS climate scenario (bottom).

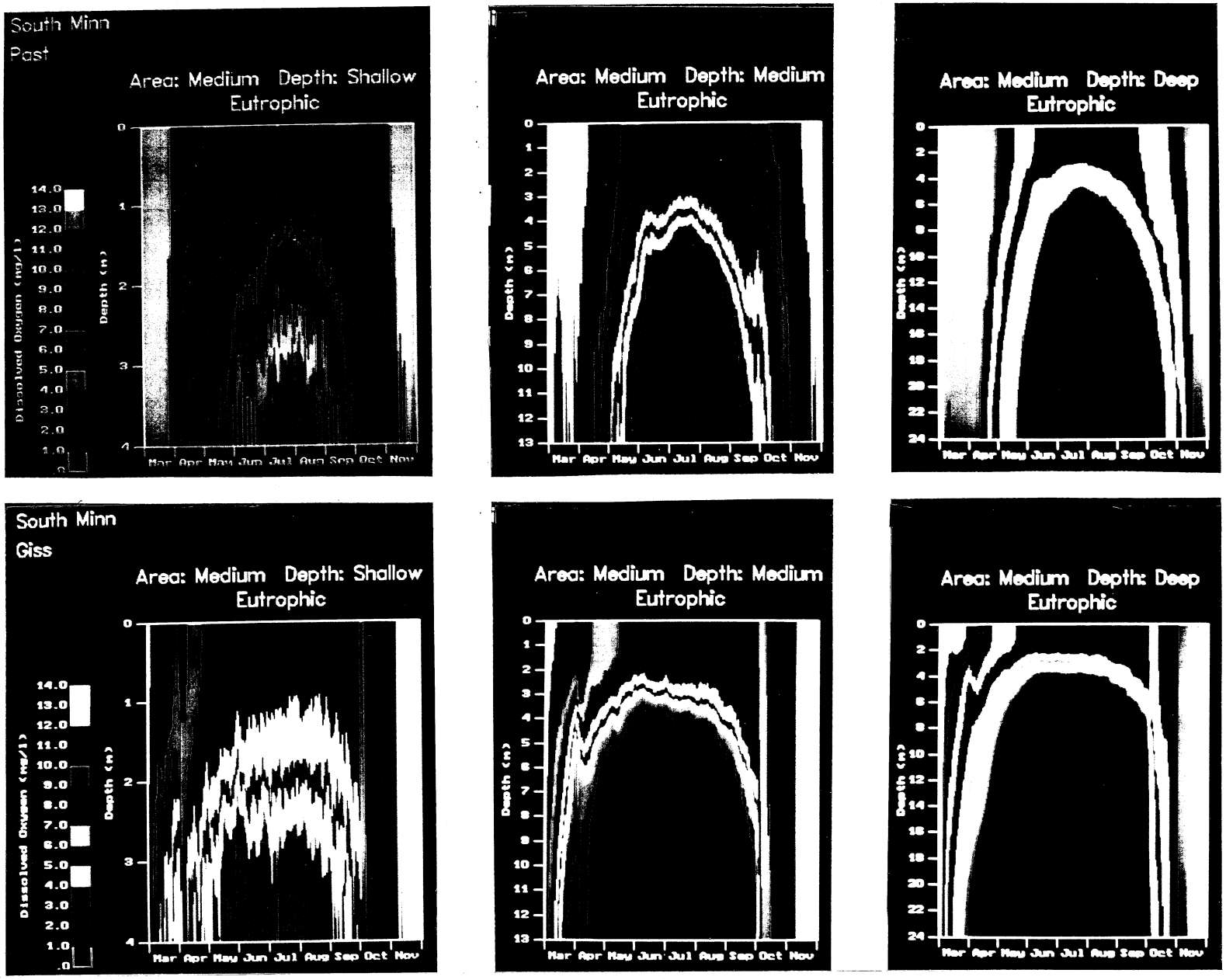


Figure 14b. Simulated dissolved oxygen isopleths in three medium area (1.7 km^2) lakes of different maximum depth: shallow (4 m), medium (13 m) and deep (24 m). Isopleth bands are in increments of 1mg/*l*. Simulated dissolved oxygen values are for past climate (1955–79) (top) and the $2XCO_2$ GISS climate scenario (bottom).

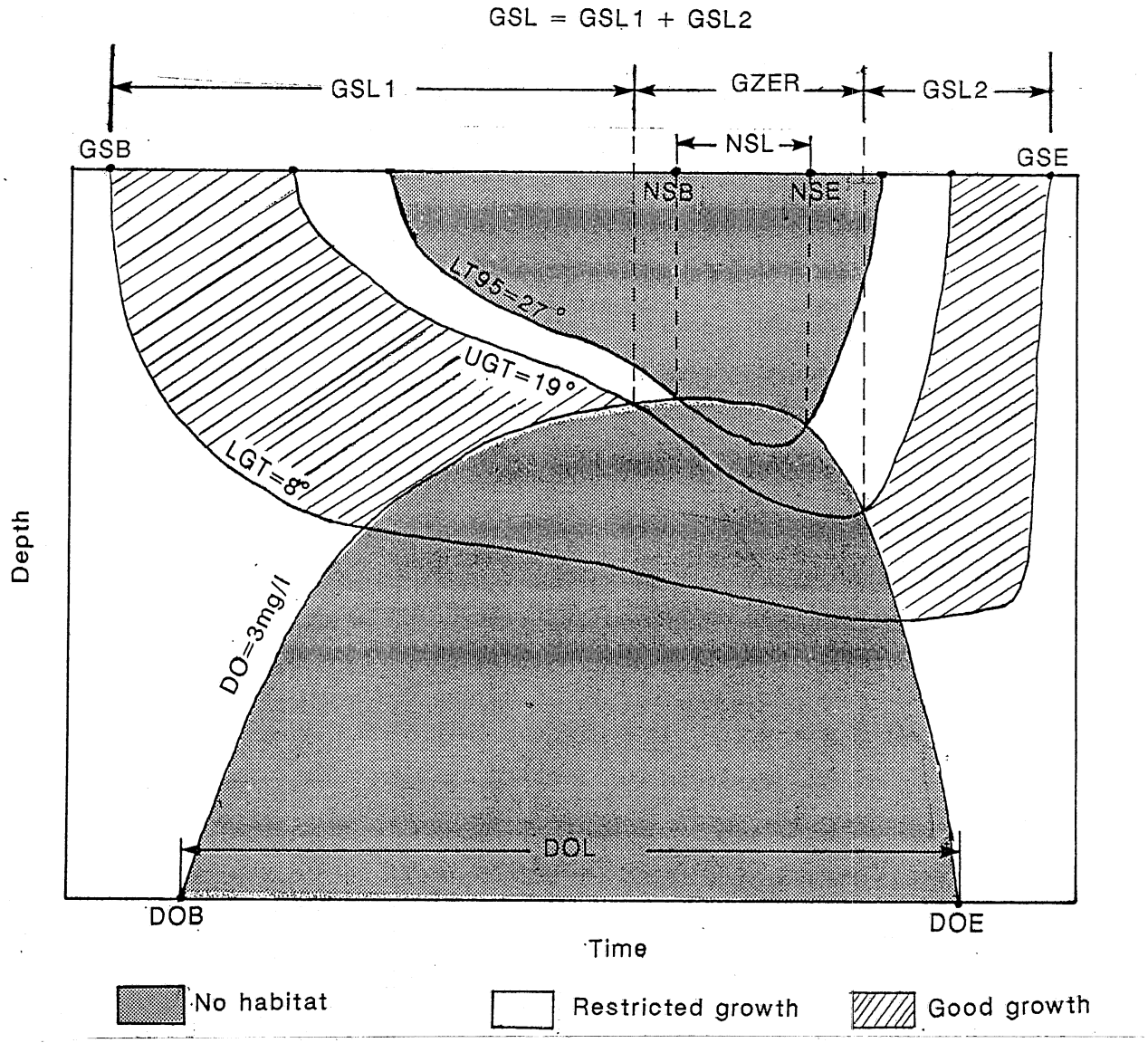


Figure 15. Example graph for fish survival and growth parameters.

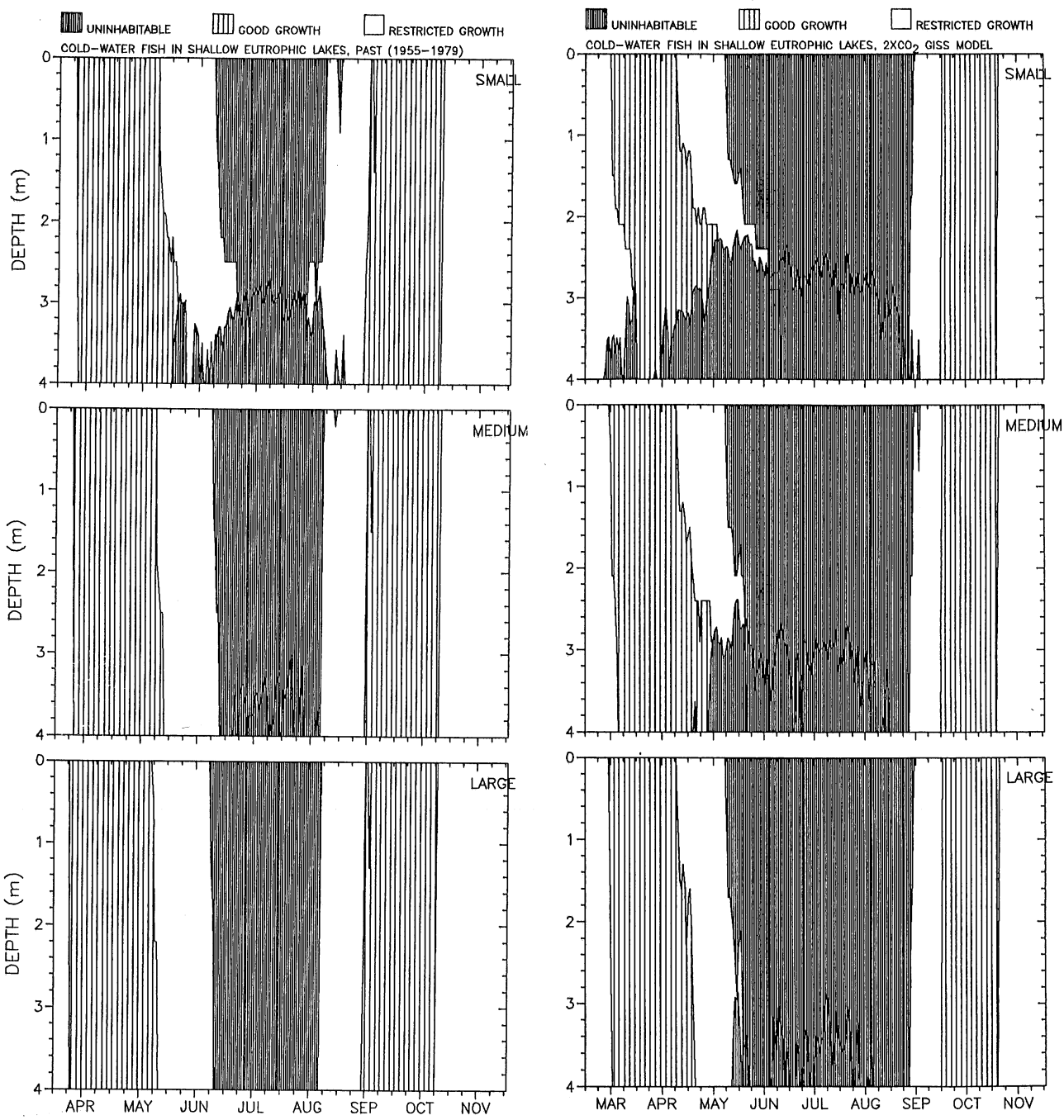


Figure 16a. Depth–time contours of coldwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

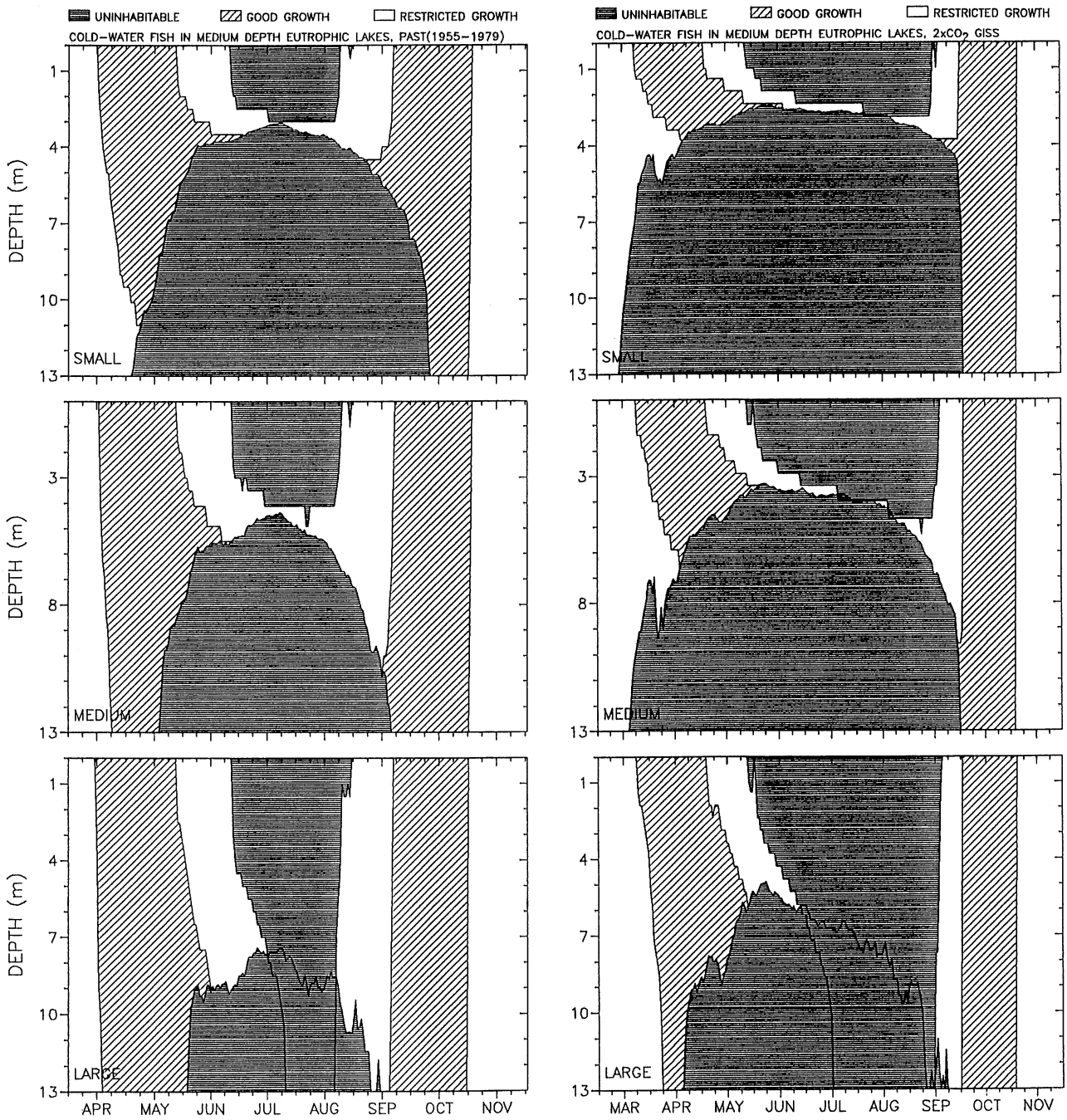


Figure 16b. Depth–time contours of coldwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

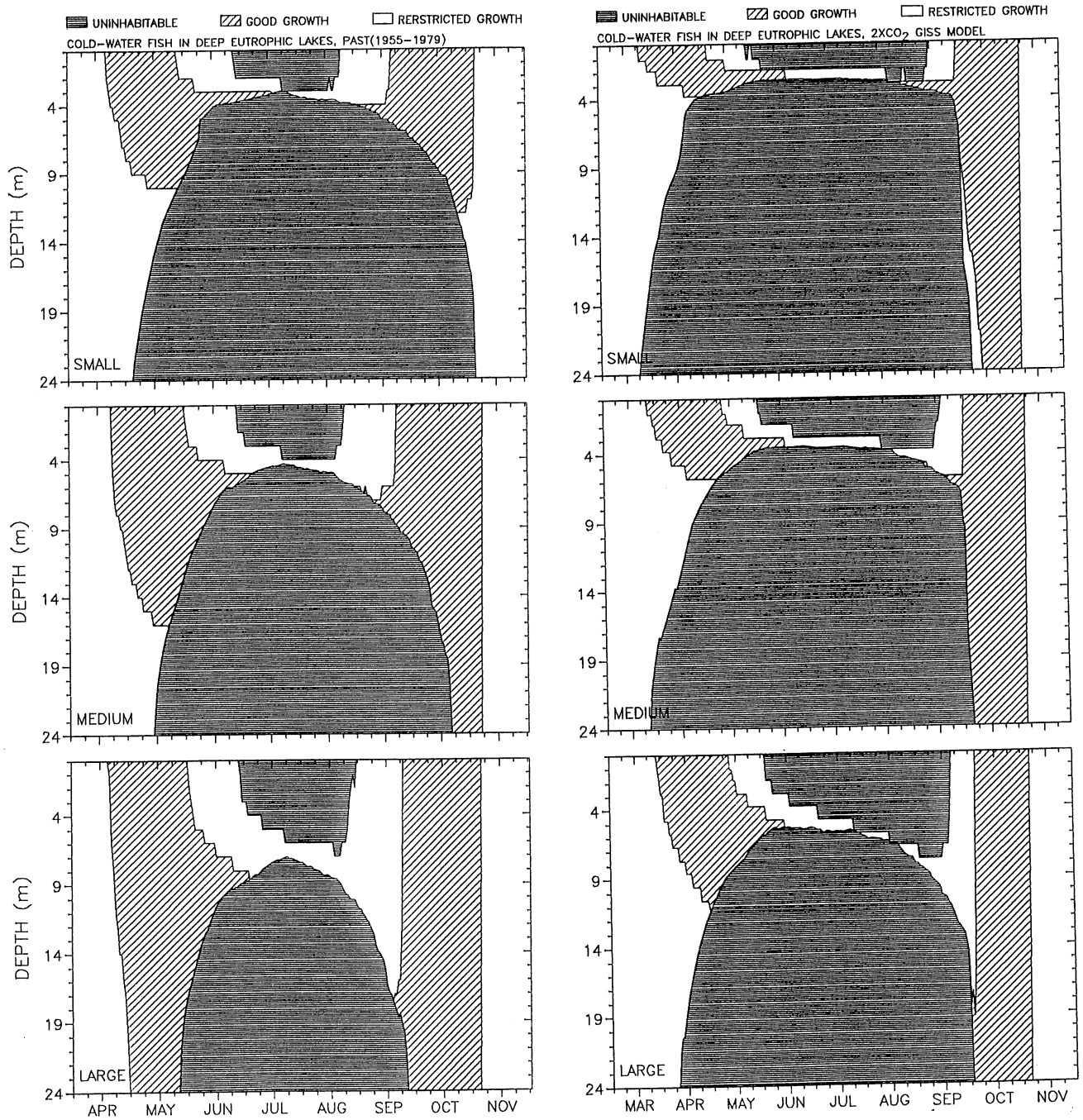


Figure 16c. Depth–time contours of coldwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

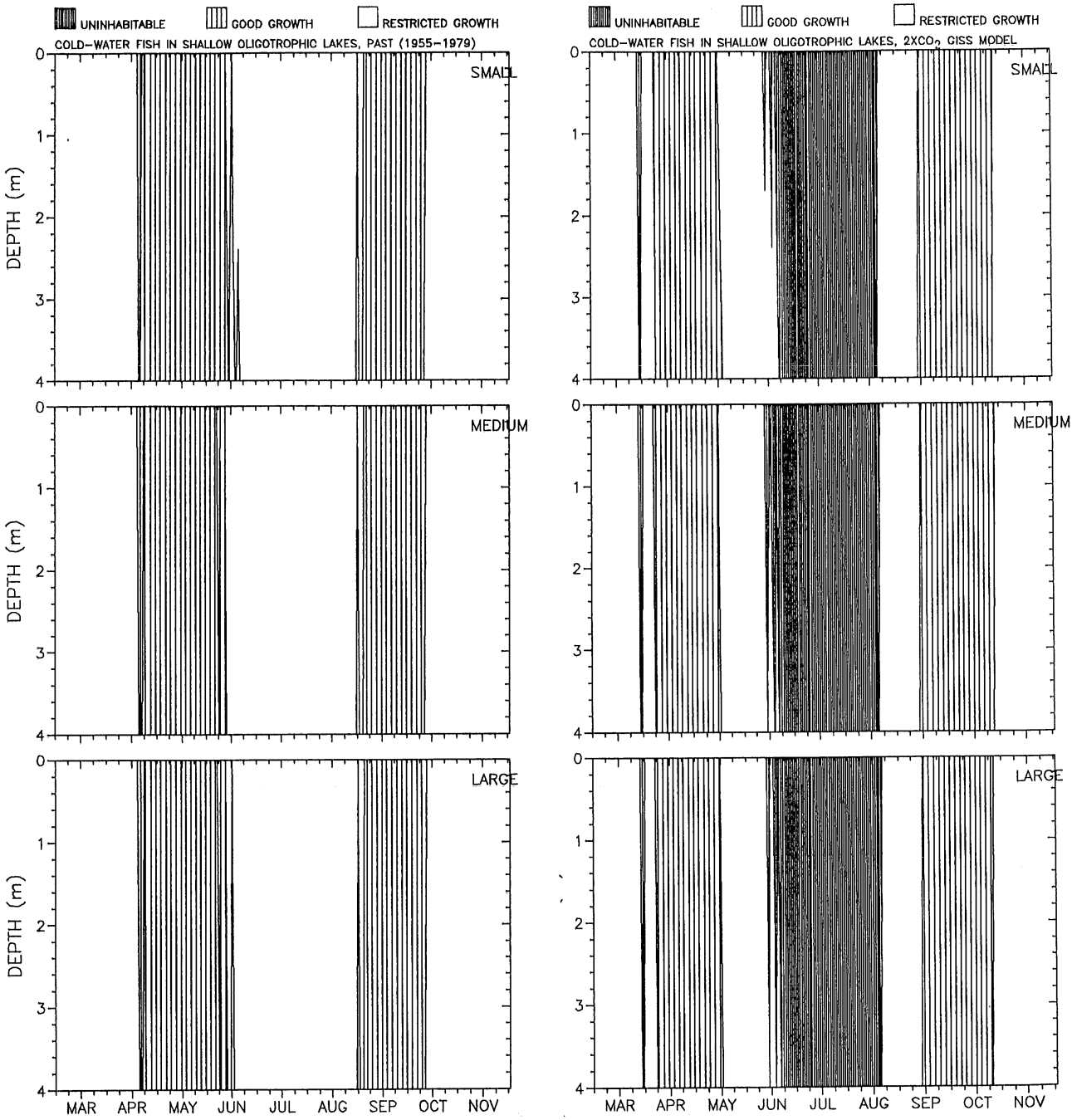


Figure 16d. Depth–time contours of coldwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

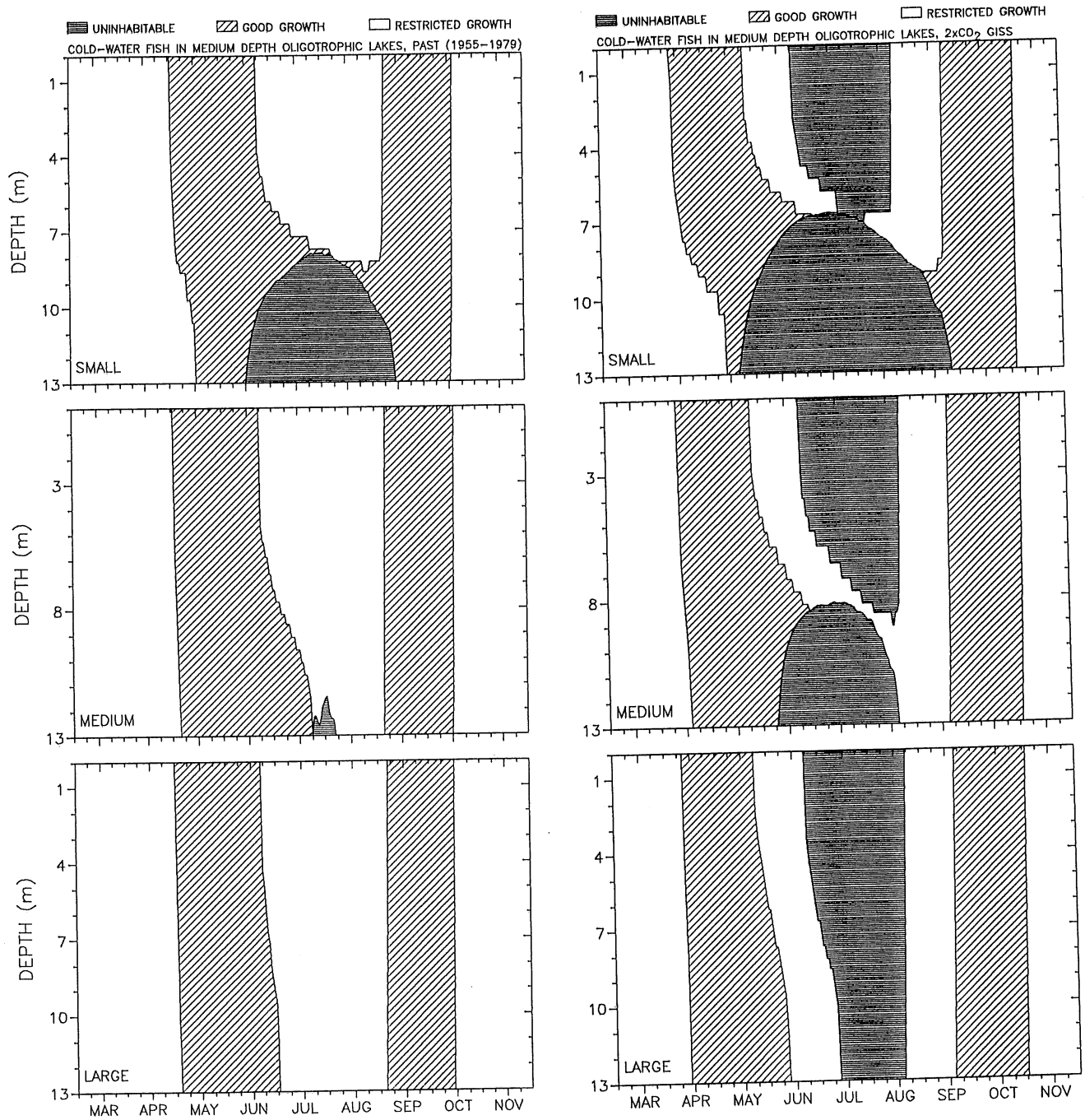


Figure 16e. Depth–time contours of coldwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

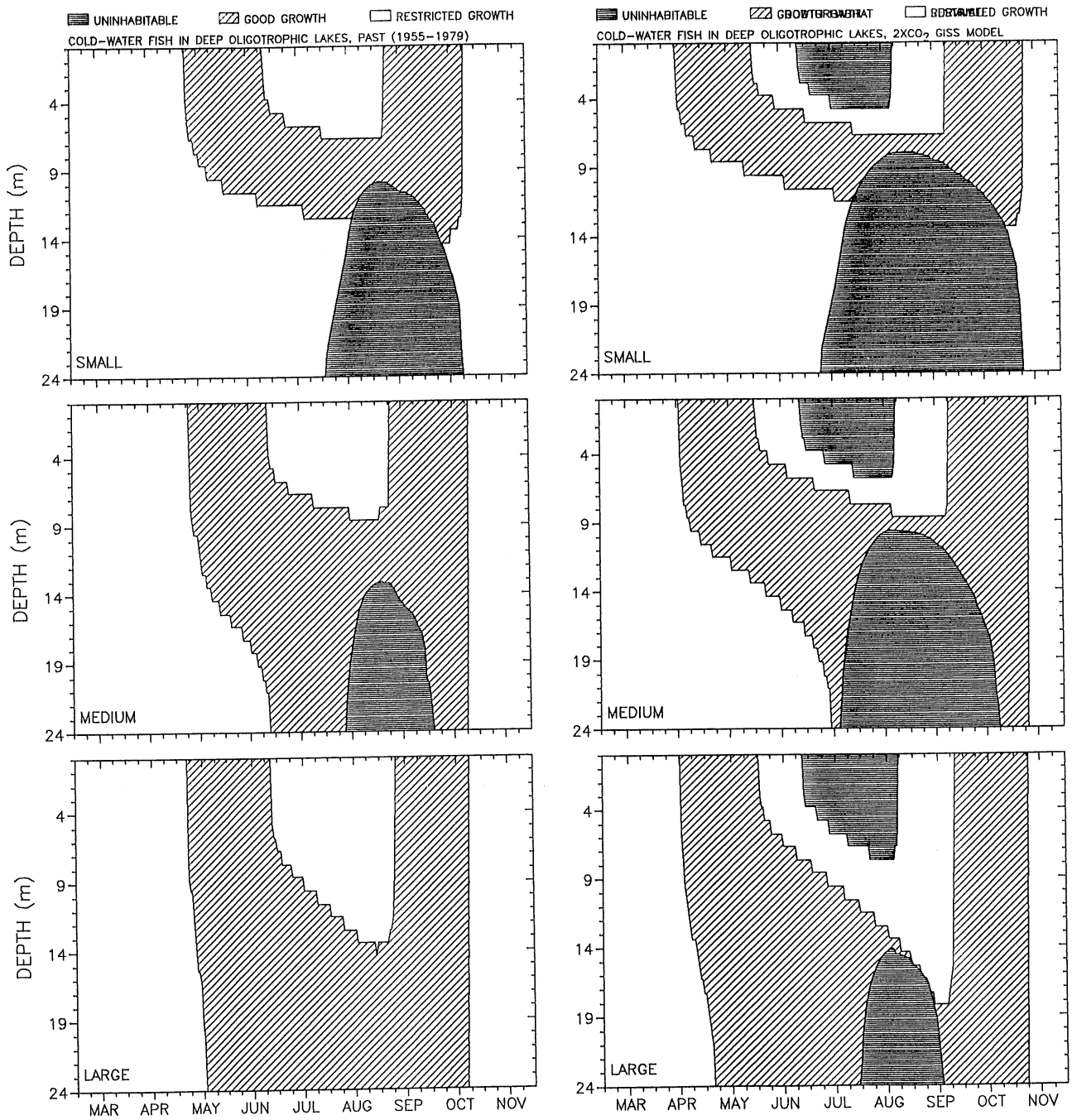


Figure 16f. Depth–time contours of coldwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

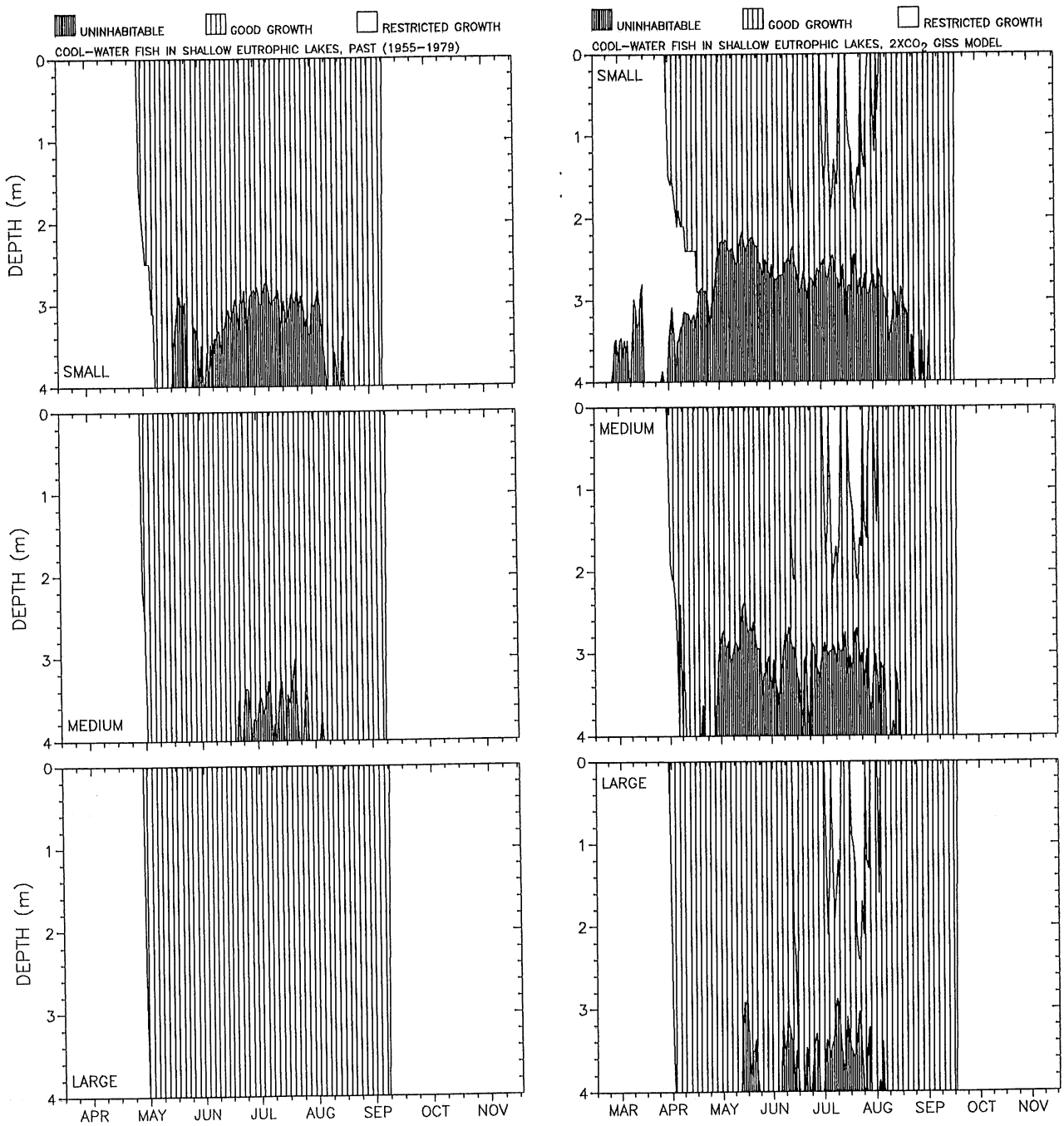


Figure 17a. Depth–time contours of coolwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

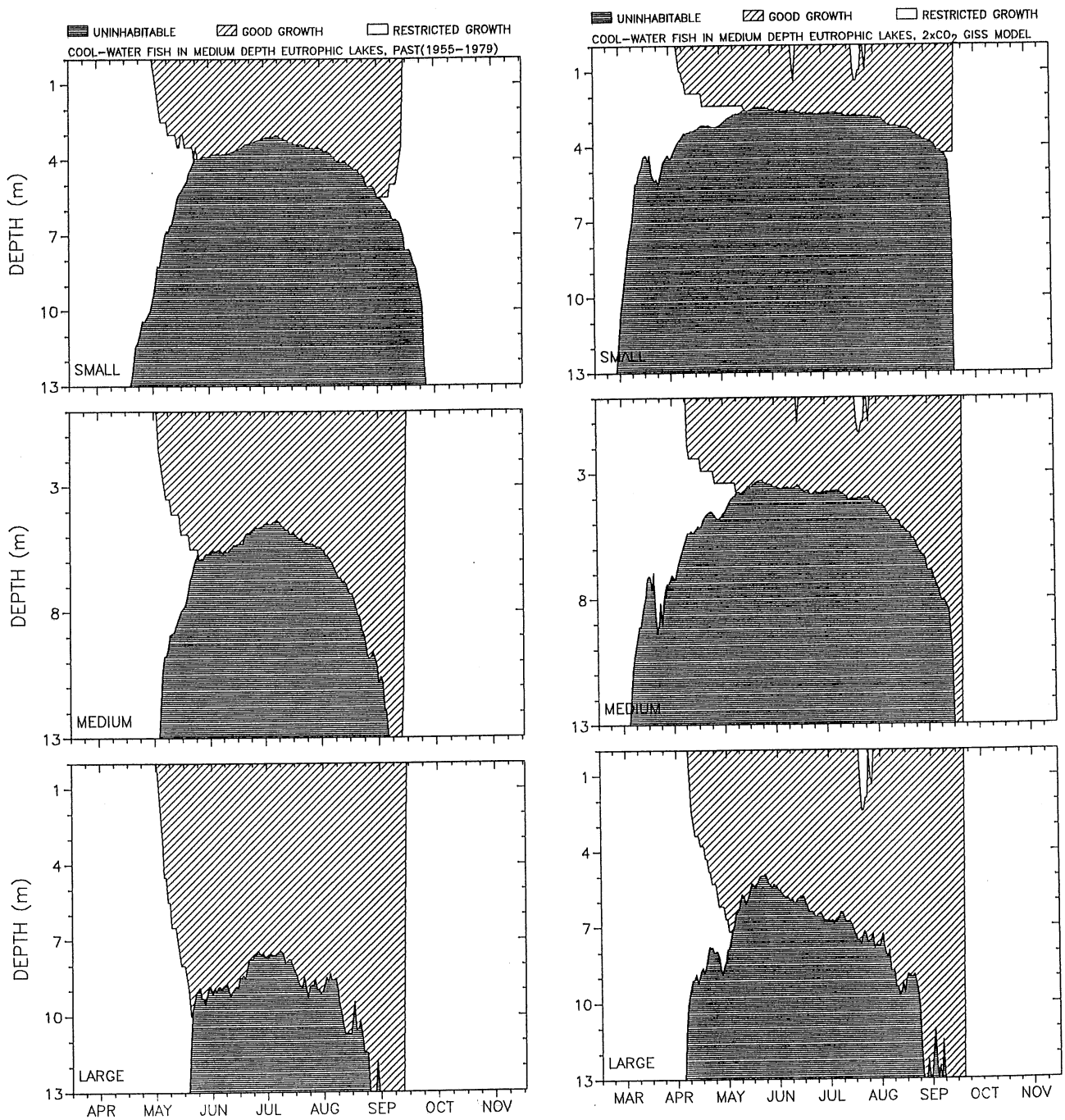


Figure 17b. Depth–time contours of coolwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

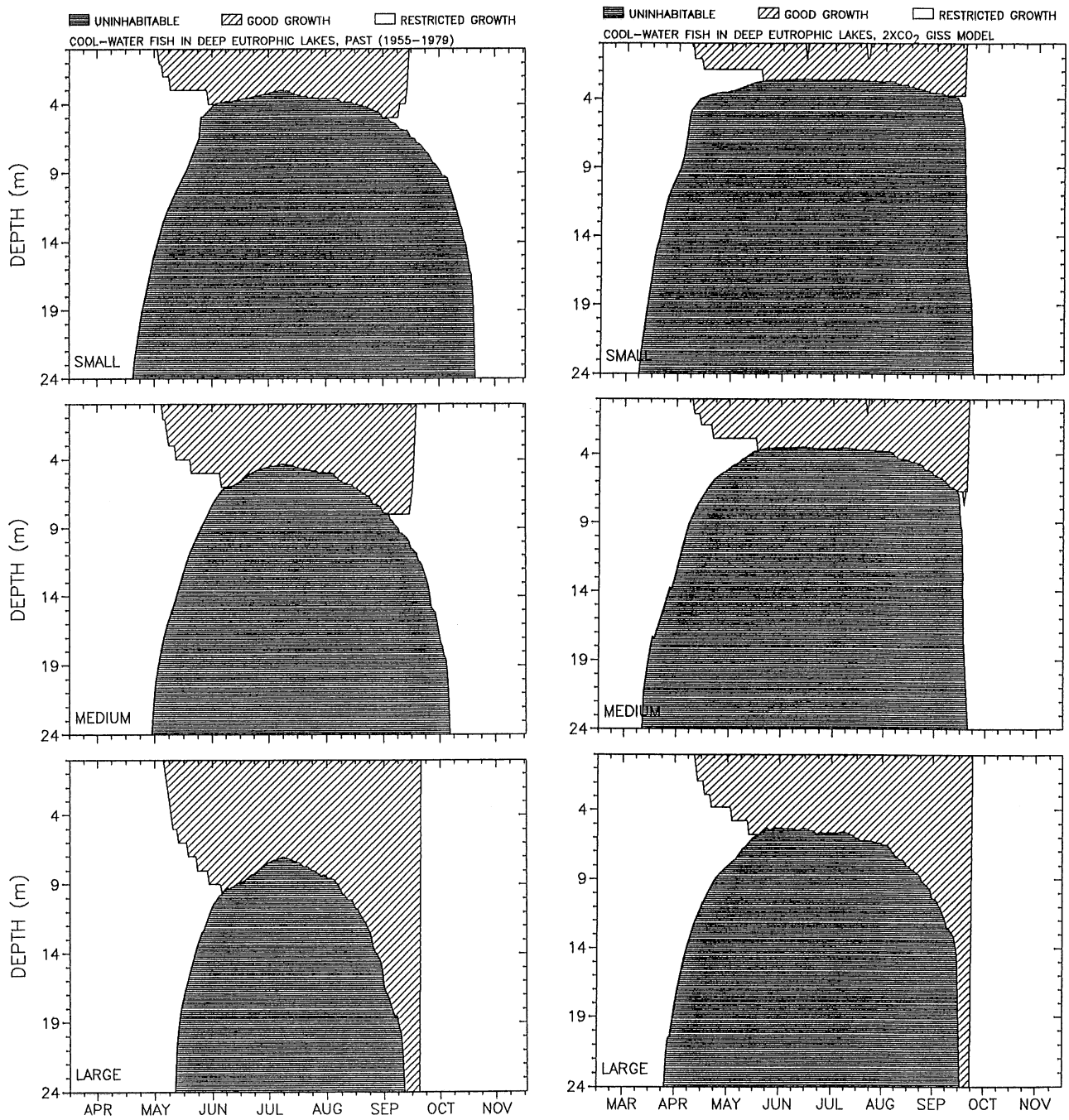


Figure 17c. Depth–time contours of coolwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

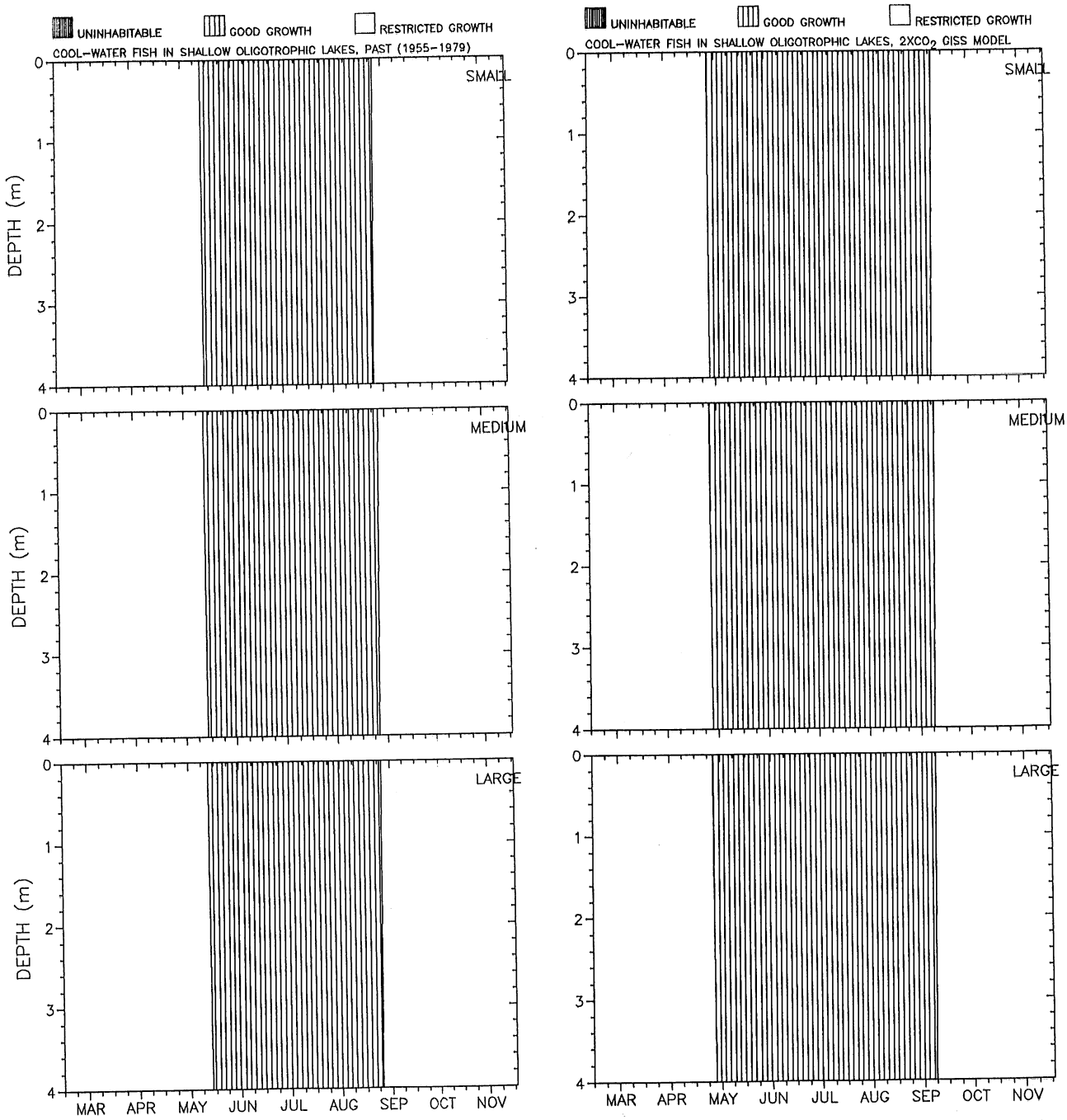


Figure 17d. Depth–time contours of coolwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

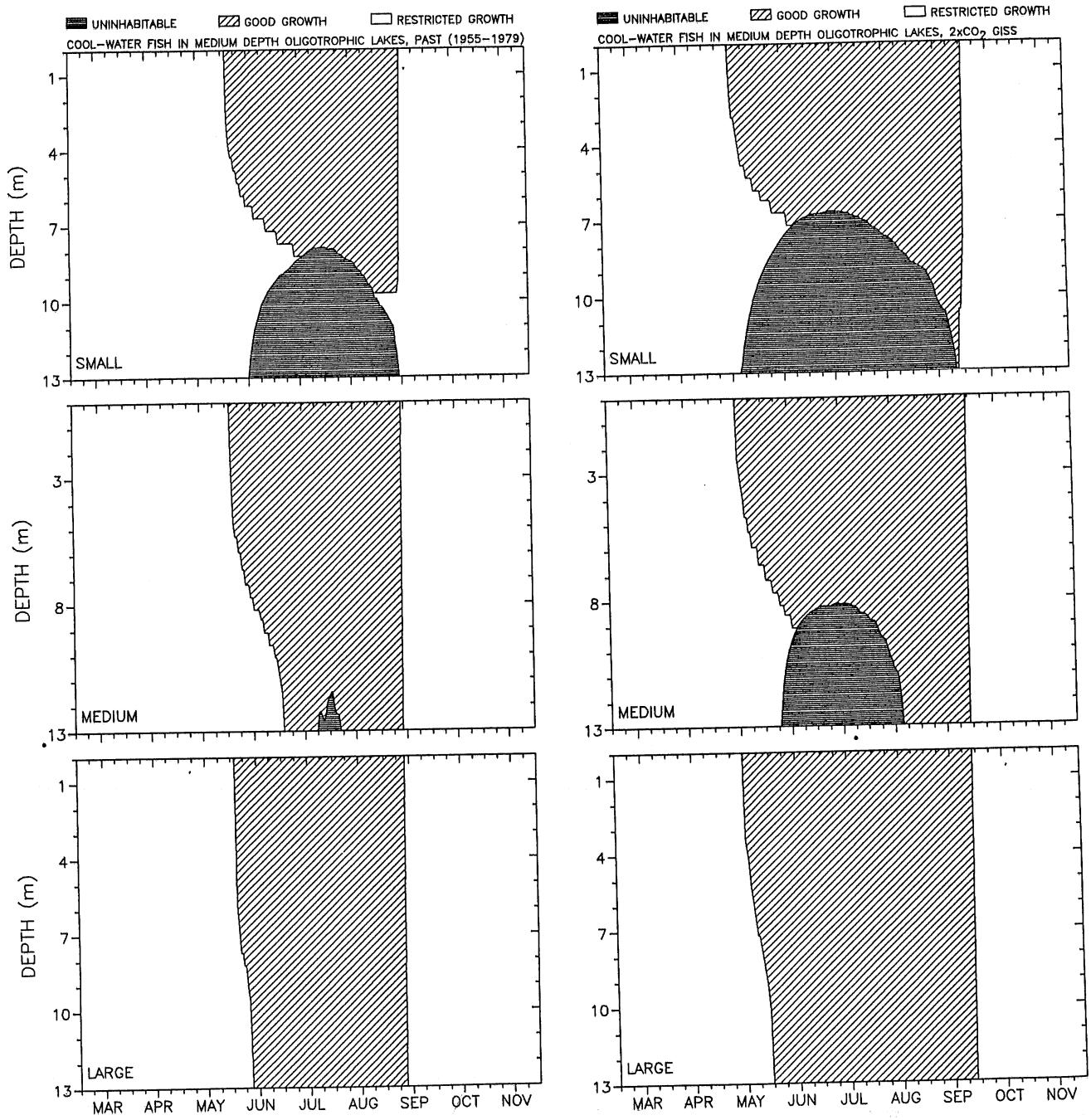


Figure 17e. Depth–time contours of coolwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

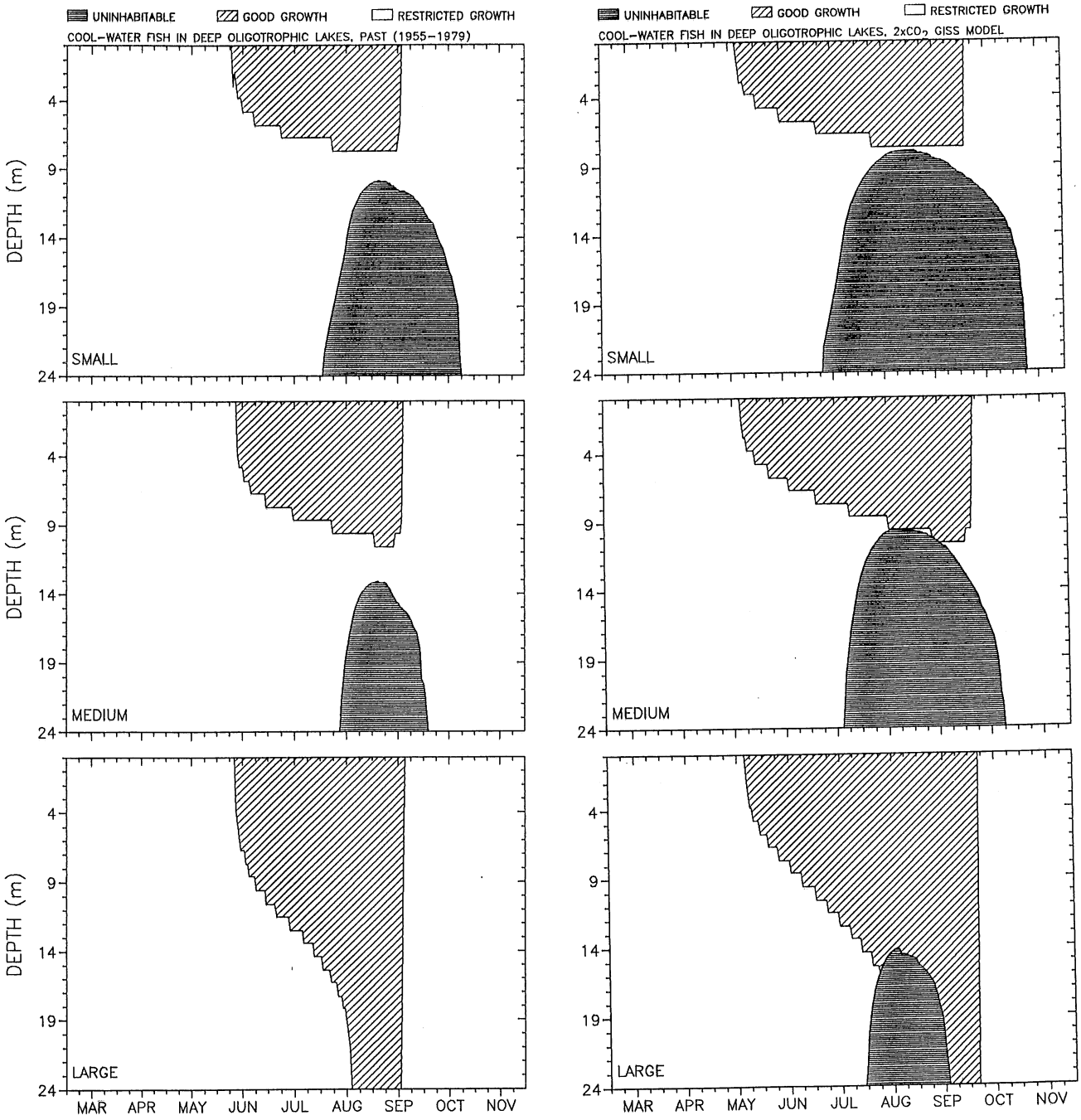


Figure 17f. Depth–time contours of coolwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

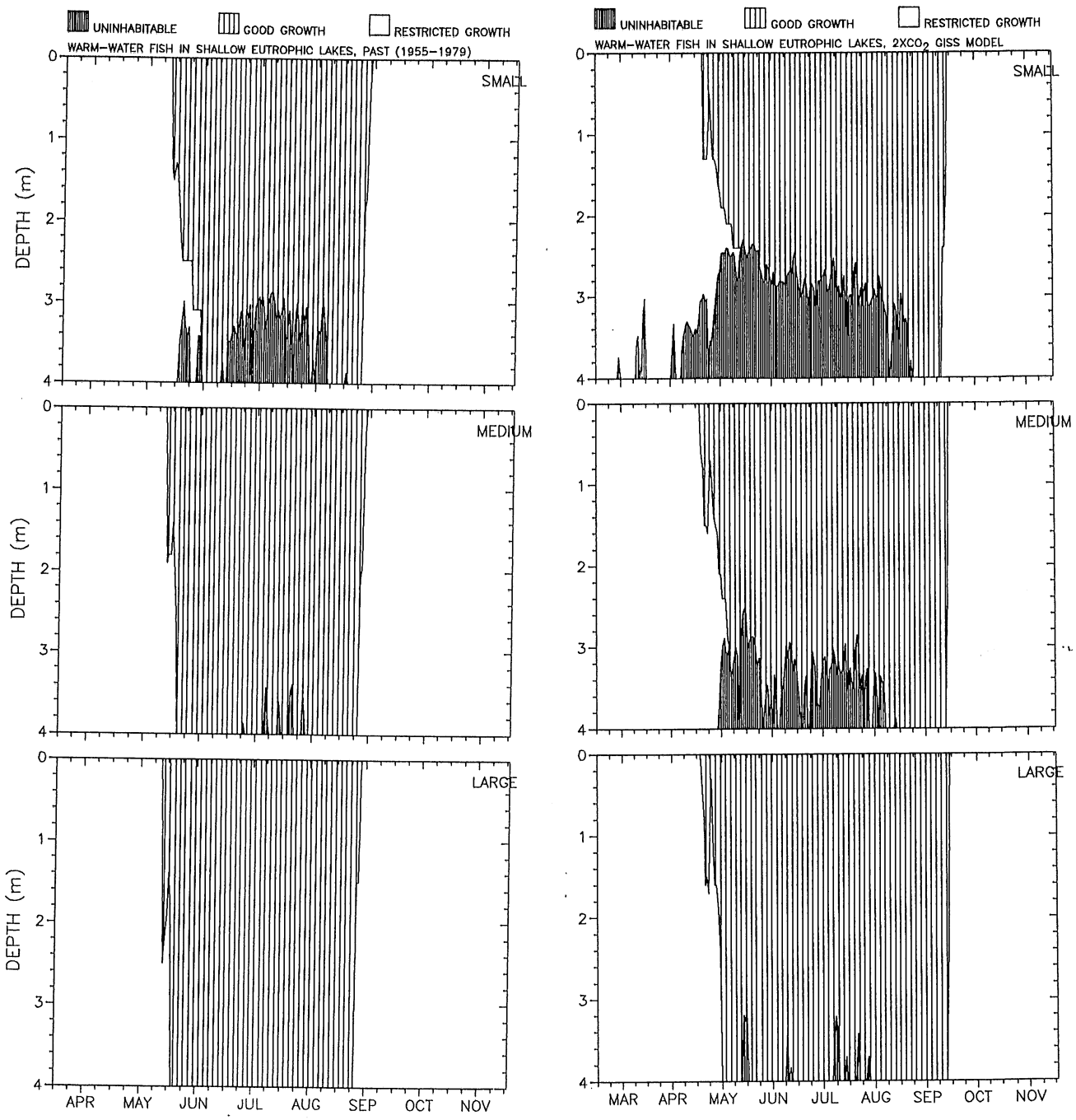


Figure 18a. Depth–time contours of warmwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

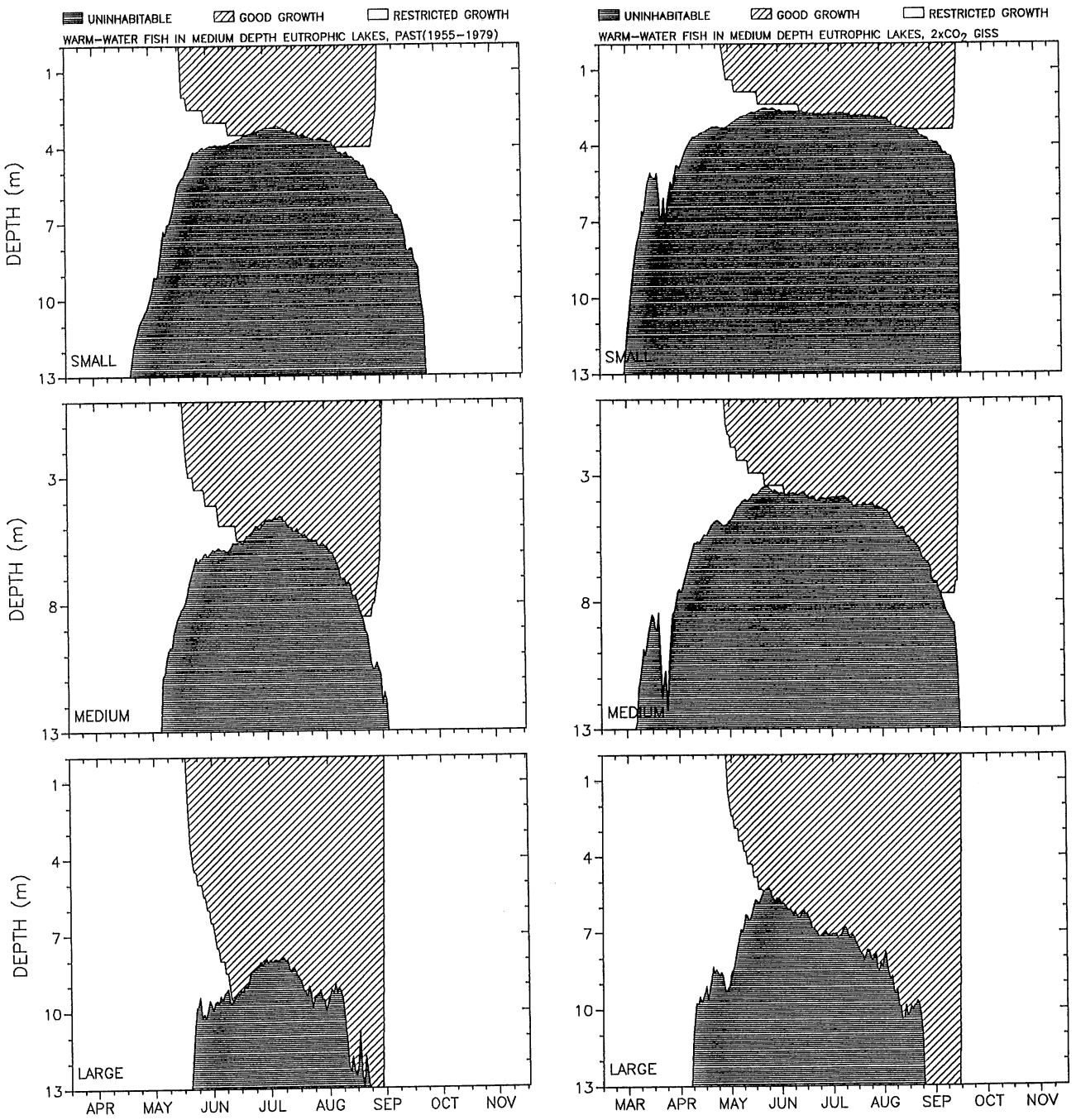


Figure 18b. Depth–time contours of warmwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

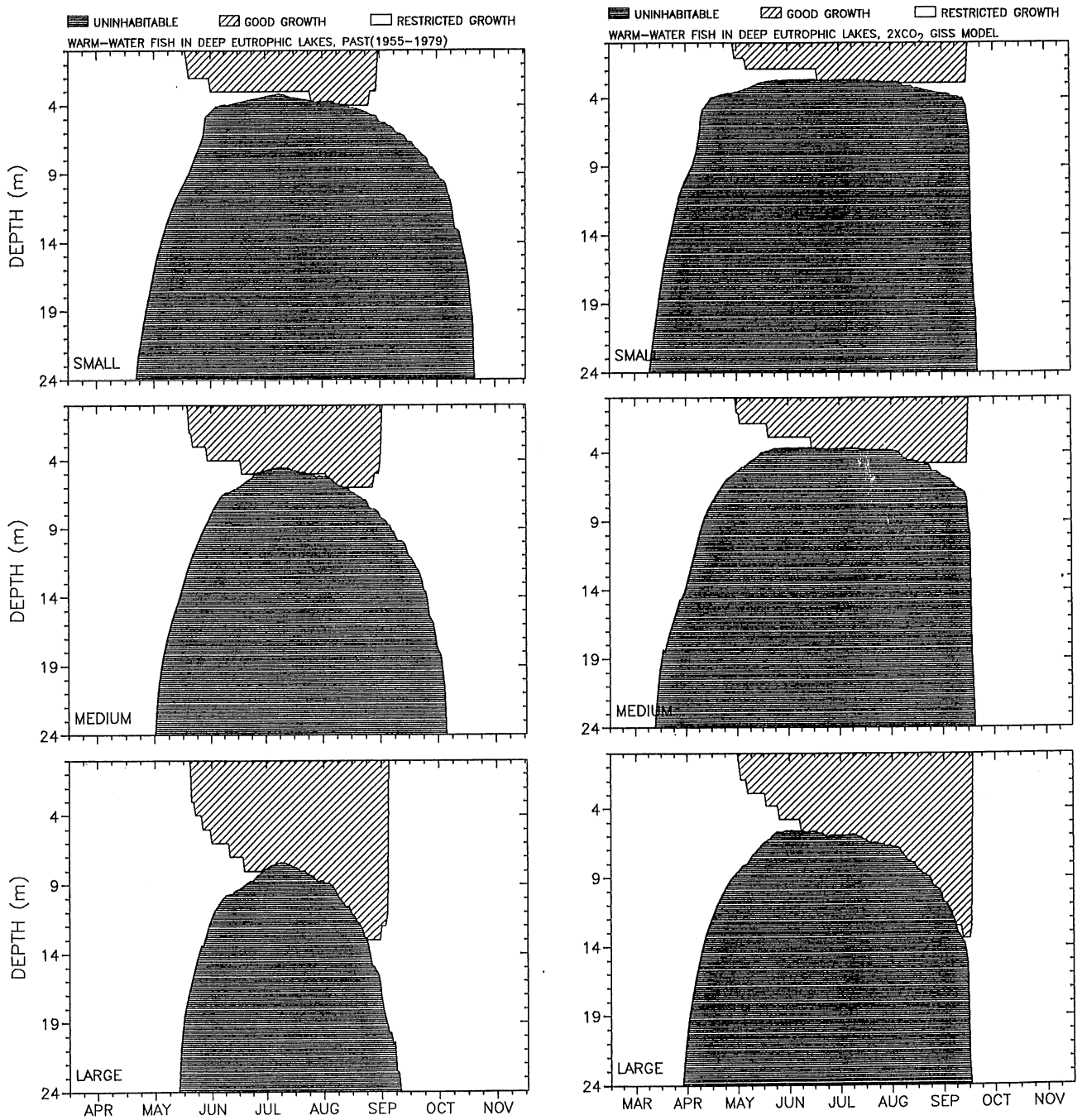


Figure 18c. Depth–time contours of warmwater fish habitats in eutrophic southern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

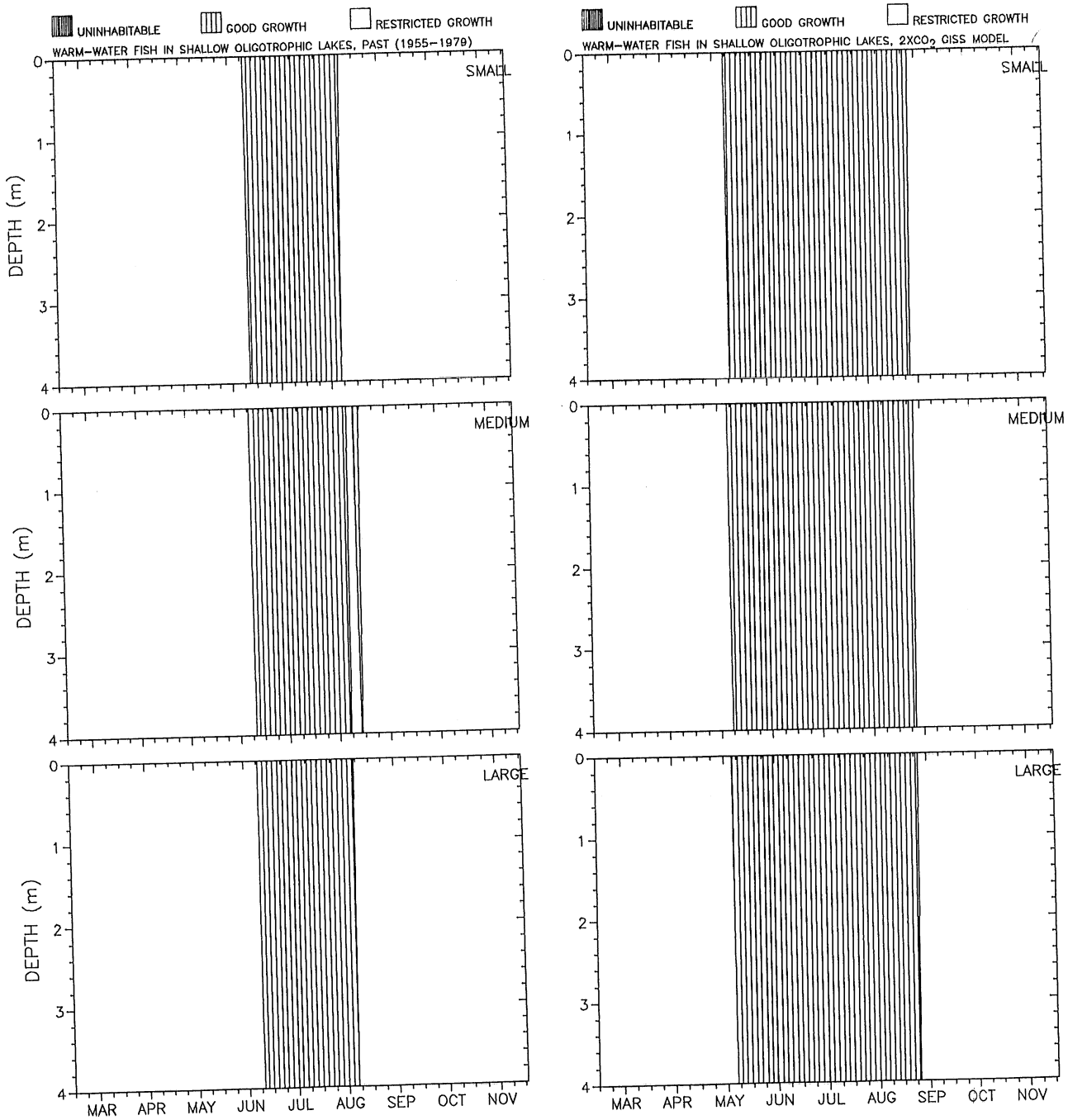


Figure 18d. Depth–time contours of warmwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

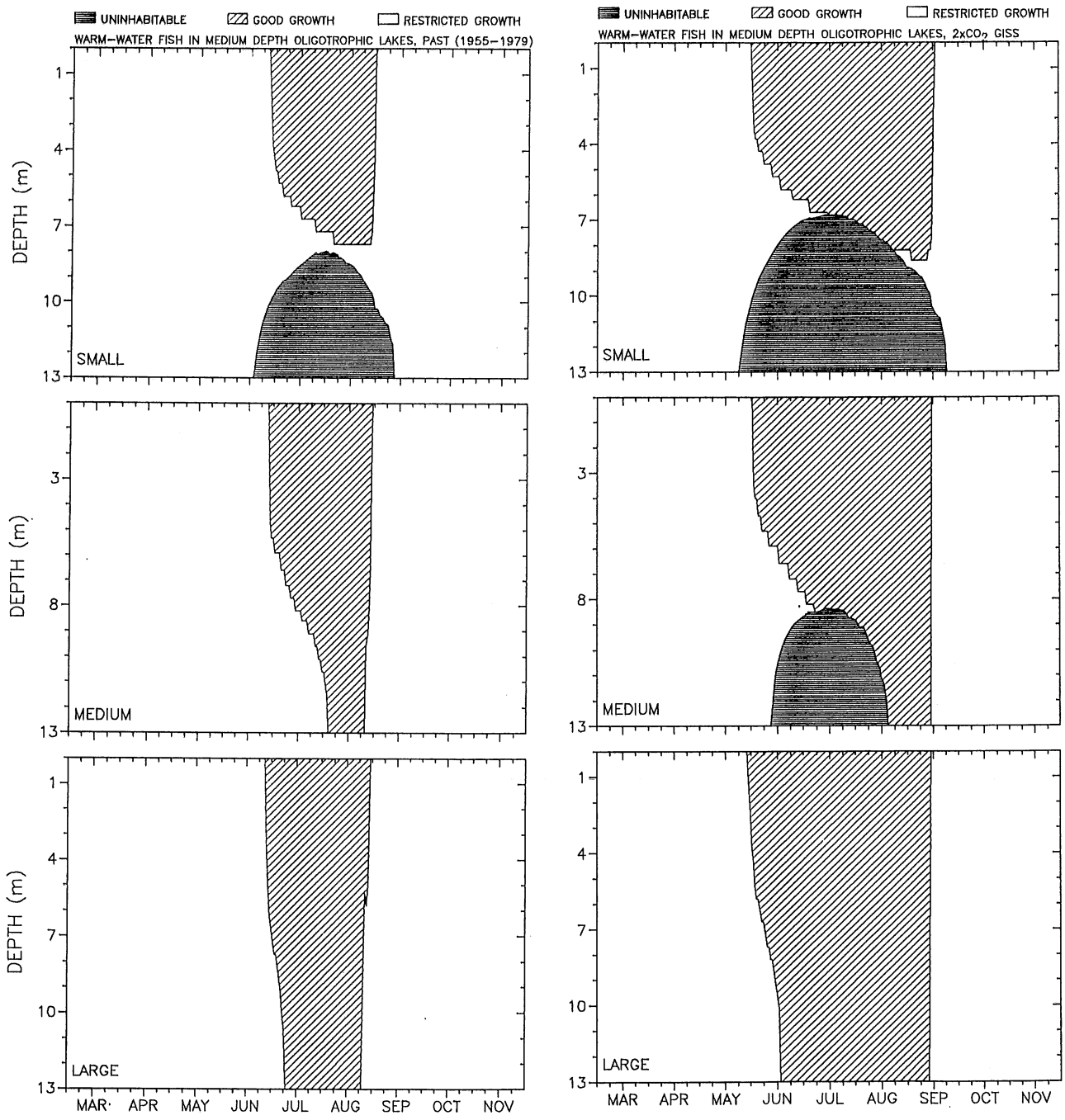


Figure 18e. Depth–time contours of warmwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

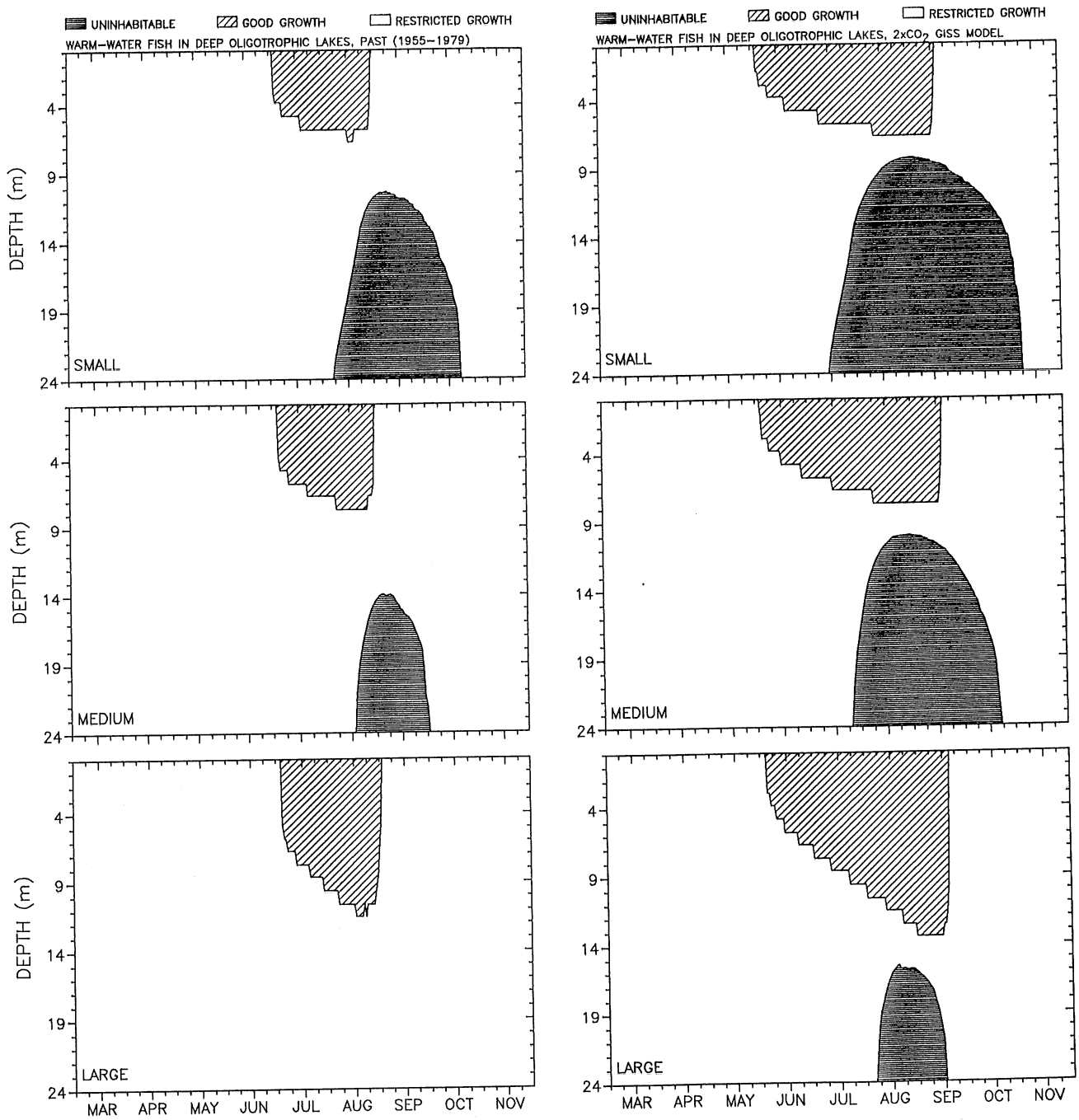


Figure 18f. Depth–time contours of warmwater fish habitats in oligotrophic northern Minnesota lakes under past (1955–1979) climate, i.e. average water temperature and D.O. conditions and for future $2xCO_2$ GISS climate scenario. 27 classes of lakes defined by depth, surface area and Secchi depth are shown.

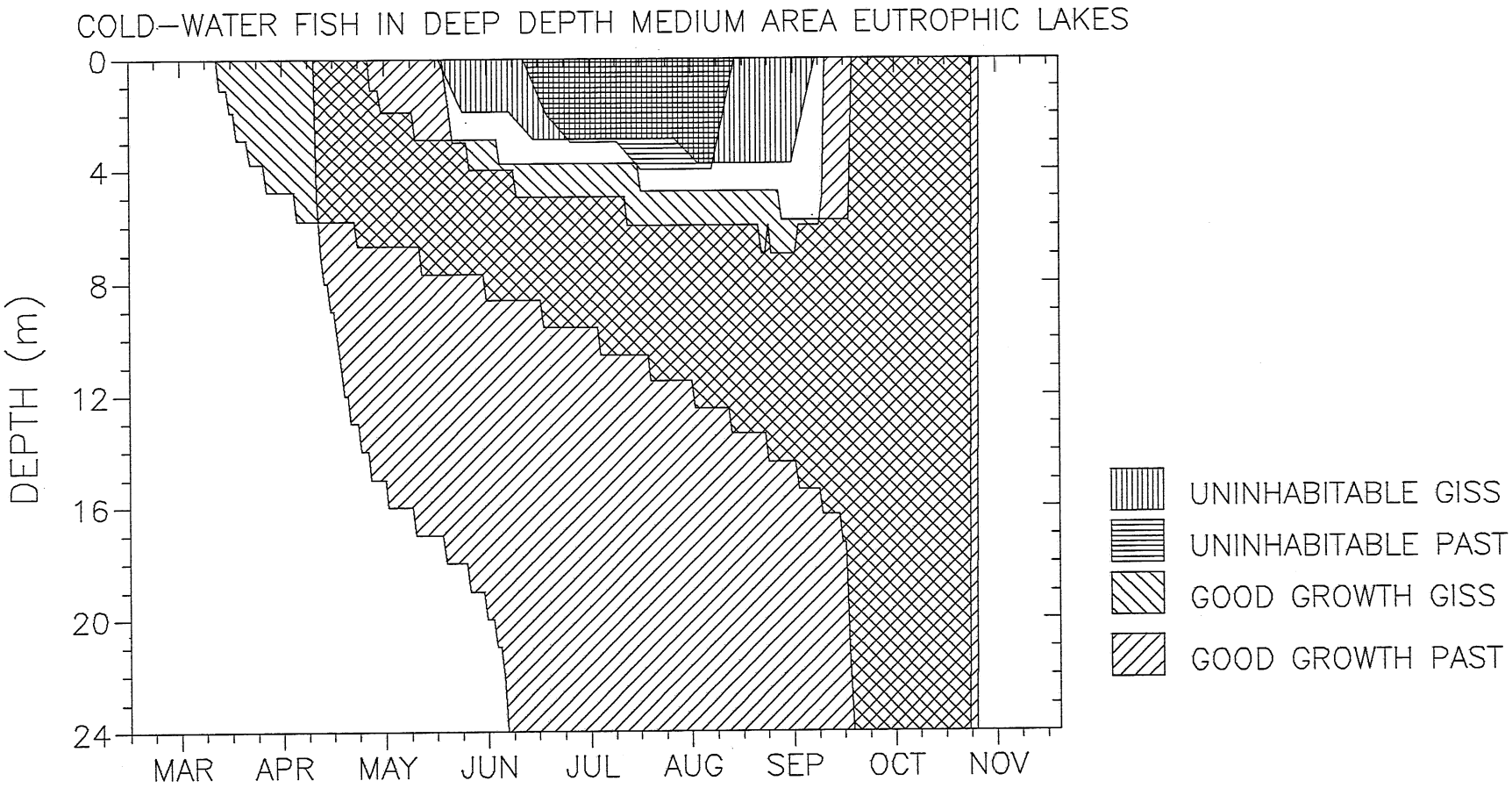


Fig. 19a. Illustrations of shifts in water temperatures, corresponding to the survival, upper and lower growth limits, when climate shifts from past (1955–1979) conditions to a $2xCO_2$ GISS climate scenario. Southern Minnesota eutrophic lakes.

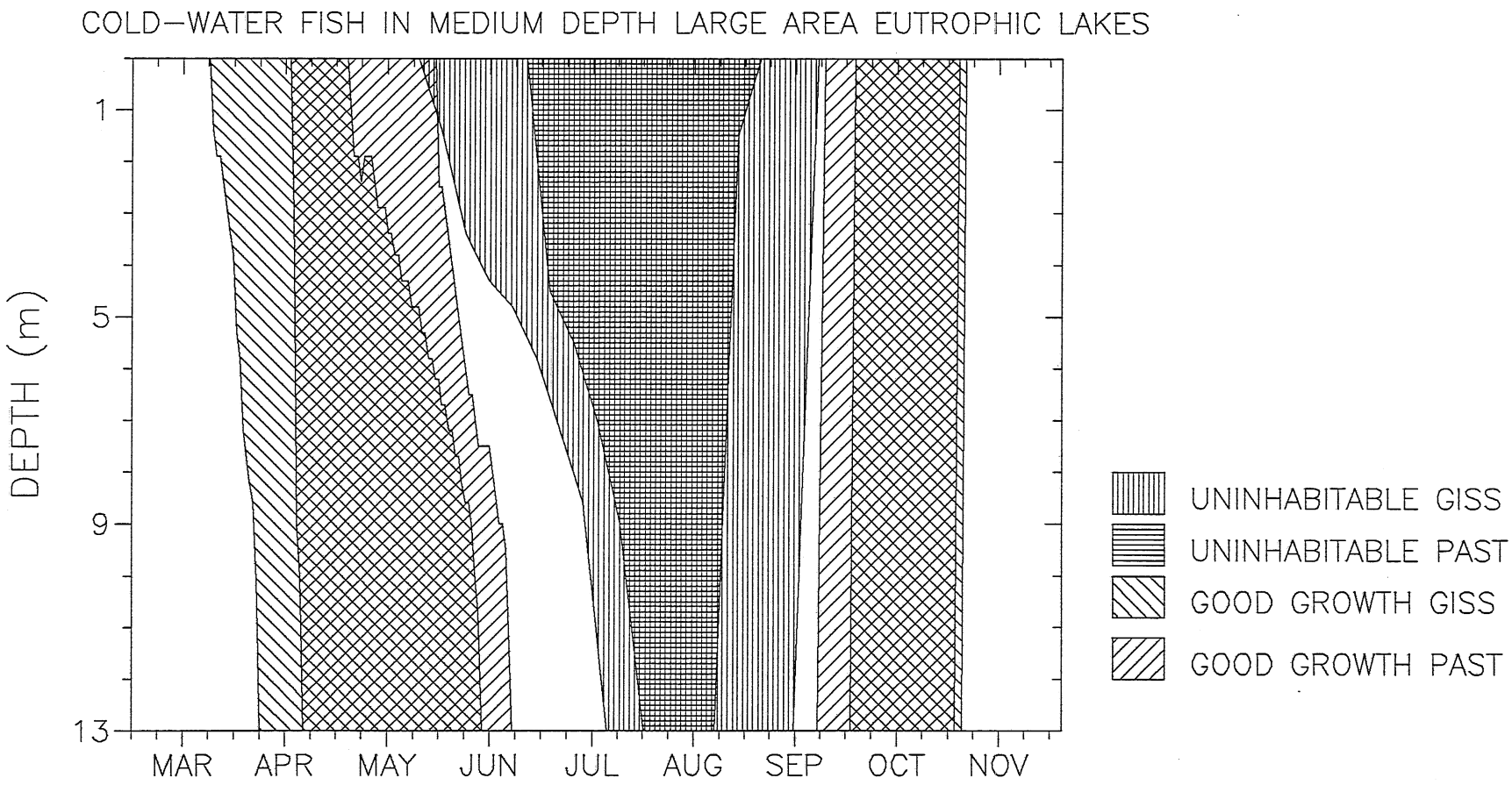


Fig. 19b. Illustrations of shifts in water temperatures, corresponding to the survival, upper and lower growth limits, when climate shifts from past (1955–1979) conditions to a $2xCO_2$ GISS climate scenario. Southern Minnesota eutrophic lakes.

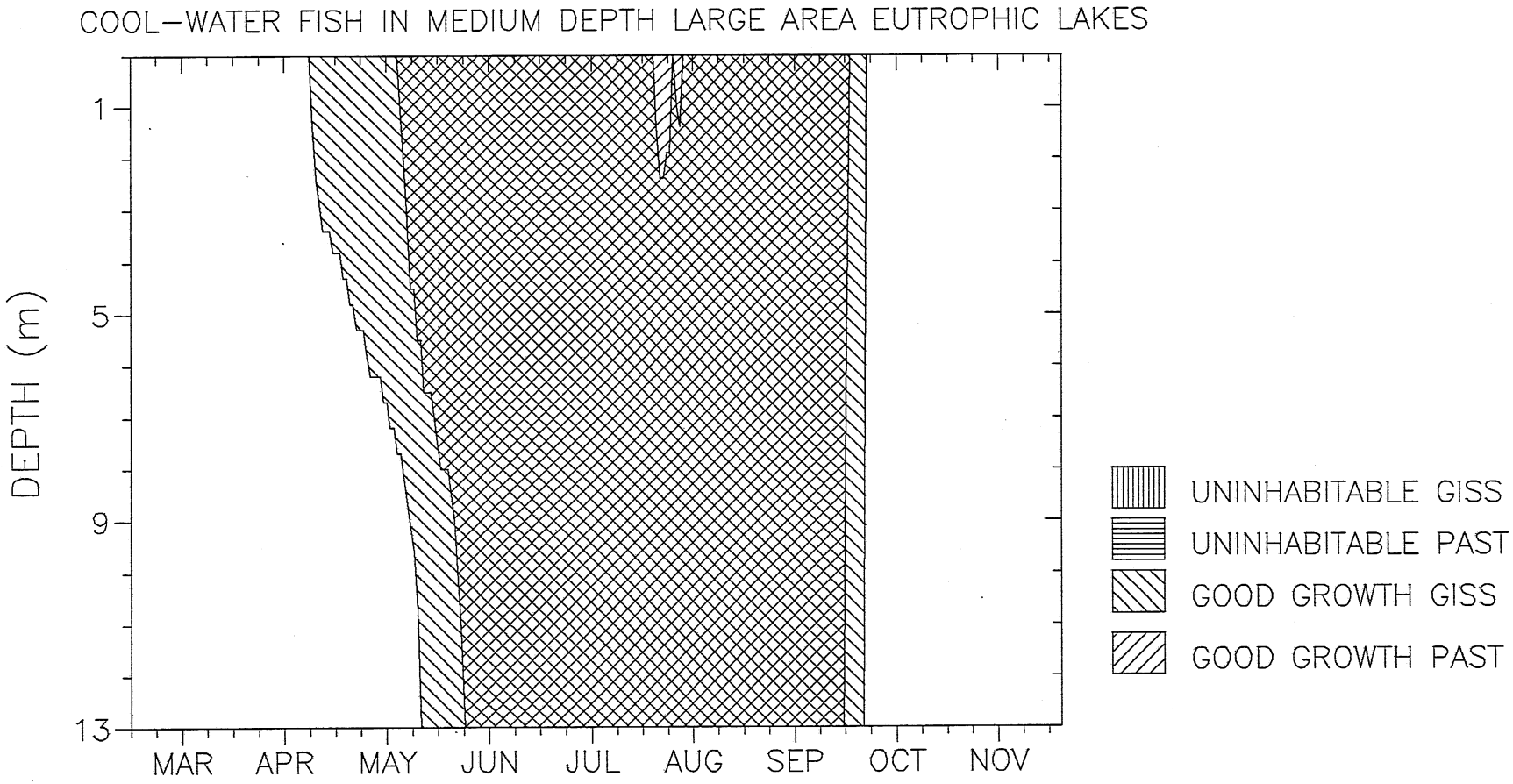


Fig. 19c. Illustrations of shifts in water temperatures, corresponding to the survival, upper and lower growth limits, when climate shifts from past (1955–1979) conditions to a $2xCO_2$ GISS climate scenario. Southern Minnesota eutrophic lakes.

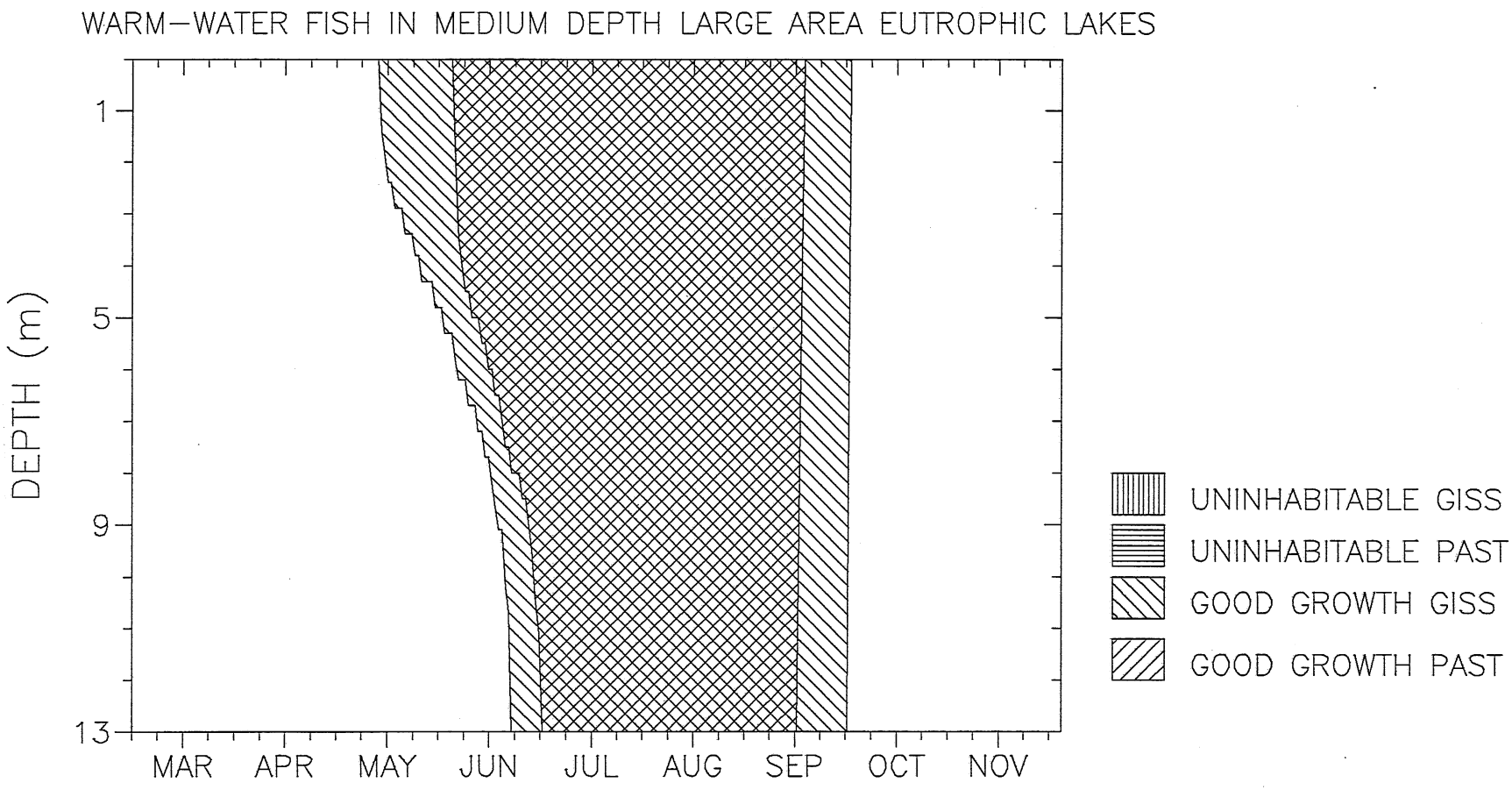


Fig. 19d. Illustrations of shifts in water temperatures, corresponding to the survival, upper and lower growth limits, when climate shifts from past (1955–1979) conditions to a $2xCO_2$ GISS climate scenario. Southern Minnesota eutrophic lakes.

Table 1. Thermal Criteria for Fish

Cold-Water Species	Lower 50% Growth Limits	Upper Growth Criteria[c]	Current FTDMS max 95th percentile	Optimum Temp.
Pink Salmon		20.3	22.3	18.3
Sockeye Salmon	9.2[b]	18	23.1	17.4
Chinook Salmon	11.8[a]	21.2[e]	23.7	18.7[f]
Chum Salmon		16.5	22.2	12.7
Coho Salmon	10.0[b]	19.9	23.1	17
Brown Trout	7.8[a]	18.5	26.6	13.3[f]
Rainbow Trout	9.2[a]	19.5	23.9	16.1[f]
Brook Trout	6.4[a]	17.3	22.1	13.0[f]
Lake Trout		15.5		11.5[d]
Mountain Whitefish			23.5	
Guild Means	9.0 (6.4-11.8)	18.5 (15.5-21.2)	23.4 (22.1-26.6)	15.3 (11.5-18.7)

Cool-Water Species	Lower 50% Growth Limits	Upper Growth Criteria[c]	Current FTDMS max 95th percentile	Optimum Temp
Northern Pike	13.2[a]	28.8[e]	31.1	25.7[f]
Muskellunge				24[d]
White Sucker	16.0[a]	27.8	28.0	25.4[f]
Black Crappie			32.2	
White Crappie			32.3	
Yellow Perch	17.7[a]	28.1	28.9	25.4[f]
Sauger			31.2	
Walleye	18.2[a]	28.2	29.0	25.2[f]
Guild means	16.3 (13.2-18.2)	28.2 (27.8-28.8)	30.4 (28.0-32.3)	25.1 (24-25.7)

Table 1 (Contd). Thermal Criteria for Fish

Warm-Water Species	Lower 50% Growth Limits	Upper Growth Criteria[c]	Current FTDMS max. 95th percentile	Optimum Temp
Gizzard Shad		32.3[d]	33.6	28.9[d]
Carp		32.8	32.2	30
Golden Shiner			30.6	
Channel Catfish	22.5[b]	32.8	31.7	30
Brown Bullhead	17.7[a]	31.4[e]	30.2	27.1[f]
White Bass	18.1[a]	29.9[e]	32.3	27.0[f]
Largemouth bass	20.1[a]	34.7	31.1	32[f]
Smallmouth bass	20.2[a]	32.0[e]	28.7	27.7[f]
Rock Bass		32.2[d]	31.0	29[d]
Green Sunfish		32.6[e]	31.2	30
Bluegill	19.8[a]	31.7	31.8	28.7[f]
Freshwater Drum		32.5[d]	32.2	31.3[d]
Guild means	19.7 (17.7-22.5)	32.3 (31.4-34.7)	31.4 (28.7-33.6)	29.2 (27-32)

[a]Lower limit value interpolated from species growth curve.

[b]Lower limit value calculated from species $\frac{OptT+LZNG}{2}$

[c] $\frac{OptT+UZNG}{2}$ or $OptT+\frac{UUILT-OptT}{3}$

Formulas from NAS, NAE 'Blue Book' (1974) and/or U.S. EPA 'Red Book' (1976).

[d]Final Temperature Preferendum used for Optimum Temperature.

[e]UUILT calculated from regression of UILTxUUILT.

[f]Maximum temperature as derived from growth equation.

Table 2. Selected Minnesota lakes and some associated limnological characteristics

LAKE	COUNTY	ID	AREA (km2)	DMAX (m)	TP (ug/l)	Chl-a (ug/l)	SD (m)	ECOREGION
WACONIA	CARVER	100059	10.0	11.0	42	23	1.9	NCHF
SQUARE	WASHINGTON	820046	0.8	20.0	16	2	7	NCHF
CALHOUN	HENNEPIN	2131	1.7	24.0	40	40	2.5	NCHF
ELMO	WASHINGTON	820106	1.2	41.8	19	9	2.8	NCHF
WILLIAMS	HUBBARD	560695	2.3	10.7	23	7	2.1	NLF
GREENWOOD	COOK	160077	7.2	34.0	14	2	6.5	NLF
FISH	JACKSON	320018	1.2	8.2	67	48	1	WCBP

ID - lake identification number
AREA - surface area
DMAX - maximum depth
TP - mean total phosphorus
Chl-a- mean chlorophyll-a
SD - mean secchi depth
NLF - Northern Lakes and Forests
NCHF - North Central Hardwood Forests
WCBP - Western Corn Belt Plains

Table 3. Selected Minnesota streams and some physical and biological characteristics.

	Period of Record	Average Flowrate (cfs)	Min. Flow (cfs)	Max. Flow (cfs)	Drainage Area (mi^2)	Stream Length (mi)	Average Width (ft)	Average Depth (ft)	Slope (ft/mi)	Fish Present	Remarks
Straight River near Ossage	1987...		21.0	62.0						Brown Trout Rainbow Trout Northern Pike White Sucker Black Crappie	Soil: sand and gravel with some muck and rubble. Cover types: heavely forested with mixed hardwoods and soft woods. Watershed use: Mostly wild forested with a small amount used for pasture. Sinuosity=1.336
Straight River near Park Rapids @ Hwy 115	1987...		26.0	81.0							
Straight River near Park Rapids	1970-71 1973 1975-76 1987...	45.0	28.0	87.0	53.2	14.7	45.0	1.0	4.76		
Baptism River near Beaver Bay	1927...	169	5.0	10,000	140	26.5	64.5	2.0		Brown T. Rainbow T. Chinook Salm.	The stream bed is composed of predominately coarse material.
Clearwater River @Plummer	1939-79 1982...	177.0	zero	3,940	512					Brown T. Rainbow T. Northern Pike White S.	Sinuosity=2.8
Clearwater River @Red Lake Falls	1909-17 1939-79 1982...	318.0	zero	10,300	1370	150.0	97.7	3.1	2.1		
Zumbro River @Zumbro Falls	1930...	517	27.0	35,000	1,400	57.7	143.0	1.5	2.9	Sauger Walleye Black & White Crappie White Sucker	Watershed: Upland soils are silt loams. Most of the stream flows through a narrow,wooded corridor with adjacent row crops and pasture. Sinuosity=2.0
Mississippi River near Anoka	1931...	8,019	529	91,000	19,100		492.4	5.8		Northern Pike Walleye	

Table 4. Summary of simulated main fish survival and growth parameters of three fish guilds in five streams under five climate scenarios. Based on 25–year simulated daily average temperatures (for acronyms see p. v).

	FISH THERMAL GUILD	PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
		SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
STRAIGHT R.	COLD	0	121	3.2	4	-4	-1.7	2	7	-1.8	74	-36	-2.6	2	-2	-1.5
	COOL	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	WARM	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
BAPTISM R.	COLD	3	113	1.8	47	-13	-0.8	51	10	-0.7	94	-63	-1.5	51	-17	-0.8
	COOL	0	91	92.0	0	24	24.0	0	49	49.0	13	55	-89.2	0	38	38.0
	WARM	0	54	55.0	0	36	36.0	0	47	47.0	2	100	100.0	0	37	37.0
CLEARWATER R.	COLD	0	90	1.3	59	-8	-0.6	42	-11	-0.5	97	-33	-0.9	59	-18	-0.6
	COOL	0	92	93.0	0	43	43.0	0	31	31.0	9	33	-90.6	0	39	39.0
	WARM	0	55	56.0	0	48	48.0	0	37	37.0	2	96	96.0	0	40	40.0
ZUMBRO R.	COLD	44	96	1.0	58	-19	-0.4	53	14	-0.2	98	-44	-0.7	47	-14	-0.3
	COOL	0	119	120.0	0	49	-63.7	0	44	-106.3	54	15	-118.2	0	20	-92.0
	WARM	0	92	93.0	0	37	37.0	0	34	34.0	35	89	-77.8	0	19	19.0
MISSISSIPPI R.	COLD	88	73	0.6	17	-1	-0.1	24	14	0.0	57	-25	-0.3	17	-15	-0.2
	COOL	0	130	11.9	17	-31	-10.5	7	-29	-10.3	76	-29	-10.9	36	-33	-10.3
	WARM	0	118	119.0	2	13	13.0	2	16	16.0	69	6	-116.9	10	14	14.0

Table 5a. Survival and growth parameters of 32 fish species under five climate scenarios.

		PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
	FISH	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
STRAIGHT T(AVG)	Brook Trout	0	140	2.7	28	-23	-1.4	27	4	-1.2	87	-68	-2.3	24	-25	-1.3
	Brown Trout	0	138	3.7	0	-19	-2.2	0	-1	-2.1	30	-47	-3.1	0	-13	-1.9
	Coho Salmon	0	136	22.8	6	-1	-20.4	7	8	-20.5	75	-33	-22.0	5	-18	-20.8
	Rainbow Trout	0	147	14.8	1	-10	-12.5	1	1	-12.6	71	-40	-14.0	1	-21	-12.7
	Lake Herring	0	121	3.2	4	-4	-1.7	2	7	-1.8	74	-36	-2.6	2	-2	-1.5
	Chinook Salmon	0	105	106.0	2	15	-103.5	2	33	-103.2	73	11	-104.8	1	6	-103.6
	Chum Salmon	0	100	1.7	23	-3	-0.7	25	10	-0.7	84	-57	-1.5	24	-3	-0.7
	Mountain Whitefish	0	121	3.2	3	-4	-1.7	2	7	-1.8	74	-36	-2.6	2	-2	-1.5
	Pink Salmon	0	156	52.3	23	-14	-49.7	24	3	-49.5	81	-37	-51.3	20	-18	-49.7
	Lake Trout	0	93	1.4	4	-2	-0.5	2	1	-0.6	74	-55	-1.2	2	-3	-0.5
	Sockeye Salmon	0	111	2.4	6	2	-1.0	7	13	-1.0	75	-41	-2.0	5	-5	-1.1
	Guild (Cold)	0	121	3.2	4	-4	-1.7	2	7	-1.8	74	-36	-2.6	2	-2	-1.5
	Northern Pike	0	93	94.0	0	43	43.0	0	68	68.0	0	110	-26.0	0	42	42.0
	Sauger	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	White Sucker	0	62	63.0	0	41	41.0	0	48	48.0	5	121	-48.8	0	36	36.0
	Yellow Perch	0	51	52.0	0	35	35.0	0	43	43.0	1	116	-18.4	0	32	32.0
	Walleye	0	40	41.0	0	42	42.0	0	48	48.0	1	116	-1.7	0	38	38.0
	Muskellunge	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	Black Crappie	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	White Crappie	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	Guild (Cool)	0	60	61.0	0	39	39.0	0	47	47.0	0	130	-13.2	0	35	35.0
	Smallmouth Bass	0	2	3.0	0	52	52.0	0	55	55.0	2	114	114.0	0	51	51.0
	Brown Bullhead	0	51	52.0	0	35	35.0	0	43	43.0	0	120	120.0	0	32	32.0
	Carp	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Freshwater Drum	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Gizzard Shad	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Golden Shiner	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Green Sunfish	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	White Bass	0	45	46.0	0	38	38.0	0	45	45.0	0	115	115.0	0	35	35.0
	Lake Sturgeon	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Rock Bass	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0
	Channel Catfish	0	0	1.0	0	16	16.0	0	20	20.0	0	80	80.0	0	14	14.0
	Largemouth Bass	0	2	3.0	0	53	53.0	0	58	58.0	0	115	115.0	0	52	52.0
	Bluegill	0	6	7.0	0	51	51.0	0	55	55.0	0	118	118.0	0	52	52.0
	Guild (Warm)	0	8	9.0	0	49	49.0	0	55	55.0	0	117	117.0	0	52	52.0

Table 5b. Survival and growth parameters of 32 fish species under five climate scenarios.

BAPTISM
T(AVG)

FISH	PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
	SCL	GSL	R'	SCL	GSL	R'	SCL	GSL	R'	SCL	GSL	R'	SCL	GSL	R'
Brook Trout	25	114	1.4	32	-1	-0.3	36	12	-0.4	99	-55	-1.1	34	-17	-0.6
Brown Trout	0	127	2.0	0	-19	-0.9	7	10	-0.7	71	-70	-1.7	2	-27	-1.0
Coho Salmon	7	107	2.0	48	1	-0.8	49	12	-0.8	94	-27	-1.5	47	-4	-0.8
Rainbow Trout	1	114	2.1	41	-11	-1.0	49	13	-0.9	91	-38	-1.6	49	-13	-1.0
Lake Herring	3	113	1.8	47	-13	-0.8	51	10	-0.7	94	-63	-1.5	51	-17	-0.8
Chinook Salmon	2	105	2.7	45	12	-0.9	52	23	-1.0	93	-26	-2.1	49	-13	-1.4
Chum Salmon	24	86	1.0	33	2	-0.2	36	9	-0.3	97	-44	-0.8	34	-18	-0.5
Mountain Whitefish	3	113	1.8	46	-13	-0.8	51	10	-0.7	94	-63	-1.5	50	-17	-0.8
Pink Salmon	21	122	2.3	35	-5	-0.9	37	14	-0.9	98	-33	-1.7	35	-12	-1.0
Lake Trout	3	76	0.8	47	-6	-0.3	51	9	-0.2	94	-37	-0.6	51	-13	-0.3
Sockeye Salmon	7	97	1.3	48	-2	-0.4	49	18	-0.3	94	-52	-1.1	47	-5	-0.4
Guild (Cold)	3	113	1.8	47	-13	-0.8	51	10	-0.7	94	-63	-1.5	51	-17	-0.8
Northern Pike	0	129	130.0	0	31	31.0	0	49	49.0	2	44	-126.2	0	28	28.0
Sauger	0	91	92.0	0	24	24.0	0	49	49.0	2	55	-89.2	0	38	38.0
White Sucker	0	95	96.0	0	26	26.0	0	47	47.0	53	50	-93.3	0	35	35.0
Yellow Perch	0	76	77.0	0	29	29.0	0	45	45.0	44	66	-74.3	0	30	30.0
Walleye	0	69	70.0	0	33	33.0	0	43	43.0	43	73	-67.2	0	32	32.0
Muskellunge	0	91	92.0	0	24	24.0	0	49	49.0	13	55	-89.2	0	38	38.0
Black Crappie	0	91	92.0	0	24	24.0	0	49	49.0	0	55	-89.2	0	38	38.0
White Crappie	0	91	92.0	0	24	24.0	0	49	49.0	0	55	-89.2	0	38	38.0
Guild (Cool)	0	91	92.0	0	24	24.0	0	49	49.0	13	55	-89.2	0	38	38.0
Smallmouth Bass	0	54	55.0	0	29	29.0	0	42	42.0	46	97	97.0	0	33	33.0
Brown Bullhead	0	76	77.0	0	29	29.0	0	45	45.0	19	116	-12.7	0	30	30.0
Carp	0	54	55.0	0	36	36.0	0	47	47.0	0	100	100.0	0	37	37.0
Freshwater Drum	0	54	55.0	0	36	36.0	0	47	47.0	0	100	100.0	0	37	37.0
Gizzard Shad	0	54	55.0	0	36	36.0	0	47	47.0	0	100	100.0	0	37	37.0
Golden Shiner	0	54	55.0	0	36	36.0	0	47	47.0	10	100	100.0	0	37	37.0
Green Sunfish	0	54	55.0	0	36	36.0	0	47	47.0	2	100	100.0	0	37	37.0
White Bass	0	71	72.0	0	32	32.0	0	42	42.0	0	97	-65.5	0	30	30.0
Lake Sturgeon	0	54	55.0	0	36	36.0	0	47	47.0	2	100	100.0	0	37	37.0
Rock Bass	0	54	55.0	0	36	36.0	0	47	47.0	2	100	100.0	0	37	37.0
Channel Catfish	0	14	15.0	0	42	42.0	0	44	44.0	1	103	103.0	0	41	41.0
Largemouth Bass	0	54	55.0	0	30	30.0	0	42	42.0	2	97	97.0	0	34	34.0
Bluegill	0	54	55.0	0	34	34.0	0	47	47.0	1	99	22.0	0	36	36.0
Guild (Warm)	0	54	55.0	0	36	36.0	0	47	47.0	2	100	100.0	0	37	37.0

Table 5c. Survival and growth parameters of 32 fish species under five climate scenarios.

		PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
	FISH	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
CLEARWATER T(AVG)	Brook Trout	20	97	1.2	53	-12	-0.5	40	12	-0.2	95	-28	-0.8	50	-20	-0.5
	Brown Trout	0	101	1.5	3	-16	-0.7	0	-5	-0.5	65	-36	-1.1	2	-14	-0.6
	Coho Salmon	2	101	1.9	60	-21	-1.1	45	-10	-0.8	102	-33	-1.4	61	-28	-1.1
	Rainbow Trout	0	99	1.7	53	-14	-0.9	37	-14	-0.8	92	-31	-1.2	52	-23	-0.9
	Lake Herring	0	90	1.3	59	-8	-0.6	42	-11	-0.5	97	-33	-0.9	59	-18	-0.6
	Chinook Salmon	0	106	3.1	57	-20	-2.1	40	-9	-1.7	92	-26	-2.5	54	-34	-2.2
	Chum Salmon	18	68	0.8	54	-10	-0.4	42	-9	-0.3	97	-23	-0.5	51	-24	-0.5
	Mountain Whitefish	0	90	1.3	59	-8	-0.6	41	-11	-0.5	94	-33	-0.9	57	-18	-0.6
	Pink Salmon	14	112	2.5	58	-16	-1.5	43	-10	-1.2	100	-39	-2.0	55	-28	-1.6
	Lake Trout	0	61	0.6	59	-11	-0.2	42	-15	-0.2	97	-27	-0.4	59	-23	-0.3
	Sockeye Salmon	2	88	1.3	60	-11	-0.6	45	-14	-0.6	102	-32	-1.0	61	-20	-0.6
	Guild (Cold)	0	90	1.3	59	-8	-0.6	42	-11	-0.5	97	-33	-0.9	59	-18	-0.6
	Northern Pike	0	130	131.0	0	26	26.0	0	23	23.0	3	28	-127.5	0	20	20.0
	Sauger	0	92	93.0	0	43	43.0	0	31	31.0	3	33	-90.6	0	39	39.0
	White Sucker	0	94	95.0	0	44	44.0	0	34	34.0	55	28	-92.8	0	38	38.0
	Yellow Perch	0	71	72.0	0	42	42.0	0	36	36.0	40	40	-70.0	0	36	36.0
	Walleye	0	69	70.0	0	42	42.0	0	34	34.0	40	44	-67.8	0	33	33.0
	Muskellunge	0	92	93.0	0	43	43.0	0	31	31.0	9	33	-90.6	0	39	39.0
	Black Crappie	0	92	93.0	0	43	43.0	0	31	31.0	0	33	-90.6	0	39	39.0
	White Crappie	0	92	93.0	0	43	43.0	0	31	31.0	0	33	-90.6	0	39	39.0
	Guild (Cool)	0	92	93.0	0	43	43.0	0	31	31.0	9	33	-90.6	0	39	39.0
	Smallmouth Bass	0	47	48.0	0	51	51.0	0	31	31.0	46	100	100.0	0	44	44.0
	Brown Bullhead	0	71	72.0	0	42	42.0	0	36	36.0	15	92	-17.3	0	36	36.0
	Carp	0	55	56.0	0	48	48.0	0	37	37.0	0	96	96.0	0	40	40.0
	Freshwater Drum	0	55	56.0	0	48	48.0	0	37	37.0	0	96	96.0	0	40	40.0
	Gizzard Shad	0	55	56.0	0	48	48.0	0	37	37.0	0	96	96.0	0	40	40.0
	Golden Shiner	0	55	56.0	0	48	48.0	0	37	37.0	8	96	96.0	0	40	40.0
	Green Sunfish	0	55	56.0	0	48	48.0	0	37	37.0	3	96	96.0	0	40	40.0
	White Bass	0	69	70.0	0	43	43.0	0	35	35.0	0	77	-62.3	0	33	33.0
	Lake Sturgeon	0	55	56.0	0	48	48.0	0	37	37.0	2	96	96.0	0	40	40.0
	Rock Bass	0	55	56.0	0	48	48.0	0	37	37.0	4	96	96.0	0	40	40.0
	Channel Catfish	0	11	12.0	0	59	59.0	0	41	41.0	0	100	100.0	0	57	57.0
	Largemouth Bass	0	47	48.0	0	51	51.0	0	33	33.0	3	100	100.0	0	44	44.0
	Bluegill	0	55	56.0	0	46	46.0	0	33	33.0	0	95	95.0	0	39	39.0
	Guild (Warm)	0	55	56.0	0	48	48.0	0	37	37.0	2	96	96.0	0	40	40.0

Table 5d. Survival and growth parameters of 32 fish species under five climate scenarios.

		PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
	FISH	SCL	GSL	R'	SCL	GSL	R'	SCL	GSL	R'	SCL	GSL	R	SCL	GSL	R'
ZUMBRO T(AVG)	Brook Trout	57	100	0.9	53	-16	-0.3	45	4	-0.2	107	-47	-0.6	41	-10	-0.2
	Brown Trout	0	99	1.0	40	-14	-0.4	42	19	-0.1	90	-42	-0.7	45	-13	-0.3
	Coho Salmon	48	97	1.1	55	-13	-0.4	49	14	-0.2	95	-45	-0.8	44	-10	-0.3
	Rainbow Trout	31	100	1.1	70	-19	-0.5	60	16	-0.2	101	-45	-0.8	51	-8	-0.3
	Lake Herring	44	96	1.0	58	-19	-0.4	53	14	-0.2	98	-44	-0.7	47	-14	-0.3
	Chinook Salmon	40	107	1.6	61	-23	-0.9	55	4	-0.6	97	-55	-1.3	49	-14	-0.7
	Chum Salmon	57	76	0.6	52	-29	-0.3	44	-4	-0.2	107	-34	-0.4	41	-8	-0.1
	Mountain Whitefish	43	96	1.0	59	-19	-0.4	54	14	-0.2	98	-44	-0.7	47	-14	-0.3
	Pink Salmon	57	104	1.2	52	-13	-0.5	44	22	-0.1	106	-45	-0.9	39	-5	-0.3
	Lake Trout	44	72	0.6	58	-33	-0.4	53	-12	-0.3	98	-33	-0.4	47	-22	-0.3
	Sockeye Salmon	48	92	0.9	55	-19	-0.4	49	12	-0.2	95	-43	-0.7	44	-15	-0.3
	Guild (Cold)	44	96	1.0	58	-19	-0.4	53	14	-0.2	98	-44	-0.7	47	-14	-0.3
	Northern Pike	0	152	153.0	0	40	40.0	0	47	-103.0	38	-5	-151.0	0	31	31.0
	Sauger	0	119	120.0	0	49	-63.7	0	44	-106.3	37	15	-118.2	0	20	-92.0
	White Sucker	0	119	120.0	3	48	-99.0	14	45	-110.3	77	14	-118.3	7	18	-107.5
	Yellow Perch	0	106	107.0	0	35	-71.5	3	25	-97.6	73	23	-105.3	0	18	-86.2
	Walleye	0	101	102.0	0	37	-55.7	0	26	-91.3	73	23	-100.4	0	22	-77.2
	Muskellunge	0	119	120.0	0	49	-63.7	0	44	-106.3	54	15	-118.2	0	20	-92.0
	Black Crappie	0	119	120.0	0	49	-63.7	0	44	-106.3	14	15	-118.2	0	20	-92.0
	White Crappie	0	119	120.0	0	49	-63.7	0	44	-106.3	11	15	-118.2	0	20	-92.0
	Guild (Cool)	0	119	120.0	0	49	-63.7	0	44	-106.3	54	15	-118.2	0	20	-92.0
	Smallmouth Bass	0	90	91.0	1	35	35.0	3	34	34.0	74	80	-83.2	0	18	18.0
	Brown Bullhead	0	106	107.0	0	38	38.0	0	38	38.0	58	65	-102.2	0	23	23.0
	Carp	0	92	93.0	0	37	37.0	0	34	34.0	14	96	-55.2	0	19	19.0
	Freshwater Drum	0	92	93.0	0	37	37.0	0	34	34.0	14	92	-72.4	0	19	19.0
	Gizzard Shad	0	92	93.0	0	37	37.0	0	34	34.0	1	89	-77.8	0	19	19.0
	Golden Shiner	0	92	93.0	0	37	37.0	0	34	34.0	49	89	-77.8	0	19	19.0
	Green Sunfish	0	92	93.0	0	37	37.0	0	34	34.0	37	94	-66.3	0	19	19.0
	White Bass	0	101	102.0	0	39	39.0	0	38	38.0	14	39	-99.7	0	26	26.0
	Lake Sturgeon	0	92	93.0	0	37	37.0	0	34	34.0	35	89	-77.8	0	19	19.0
	Rock Bass	0	92	93.0	0	37	37.0	0	34	34.0	41	87	-80.1	0	19	19.0
	Channel Catfish	0	55	56.0	0	52	52.0	0	46	46.0	29	96	-25.6	0	39	39.0
	Largemouth Bass	0	91	92.0	0	35	35.0	0	34	34.0	38	100	100.0	0	19	19.0
	Bluegill	0	92	93.0	0	34	34.0	0	34	34.0	26	72	-87.3	0	18	18.0
	Guild (Warm)	0	92	93.0	0	37	37.0	0	34	34.0	35	89	-77.8	0	19	19.0

Table 5e. Survival and growth parameters of 32 fish species under five climate scenarios.

		PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
	FISH	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
MISSISSIPPI T(AVG)	Brook Trout	96	77	0.6	18	-10	-0.2	28	15	0.0	59	-19	-0.3	22	-3	-0.1
	Brown Trout	45	76	0.6	40	1	-0.1	36	19	0.0	69	-19	-0.3	45	-6	-0.1
	Coho Salmon	90	76	0.7	17	-5	-0.2	23	18	0.0	57	-24	-0.4	16	-8	-0.2
	Rainbow Trout	80	75	0.6	21	7	0.0	26	25	0.1	62	-20	-0.3	20	-8	-0.1
	Lake Herring	88	73	0.6	17	-1	-0.1	24	14	0.0	57	-25	-0.3	17	-15	-0.2
	Chinook Salmon	85	73	0.7	18	-3	-0.1	22	8	-0.1	58	-25	-0.4	15	-8	-0.2
	Chum Salmon	96	56	0.4	18	-4	-0.1	26	17	0.0	56	-19	-0.2	20	-15	-0.1
	Mountain Whitefish	88	73	0.6	17	-1	-0.1	23	14	0.0	56	-25	-0.3	16	-15	-0.2
	Pink Salmon	96	83	0.8	16	4	-0.1	23	23	0.0	54	-22	-0.5	18	-12	-0.2
	Lake Trout	88	51	0.4	17	-8	-0.1	24	10	-0.1	57	-19	-0.2	17	-16	-0.2
	Sockeye Salmon	90	67	0.5	17	-3	-0.1	23	14	0.0	57	-21	-0.3	16	-14	-0.1
	Guild (Cold)	88	73	0.6	17	-1	-0.1	24	14	0.0	57	-25	-0.3	17	-15	-0.2
	Northern Pike	0	158	19.9	9	-20	-17.3	3	-8	-16.5	72	-40	-18.7	14	-32	-17.7
	Sauger	0	130	11.9	7	-31	-10.5	2	-29	-10.3	72	-29	-10.9	12	-33	-10.3
	White Sucker	12	121	5.5	63	-28	-4.3	54	-24	-4.1	94	-22	-4.6	56	-35	-4.3
	Yellow Perch	6	115	8.9	45	-28	-7.6	35	-22	-7.5	90	-27	-8.1	51	-30	-7.6
	Walleye	2	115	10.5	48	-35	-9.3	32	-26	-9.1	90	-25	-9.6	54	-32	-9.1
	Muskellunge	0	130	11.9	17	-31	-10.5	7	-29	-10.3	76	-29	-10.9	36	-33	-10.3
	Black Crappie	0	130	11.9	0	-31	-10.5	0	-29	-10.3	63	-29	-10.9	0	-33	-10.3
	White Crappie	0	130	11.9	0	-31	-10.5	0	-29	-10.3	59	-29	-10.9	0	-33	-10.3
	Guild (Cool)	0	130	11.9	17	-31	-10.5	7	-29	-10.3	76	-29	-10.9	36	-33	-10.3
	Smallmouth Bass	7	111	112.0	47	19	19.0	42	20	-46.0	91	3	-110.2	50	15	-69.7
	Brown Bullhead	0	127	128.0	20	27	-76.3	10	29	-75.7	77	-3	-126.2	43	11	-115.4
	Carp	0	118	119.0	0	13	13.0	0	16	16.0	63	11	-116.6	0	14	14.0
	Freshwater Drum	0	118	119.0	0	13	13.0	0	16	16.0	63	9	-116.7	0	14	14.0
	Gizzard Shad	0	118	119.0	0	13	13.0	0	16	16.0	43	6	-116.9	0	14	14.0
	Golden Shiner	0	118	119.0	13	13	13.0	3	16	16.0	73	6	-116.9	33	14	14.0
	Green Sunfish	0	118	119.0	7	13	13.0	2	16	16.0	72	10	-116.7	12	14	14.0
	White Bass	0	126	127.0	0	-11	-123.6	0	15	-116.9	63	-11	-125.5	0	-31	-125.1
	Lake Sturgeon	0	118	119.0	2	13	13.0	2	16	16.0	69	6	-116.9	10	14	14.0
	Rock Bass	0	118	119.0	9	13	13.0	3	16	16.0	72	1	-117.1	17	14	14.0
	Channel Catfish	0	92	93.0	0	20	20.0	2	26	26.0	68	4	-91.2	7	20	20.0
	Largemouth Bass	0	111	112.0	9	19	19.0	3	21	21.0	72	52	-102.4	14	18	18.0
	Bluegill	0	116	117.0	0	14	14.0	2	16	-72.7	67	-2	-115.3	7	8	-101.4
	Guild (Warm)	0	118	119.0	2	13	13.0	2	16	16.0	69	6	-116.9	10	14	14.0

Table 6. Summary of survival and good growth periods (days) of three fish guilds in five streams under past, probable future and extreme future climate.

STREAM	GUILD	GSL (days)		
		PAST[a]	FUTURE[b]	EXT. FUT.[c]
STRAIGHT R.	COLD	121	121	
	COOL	60	100	190
	WARM	8	60	125
BAPTISM R.	COLD	113		
	COOL	91	128	
	WARM	54	94	154
CLEARWATER R.	COLD	90		
	COOL	92	130	
	WARM	55	97	151
ZUMBRO R.	COLD			
	COOL	119	157	
	WARM	92	122	181
MISSISSIPPI R.	COLD			
	COOL	130		
	WARM	118	132	124

Shaded boxes indicate uninhabitable conditions.

a- Based on simulation with historical weather (1953-1979).
b- Based on arithmetic average simulation of three GCC models.
c- Based on highest simulated response of climate change model (UKMO climate scenario).

Table 7a. Fish observations, survival and good growth periods (days) of 32 fish species derived from long–term, daily average water temperatures simulated for past and future climate conditions with current shading and no future shading.

Straight River : GSL (days)		60%(PRESENT) SHADING			20% SHADING		0% SHADING	
FISH	OBS.	PAST[a]	FUT.[b]	EXT FUT[c]	FUT.	EXT. FUT.	FUT.	EXT. FUT.
Brook Trout		140						
Brown Trout	22/22	138	127					
Coho Salmon		136	132					
Rainbow Trout	5/22	147	137					
Lake Herring		121	121					
Chinook Salmon		100	123					
Chum Salmon		100						
Mountain Whitefish		121	121					
Pink Salmon		156						
Lake Trout		93	92					
Sockeye Salmon		111	114					
Guild (Cold)		121	121					
Northern Pike	8/32	93	144	203	175		165	
Sauger		60	100	190	137		118	
White Sucker	13/39	62	104	183	139			
Yellow Perch	3/22	51	88	167	123			
Walleye	1/22	40	83	156	117			
Muskellunge		60	100	190	137		118	
Black Crappie	2/7	60	100	190	137	137	118	
White Crappie		60	100	190	137	137	118	
Guild (Cool)		60	100	190	137		118	
Smallmouth Bass		2	55	116	99	158	115	123
Brown Bullhead		51	88	171	124	180	130	150
Carp		8	60	125	103	173	118	151
Freshwater Drum		8	60	125	103	172	118	142
Gizzard Shad		8	60	125	103	172	118	137
Golden Shiner	1/22	8	60	125	103	172	118	137
Green Sunfish	1/22	8	60	125	103	172	118	147
White Bass		45	84	125	119	148	128	132
Lake Sturgeon		8	60	125	103	172	118	137
Rock Bass	2/22	8	60	125	103	172	118	137
Channel Catfish		0	17	80	81	131	98	118
Largemouth Bass	5/22	2	56	117	101	170	116	170
Bluegill	1/22	6	59	124	102	162	117	128
Guild (Warm)		8	60	125	103	172	118	137

Shaded boxes indicate uninhabitable conditions.
OBS. = Observed in fish surveys. 5/22 means fish species observed in 5 of 22 surveys.
a, b and c - See footnotes on table 6.

Table 7b. Fish observations, survival and good growth periods (days) of 32 fish species derived from long–term, daily average water temperatures simulated for past and future climate conditions with current shading and no future shading.

Baptism River : GSL (days)

		40%(PRESENT) SHADING			20% SHADING		0% SHADING	
FISH	OBS.	PAST[a]	FUT.[b]	EXT. FUT[c].	FUT.	EXT. FUT.	FUT.	EXT. FUT.
Brook Trout	1/7							
Brown Trout	2/7	127	115					
Coho Salmon		107						
Rainbow Trout	7/10	114						
Lake Herring		113						
Chinook Salmon	5/7	105						
Chum Salmon								
Mountain Whitefish		113						
Pink Salmon								
Lake Trout		76						
Sockeye Salmon		97						
Guild (Cold)		113						
Northern Pike		129	165	173	179		144	
Sauger		91	128	146	133		95	
White Sucker	2/7	95	131					
Yellow Perch	3/7	76	111		121			
Walleye		69	105		118			
Muskellunge		91	128		133		95	
Black Crappie		91	128	146	133		95	
White Crappie		91	128	146	133		95	
Guild (Cool)		91	128		133		95	
Smallmouth Bass		54	89	151	106	149	120	122
Brown Bullhead		76	111	192	130	162	132	139
Carp		54	94	154	112	176	122	140
Freshwater Drum		54	94	154	112	172	122	135
Gizzard Shad		54	94	154	112	167	122	135
Golden Shiner		54	94	154	112	167	122	135
Green Sunfish		54	94	154	112	174	122	138
White Bass		71	106	168	127	143	119	123
Lake Sturgeon		54	94	154	112	167	122	135
Rock Bass		54	94	154	112	162	122	135
Channel Catfish		14	56	117	90	137	102	102
Largemouth Bass		54	89	151	108	174	121	169
Bluegill		54	93	153	111	153	122	130
Guild (Warm)		54	94	154	112	167	122	135

Shaded boxes indicate uninhabitable conditions.
OBS. = Observed in fish surveys. 1/7 means fish species observed in 1 of 7 surveys.
a, b and c - See footnotes on table 6.

Table 7c. Fish observations, survival and good growth periods (days) of 32 fish species derived from long–term, daily average water temperatures simulated for past and future climate conditions with current shading and no future shading.

Clearwater River : GSL (days)		50%(PRESENT) SHADING			20% SHADING		0% SHADING	
FISH	OBS.	PAST[a]	FUT.[b]	EXT. FUT.[c]	FUT.	EXT. FUT.	FUT.	EXT. FUT.
Brook Trout								
Brown Trout	11/13	101	89					
Coho Salmon		101						
Rainbow Trout	11/13	99						
Lake Herring		90						
Chinook Salmon		106						
Chum Salmon								
Mountain Whitefish		90						
Pink Salmon								
Lake Trout		61						
Sockeye Salmon		88						
Guild (Cold)		90						
Northern Pike	5/18	130	153	158	130			
Sauger		92	130	125	97			
White Sucker	8/18	94	133					
Yellow Perch	2/13	71	109					
Walleye	3/18	69	105					
Muskellunge		92	130		97			
Black Crappie		92	130	125	97		83	
White Crappie		92	130	125	97		83	
Guild (Cool)		92	130		97			
Smallmouth Bass		47	89	147	114	104	124	104
Brown Bullhead	1/13	71	109	163	130	115	128	114
Carp	1/13	55	97	151	118	121	130	114
Freshwater Drum	2/13	55	97	151	118	115	129	109
Gizzard Shad		55	97	151	118	110	128	108
Golden Shiner		55	97	151	118	110	128	108
Green Sunfish	1/13	55	97	151	118	117	129	110
White Bass		69	106	146	123	97	95	100
Lake Sturgeon		55	97	151	118	110	128	108
Rock Bass	6/18	55	97	151	118	109	127	107
Channel Catfish	2/13	11	63	111	99	100	114	94
Largemouth Bass		47	90	147	114	152	129	139
Bluegill	1/13	55	94	150	117	99	121	101
Guild (Warm)		55	97	151	118	110	128	108

Shaded boxes indicate uninhabitable conditions.
OBS. = Observed in fish surveys. 11/13 means fish species observed in 11 of 13 surveys.
a, b and c - See footnotes on table 6.

Table 7d. Fish observations, survival and good growth periods (days) of 32 fish species derived from long-term, daily average water temperatures simulated for past and future climate conditions with current shading and no future shading.

Zumbro River : GSL (days)		50%(PRESENT) SHADING			20% SHADING		0% SHADING	
FISH	OBS.	PAST[a]	FUT.[b]	EXT. FUT.[c]	FUT.	EXT. FUT.	FUT.	EXT. FUT.
Brook Trout								
Brown Trout	1/50	99						
Coho Salmon								
Rainbow Trout	4/50							
Lake Herring								
Chinook Salmon								
Chum Salmon								
Mountain Whitefish								
Pink Salmon								
Lake Trout								
Sockeye Salmon								
Guild (Cold)								
Northern Pike	6/50	152	191					
Sauger	17/50	119	157					
White Sucker	16/67	119	157					
Yellow Perch	4/50	106	132					
Walleye	14/54	101	129					
Muskellunge		119	157					
Black Crappie	15/50	119	157		111			
White Crappie	10/50	119	157		111			
Guild (Cool)		119	157					
Smallmouth Bass	35/54	90	119	170	142	126	115	111
Brown Bullhead		106	139	171	164	132	122	114
Carp	11/50	92	122	188	150	137	138	125
Freshwater Drum	5/50	92	122	184	150	135	131	124
Gizzard Shad	2/50	92	122	181	150	133	126	122
Golden Shiner		92	122	181	150	133	126	122
Green Sunfish	5/50	92	122	186	150	136	133	124
White Bass	16/63	101	135	140	122	120	92	92
Lake Sturgeon		92	122	181	150	133	126	122
Rock Bass		92	122	179	150	132	123	122
Channel Catfish	16/63	55	101	151	126	123	114	111
Largemouth Bass	25/50	91	120	191	145	168	156	139
Bluegill	14/50	92	121	164	146	129	111	109
Guild (Warm)		92	122	181	150	133	126	122

Shaded boxes indicate uninhabitable conditions.
OBS. = Observed in fish surveys. 1/50 means fish species observed in 1 of 50 surveys.
a. b and c - See footnotes on table 6.

Table 7e. Fish observations, survival and good growth periods (days) of 32 fish species derived from long–term, daily average water temperatures simulated for past and future climate conditions with current shading and no future shading.

Mississippi River : GSL (days) 0%(PRESENT) SHADING

FISH	OBS.	PAST[a]	FUTURE[b]	EXT. FUT.[c]
Brook Trout				
Brown Trout				
Coho Salmon				
Rainbow Trout				
Lake Herring				
Chinook Salmon				
Chum Salmon				
Mountain Whitefish				
Pink Salmon				
Lake Trout				
Sockeye Salmon				
Guild (Cold)				
Northern Pike	*	158		
Sauger		130		
White Sucker	*			
Yellow Perch	*	115		
Walleye	*	115		
Muskellunge		130		
Black Crappie	*	130	99	
White Crappie		130	99	
Guild (Cool)		130		
Smallmouth Bass	*	111	129	114
Brown Bullhead		127	149	124
Carp	*	118	132	129
Freshwater Drum		118	132	127
Gizzard Shad		118	132	124
Golden Shiner		118	132	124
Green Sunfish		118	132	128
White Bass		126	117	115
Lake Sturgeon		118	132	124
Rock Bass	*	118	132	119
Channel Catfish		92	114	96
Largemouth Bass	*	111	130	163
Bluegill	*	116	129	114
Guild (Warm)		118	132	124

Shaded boxes indicate uninhabitable conditions.
OBS. = Observed in fish surveys. * designates species collected from river reach modelled.
a, b and c - See footnotes on table 6.

Table 8a. Summary of main fish survival and growth parameters of three fish guilds in five streams under five climate scenarios. Based on 25 year daily extreme (average + one standard deviation) simulated water temperatures (for acronyms see p. v).

	FISH THERMAL GUILD	PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
		SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
STRAIGHT R.	COLD	4	113	1.3	59	-11	-0.4	68	-21	-0.7	143	-61	-1.0	60	-17	-0.4
	COOL	0	103	104.0	0	69	69.0	0	82	82.0	28	46	-101.8	0	55	55.0
	WARM	0	65	66.0	0	40	40.0	0	65	65.0	12	134	34.0	0	35	35.0
BAPTISM R.	COLD	59	91	0.9	36	-4	-0.3	44	2	-0.3	109	-41	-0.7	34	-21	-0.4
	COOL	0	138	139.0	0	1	-134.6	2	7	-135.5	71	0	-137.4	1	-11	-135.7
	WARM	0	95	96.0	0	30	30.0	0	56	56.0	58	56	-93.1	0	39	39.0
CLEARWATER R.	COLD	55	84	0.8	45	-24	-0.4	39	2	-0.2	108	-38	-0.6	42	-31	-0.4
	COOL	0	133	134.0	0	-9	-131.3	0	10	-126.0	67	-16	-132.7	0	-22	-131.6
	WARM	0	95	96.0	0	49	49.0	0	33	33.0	59	46	-93.2	0	41	41.0
ZUMBRO R.	COLD	94	80	0.6	39	-32	-0.3	36	-16	-0.3	104	-38	-0.4	24	-25	-0.3
	COOL	0	158	22.7	26	-56	-21.6	35	-22	-21.0	93	-61	-22.0	33	-38	-21.0
	WARM	0	123	124.0	9	53	-35.5	14	61	-62.3	79	16	-122.1	5	28	-48.0
MISSISSIPPI R.	COLD	117	61	0.4	17	-15	-0.1	19	12	0.0	70	-12	-0.2	15	-2	0.0
	COOL	32	106	1.8	51	-10	-0.8	50	1	-0.7	84	-31	-1.3	51	-18	-0.9
	WARM	3	138	139.0	63	-16	-136.3	58	17	-131.6	101	-25	-137.8	63	-37	-137.3

Table 8b. Summary of main fish survival and growth parameters of three fish guilds in five streams under five climate scenarios. Based on 25 year daily extreme (average – one standard deviation) simulated water temperatures (for acronyms see p. v).

	FISH THERMAL GUILD	PAST			GISS-PAST			GFDL-PAST			UKMO-PAST			OSU-PAST		
		SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R	SCL	GSL	R
STRAIGHT R.	COLD	0	94	95.0	0	12	-90.5	0	36	-90.1	30	29	-93.5	0	13	-91.0
	COOL	0	10	11.0	0	43	43.0	0	47	47.0	0	97	97.0	0	44	44.0
	WARM	0	0	1.0	0	6	6.0	0	12	12.0	0	71	71.0	0	6	6.0
BAPTISM R.	COLD	0	103	3.9	1	13	2.1	4	24	2.1	55	4	1.0	2	-6	1.7
	COOL	0	53	54.0	0	23	77.0	0	36	90.0	0	93	73.5	0	30	84.0
	WARM	0	8	9.0	0	36	45.0	0	45	54.0	0	87	96.0	0	45	54.0
CLEARWATER R.	COLD	0	105	4.1	1	11	-2.0	0	-5	-2.3	59	0	-3.1	5	-26	-3.0
	COOL	0	49	50.0	0	27	27.0	0	32	32.0	0	85	-23.0	0	35	35.0
	WARM	0	6	7.0	0	38	38.0	0	37	37.0	0	88	88.0	0	49	49.0
ZUMBRO R.	COLD	0	99	1.7	31	-18	-1.0	37	-3	-0.8	81	-30	-1.2	36	-13	-0.8
	COOL	0	90	91.0	0	32	32.0	0	28	28.0	2	65	-85.4	0	16	16.0
	WARM	0	51	52.0	0	51	51.0	0	42	42.0	0	79	79.0	0	35	35.0
MISSISSIPPI R.	COLD	46	76	0.8	35	3	-0.1	35	2	-0.1	66	-11	-0.4	38	-9	-0.2
	COOL	0	111	112.0	0	10	-98.4	0	20	-85.6	43	6	-110.1	1	-2	-106.5
	WARM	0	86	87.0	0	19	19.0	0	22	22.0	27	46	-73.7	0	20	20.0

Table 9a. Fish observations, survival and good growth periods (GSL–days) of 32 fish species derived from simulated extreme low, average and extreme high stream temperatures in the Straight River.

FISH	OBSERVED	(LOW TEMP.)[a]	(AVG. TEMP.)[b]	(HIGH TEMP.)[c]
Brook Trout		121	140	
Brown Trout	22/22	106	138	116
Coho Salmon		83	136	131
Rainbow Trout	5/22	91	147	130
Lake Herring		94	121	113
Chinook Salmon		63	105	127
Chum Salmon		88	100	
Mountain Whitefish		94	121	113
Pink Salmon		94	156	
Lake Trout		71	93	81
Sockeye Salmon		91	111	107
Guild (Cold)		94	121	113
Northern Pike	8/32	53	93	165
Sauger		10	60	103
White Sucker	13/39	16	62	107
Yellow Perch	3/22	0	51	91
Walleye	1/22	0	40	90
Muskellunge		10	60	103
Black Crappie	2/7	10	60	103
White Crappie		10	60	103
Guild (Cool)		10	60	103
Smallmouth Bass		0	2	64
Brown Bullhead		0	51	91
Carp		0	8	65
Freshwater Drum		0	8	65
Gizzard Shad		0	8	65
Golden Shiner	1/22	0	8	65
Green Sunfish	1/22	0	8	65
White Bass		0	45	90
Lake Sturgeon		0	8	65
Rock Bass	2/22	0	8	65
Channel Catfish		0	0	27
Largemouth Bass	5/22	0	2	64
Bluegill	1/22	0	6	65
Guild (Warm)		0	8	65

Shaded boxes indicate uninhabitable conditions.
a : 25-year average of water temperatures minus standard deviation.
b : 25-year average of water temperatures.
c : 25-year average of water temperatures plus standard deviation.

Table 9b. Fish observations, survival and good growth periods (GSL–days) of 32 fish species derived from simulated extreme low, average and extreme high stream temperatures in the Baptism River.

FISH	OBSERVED	(LOW TEMP.)[a]	(AVG. TEMP.)[b]	(HIGH TEMP.)[c]
Brook Trout	1/7	126		
Brown Trout	2/7	118	127	98
Coho Salmon		120	107	
Rainbow Trout	7/10	117	114	
Lake Herring		103	113	
Chinook Salmon	5/7	100	105	
Chum Salmon		76		
Mountain Whitefish		103	113	
Pink Salmon		127		
Lake Trout		74	76	
Sockeye Salmon		96	97	
Guild (Cold)		103	113	
Northern Pike		80	129	169
Sauger		53	91	138
White Sucker	2/7	54	95	142
Yellow Perch	3/7	35	76	119
Walleye		31	69	109
Muskellunge		53	91	138
Black Crappie		53	91	138
White Crappie		53	91	138
Guild (Cool)		53	91	138
Smallmouth Bass		2	54	92
Brown Bullhead		35	76	119
Carp		8	54	95
Freshwater Drum		8	54	95
Gizzard Shad		8	54	95
Golden Shiner		8	54	95
Green Sunfish		8	54	95
White Bass		31	71	113
Lake Sturgeon		8	54	95
Rock Bass		8	54	95
Channel Catfish		0	14	67
Largemouth Bass		2	54	93
Bluegill		4	54	95
Guild (Warm)		0	54	95

Shaded boxes indicate uninhabitable conditions.
a : 25-year average of water temperatures minus standard deviation.
b : 25-year average of water temperatures.
c : 25-year average of water temperatures plus standard deviation.

Table 9c. Fish observations, survival and good growth periods (GSL–days) of 32 fish species derived from simulated extreme low, average and extreme high stream temperatures in the Clearwater River.

FISH	OBSERVED	(LOW TEMP.)[a]	(AVG. TEMP.)[b]	(HIGH TEMP.)[c]
Brook Trout		108		
Brown Trout	11/13	114	101	93
Coho Salmon		113	101	
Rainbow Trout	11/13	121	99	
Lake Herring		105	90	
Chinook Salmon		99	106	
Chum Salmon		85		
Mountain Whitefish		105	90	
Pink Salmon		130		
Lake Trout		69	61	
Sockeye Salmon		99	88	
Guild (Cold)		105	90	
Northern Pike	5/18	82	130	158
Sauger		49	92	133
White Sucker	8/18	54	94	137
Yellow Perch	2/13	36	71	113
Walleye	3/18	30	69	102
Muskellunge		49	92	133
Black Crappie		49	92	133
White Crappie		49	92	133
Guild (Cool)		49	92	133
Smallmouth Bass		0	47	92
Brown Bullhead	1/13	36	71	113
Carp	1/13	6	55	95
Freshwater Drum	2/13	6	55	95
Gizzard Shad		6	55	95
Golden Shiner		6	55	95
Green Sunfish	1/13	6	55	95
White Bass		31	69	107
Lake Sturgeon		6	55	95
Rock Bass	6/18	6	55	95
Channel Catfish	2/13	0	11	64
Largemouth Bass		1	47	93
Bluegill	1/13	5	55	94
Guild (Warm)		6	55	95

Shaded boxes indicate uninhabitable conditions.
a : 25-year average of water temperatures minus standard deviation.
b : 25-year average of water temperatures.
c : 25-year average of water temperatures plus standard deviation.

Table 9d. Fish observations, survival and good growth periods (GSL–days) of 32 fish species derived from simulated extreme low, average and extreme high stream temperatures in the Zumbro River.

FISH	OBSERVED	(LOW TEMP.)[a]	(AVG. TEMP.)[b]	(HIGH TEMP.)[c]
Brook Trout		112		
Brown Trout	1/50	114	99	
Coho Salmon		90		
Rainbow Trout	4/50	102		
Lake Herring		99		
Chinook Salmon		102		
Chum Salmon		68		
Mountain Whitefish		99		
Pink Salmon		120		
Lake Trout		63		
Sockeye Salmon		93		
Guild (Cold)		99		
Northern Pike	6/50	107	152	193
Sauger	17/50	90	119	158
White Sucker	16/67	92	119	
Yellow Perch	4/50	65	106	133
Walleye	14/54	58	101	128
Muskellunge		90	119	158
Black Crappie	15/50	90	119	158
White Crappie	10/50	90	119	158
Guild (Cool)		90	119	158
Smallmouth Bass	35/54	41	90	117
Brown Bullhead		65	106	141
Carp	11/50	51	92	123
Freshwater Drum	5/50	51	92	123
Gizzard Shad	2/50	51	92	123
Golden Shiner		51	92	123
Green Sunfish	5/50	51	92	123
White Bass	16/63	60	101	134
Lake Sturgeon		51	92	123
Rock Bass		51	92	123
Channel Catfish	16/63	2	55	98
Largemouth Bass	25/50	45	91	118
Bluegill	14/50	50	92	122
Guild (Warm)		51	92	123

Shaded boxes indicate uninhabitable conditions.
a : 25-year average of water temperatures minus standard deviation.
b : 25-year average of water temperatures.
c : 25-year average of water temperatures plus standard deviation.

Table 9e. Fish observations, survival and good growth periods (GSL–days) fish species derived from simulated extreme low, average and extr high stream temperatures in the Mississippi River.

FISH	OBSERVED	(LOW TEMP.)[a]	(AVG. TEMP.)[b]	(HIGH TEMP.)[c]
Brook Trout				
Brown Trout		79		
Coho Salmon				
Rainbow Trout				
Lake Herring				
Chinook Salmon				
Chum Salmon				
Mountain Whitefish				
Pink Salmon				
Lake Trout				
Sockeye Salmon				
Guild (Cold)				
Northern Pike	*	135	158	136
Sauger		111	130	106
White Sucker	*	112		
Yellow Perch	*	101	115	
Walleye	*	98	115	
Muskellunge		111	130	
Black Crappie	*	111	130	106
White Crappie		111	130	106
Guild (Cool)		111	130	
Smallmouth Bass	*	82	111	
Brown Bullhead		101	127	
Carp	*	86	118	138
Freshwater Drum		86	118	138
Gizzard Shad		86	118	138
Golden Shiner		86	118	
Green Sunfish		86	118	138
White Bass		98	126	110
Lake Sturgeon		86	118	138
Rock Bass	*	86	118	
Channel Catfish		56	118	123
Largemouth Bass	*	82	111	135
Bluegill	*	85	116	135
Guild (Warm)		86	118	138

* designates species collected from river reach modelled
a : 25-year average of water temperatures minus standard deviation.
b : 25-year average of water temperatures.
c : 25-year average of water temperatures plus standard deviation.

Table 10. Effect of stream flow reduction to 50% of past values on fish parameters under 2xCO_2 GISS climate scenario. (for acronyms see page v)

STREAM	FISH GUILD	SCL (days)			GSL (days)			GZERO (days)		
		min.	ave.	max.	min.	ave.	max.	min.	ave.	max.
STRAIGHT R.	COLD	-4	-2	0	-3	2	2	-1	2	3
	COOL	0	0	0	-1	0	3	0	0	0
	WARM	0	0	0	-4	3	4	0	0	0
BAPTISM R.	COLD	1	3	7	-12	3	0	2	5	14
	COOL	0	0	0	1	10	15	0	0	0
	WARM	0	0	0	1	5	8	0	0	0
ZUMBRO R.	COLD	0	2	7	-12	-2	4	2	5	13
	COOL	0	0	4	-5	0	4	3	3	6
	WARM	0	0	3	1	5	8	0	0	0
MISSISSIPPI R.	COLD	-1	0	3	-2	1	4	-2	1	1
	COOL	0	2	3	-4	-3	-1	1	3	5
	WARM	0	3	6	-2	-1	5	-3	0	3

Table 11. Lake physical parameters that describe the 27 Minnesota lake classifications used in this study.

Lake key parameter	Range	Cumulative frequency	Representative value used	Descriptive term	Code [1]
Maximum depth (m)	< 5	Lower 30%	4	Shallow	S
	5 - 20	Central 60%	13	Medium	M
	> 20	Upper 10%	24	Deep	D
Surface area (km^2)	< 0.4	Lower 30%	0.2	Small	S
	0.4 - 5	Central 60%	1.7	Medium	M
	> 5	Upper 10%	10.	Large	L
Secchi depth (m)	< 1.8	Lower 20-50%	1.2	Eutrophic	E
	1.8 - 4.5	Central 20-50%	2.5	Mesotrophic	M
	> 4.5	Upper 0-10%	4.5	Oligotrophic	O

[1] Example: SSE = Shallow (depth), Small (area), Eutrophic

Table 12. Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 01 SSE (Depth/Area/Secchi)						
WHITE SUCKER	122/185	65.9%	22/ 45	48.9%	144/230	62.6%
YELLOW PERCH	112/185	60.5%	16/ 45	35.6%	128/230	55.7%
NORTHERN PIKE	99/185	53.5%	14/ 45	31.1%	113/230	49.1%
BLUEGILL	29/185	15.7%	30/ 45	66.7%	59/230	25.7%
BLACK CRAPPIE	30/185	16.2%	29/ 45	64.4%	59/230	25.7%
WALLEYE	35/185	18.9%	10/ 45	22.2%	45/230	19.6%
BROWN BULLHEAD	22/185	11.9%	13/ 45	28.9%	35/230	15.2%
GOLDEN SHINER	12/185	6.49%	17/ 45	37.8%	29/230	12.6%
LARGEMOUTH BASS	9/185	4.86%	16/ 45	35.6%	25/230	10.9%
GREEN SUNFISH	9/185	4.86%	14/ 45	31.1%	23/230	10.0%
CARP	2/185	1.08%	17/ 45	37.8%	19/230	8.26%
WHITE CRAPPIE	0/185	0.00%	12/ 45	26.7%	12/230	5.22%
SMALLMOUTH BASS	8/185	4.32%	1/ 45	2.22%	9/230	3.91%
FRESHWATER DRUM	0/185	0.00%	2/ 45	4.44%	2/230	0.87%
WHITE BASS	0/185	0.00%	1/ 45	2.22%	1/230	0.43%
Class: 02 SSM (Depth/Area/Secchi)						
YELLOW PERCH	136/189	72.0%	10/ 12	83.3%	146/201	72.6%
NORTHERN PIKE	127/189	67.2%	8/ 12	66.7%	135/201	67.2%
WHITE SUCKER	128/189	67.7%	7/ 12	58.3%	135/201	67.2%
BLUEGILL	48/189	25.4%	10/ 12	83.3%	58/201	28.9%
WALLEYE	51/189	27.0%	5/ 12	41.7%	56/201	27.9%
BLACK CRAPPIE	40/189	21.2%	9/ 12	75.0%	49/201	24.4%
LARGEMOUTH BASS	37/189	19.6%	7/ 12	58.3%	44/201	21.9%
BROWN BULLHEAD	36/189	19.0%	5/ 12	41.7%	41/201	20.4%
GOLDEN SHINER	14/189	7.41%	2/ 12	16.7%	16/201	7.96%
GREEN SUNFISH	6/189	3.17%	3/ 12	25.0%	9/201	4.48%
SMALLMOUTH BASS	9/189	4.76%	0/ 12	0.00%	9/201	4.48%
WHITE CRAPPIE	1/189	0.53%	3/ 12	25.0%	4/201	1.99%
LAKE WHITEFISH	4/189	2.12%	0/ 12	0.00%	4/201	1.99%
LAKE HERRING (CISCO)	4/189	2.12%	0/ 12	0.00%	4/201	1.99%
CARP	1/189	0.53%	3/ 12	25.0%	4/201	1.99%
Class: 03 SSO (Depth/Area/Secchi)						
BLUEGILL	1/ 3	33.3%	1/ 1	100%	2/ 4	50.0%
NORTHERN PIKE	2/ 3	66.7%	0/ 1	0.00%	2/ 4	50.0%
WHITE SUCKER	2/ 3	66.7%	0/ 1	0.00%	2/ 4	50.0%
YELLOW PERCH	2/ 3	66.7%	0/ 1	0.00%	2/ 4	50.0%
WALLEYE	1/ 3	33.3%	0/ 1	0.00%	1/ 4	25.0%
SMALLMOUTH BASS	1/ 3	33.3%	0/ 1	0.00%	1/ 4	25.0%
LAKE HERRING (CISCO)	1/ 3	33.3%	0/ 1	0.00%	1/ 4	25.0%
LAKE TROUT	1/ 3	33.3%	0/ 1	0.00%	1/ 4	25.0%

SSE = Shallow (depth), Small (area), Eutrophic. See Table 11 for code.

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 04 SME (Depth/Area/Secchi)						
YELLOW PERCH	137/150	91.3%	111/168	66.1%	248/318	78.0%
WHITE SUCKER	127/150	84.7%	102/168	60.7%	229/318	72.0%
NORTHERN PIKE	124/150	82.7%	103/168	61.3%	227/318	71.4%
WALLEYE	93/150	62.0%	88/168	52.4%	181/318	56.9%
BLACK CRAPPIE	61/150	40.7%	108/168	64.3%	169/318	53.1%
BLUEGILL	62/150	41.3%	103/168	61.3%	165/318	51.9%
CARP	5/150	3.33%	94/168	56.0%	99/318	31.1%
BROWN BULLHEAD	47/150	31.3%	42/168	25.0%	89/318	28.0%
LARGEMOUTH BASS	33/150	22.0%	37/168	22.0%	70/318	22.0%
GREEN SUNFISH	9/150	6.00%	49/168	29.2%	58/318	18.2%
WHITE CRAPPIE	0/150	0.00%	55/168	32.7%	55/318	17.3%
GOLDEN SHINER	16/150	10.7%	34/168	20.2%	50/318	15.7%
FRESHWATER DRUM	0/150	0.00%	18/168	10.7%	18/318	5.66%
LAKE HERRING (CISCO)	8/150	5.33%	0/168	0.00%	8/318	2.52%
WHITE BASS	0/150	0.00%	8/168	4.76%	8/318	2.52%
SMALLMOUTH BASS	6/150	4.00%	1/168	0.60%	7/318	2.20%
LAKE WHITEFISH	2/150	1.33%	0/168	0.00%	2/318	0.63%
Class: 05 SMM (Depth/Area/Secchi)						
YELLOW PERCH	93/ 99	93.9%	16/ 25	64.0%	109/124	87.9%
NORTHERN PIKE	89/ 99	89.9%	17/ 25	68.0%	106/124	85.5%
WHITE SUCKER	85/ 99	85.9%	12/ 25	48.0%	97/124	78.2%
WALLEYE	64/ 99	64.6%	12/ 25	48.0%	76/124	61.3%
BLUEGILL	51/ 99	51.5%	18/ 25	72.0%	69/124	55.6%
BLACK CRAPPIE	43/ 99	43.4%	14/ 25	56.0%	57/124	46.0%
LARGEMOUTH BASS	38/ 99	38.4%	8/ 25	32.0%	46/124	37.1%
BROWN BULLHEAD	36/ 99	36.4%	6/ 25	24.0%	42/124	33.9%
GREEN SUNFISH	2/ 99	2.02%	10/ 25	40.0%	12/124	9.68%
GOLDEN SHINER	5/ 99	5.05%	7/ 25	28.0%	12/124	9.68%
CARP	3/ 99	3.03%	9/ 25	36.0%	12/124	9.68%
SMALLMOUTH BASS	10/ 99	10.1%	1/ 25	4.00%	11/124	8.87%
LAKE HERRING (CISCO)	7/ 99	7.07%	0/ 25	0.00%	7/124	5.65%
WHITE CRAPPIE	0/ 99	0.00%	4/ 25	16.0%	4/124	3.23%
LAKE WHITEFISH	2/ 99	2.02%	0/ 25	0.00%	2/124	1.61%
FRESHWATER DRUM	0/ 99	0.00%	1/ 25	4.00%	1/124	0.81%
WHITE BASS	0/ 99	0.00%	1/ 25	4.00%	1/124	0.81%
Class: 06 SMO (Depth/Area/Secchi)						
BLACK CRAPPIE	2/ 2	100%	0/ 2	0.00%	2/ 4	50.0%
BLUEGILL	2/ 2	100%	0/ 2	0.00%	2/ 4	50.0%
NORTHERN PIKE	2/ 2	100%	0/ 2	0.00%	2/ 4	50.0%
YELLOW PERCH	2/ 2	100%	0/ 2	0.00%	2/ 4	50.0%
BROWN BULLHEAD	1/ 2	50.0%	0/ 2	0.00%	1/ 4	25.0%
LARGEMOUTH BASS	1/ 2	50.0%	0/ 2	0.00%	1/ 4	25.0%
GOLDEN SHINER	1/ 2	50.0%	0/ 2	0.00%	1/ 4	25.0%
WALLEYE	1/ 2	50.0%	0/ 2	0.00%	1/ 4	25.0%
WHITE SUCKER	1/ 2	50.0%	0/ 2	0.00%	1/ 4	25.0%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 07 SLE (Depth/Area/Secchi)						
YELLOW PERCH	7/ 7	100%	17/ 19	89.5%	24/ 26	92.3%
NORTHERN PIKE	7/ 7	100%	16/ 19	84.2%	23/ 26	88.5%
WALLEYE	7/ 7	100%	16/ 19	84.2%	23/ 26	88.5%
WHITE SUCKER	7/ 7	100%	16/ 19	84.2%	23/ 26	88.5%
BLACK CRAPPIE	4/ 7	57.1%	18/ 19	94.7%	22/ 26	84.6%
BLUEGILL	4/ 7	57.1%	14/ 19	73.7%	18/ 26	69.2%
CARP	1/ 7	14.3%	17/ 19	89.5%	18/ 26	69.2%
BROWN BULLHEAD	3/ 7	42.9%	9/ 19	47.4%	12/ 26	46.2%
WHITE CRAPPIE	0/ 7	0.00%	11/ 19	57.9%	11/ 26	42.3%
LARGEMOUTH BASS	2/ 7	28.6%	5/ 19	26.3%	7/ 26	26.9%
WHITE BASS	0/ 7	0.00%	6/ 19	31.6%	6/ 26	23.1%
FRESHWATER DRUM	0/ 7	0.00%	5/ 19	26.3%	5/ 26	19.2%
GREEN SUNFISH	0/ 7	0.00%	4/ 19	21.1%	4/ 26	15.4%
GOLDEN SHINER	0/ 7	0.00%	3/ 19	15.8%	3/ 26	11.5%
LAKE WHITEFISH	1/ 7	14.3%	1/ 19	5.26%	2/ 26	7.69%
SMALLMOUTH BASS	0/ 7	0.00%	1/ 19	5.26%	1/ 26	3.85%
Class: 08 SLM (Depth/Area/Secchi)						
BLACK CRAPPIE	3/ 3	100%	2/ 2	100%	5/ 5	100%
NORTHERN PIKE	3/ 3	100%	2/ 2	100%	5/ 5	100%
WHITE SUCKER	3/ 3	100%	2/ 2	100%	5/ 5	100%
YELLOW PERCH	3/ 3	100%	2/ 2	100%	5/ 5	100%
WALLEYE	3/ 3	100%	1/ 2	50.0%	4/ 5	80.0%
BLUEGILL	2/ 3	66.7%	1/ 2	50.0%	3/ 5	60.0%
BROWN BULLHEAD	2/ 3	66.7%	1/ 2	50.0%	3/ 5	60.0%
GOLDEN SHINER	2/ 3	66.7%	1/ 2	50.0%	3/ 5	60.0%
LARGEMOUTH BASS	2/ 3	66.7%	0/ 2	0.00%	2/ 5	40.0%
CARP	0/ 3	0.00%	2/ 2	100%	2/ 5	40.0%
GREEN SUNFISH	0/ 3	0.00%	2/ 2	100%	2/ 5	40.0%
LAKE WHITEFISH	1/ 3	33.3%	0/ 2	0.00%	1/ 5	20.0%
SMALLMOUTH BASS	1/ 3	33.3%	0/ 2	0.00%	1/ 5	20.0%
LAKE HERRING (CISCO)	1/ 3	33.3%	0/ 2	0.00%	1/ 5	20.0%
WHITE CRAPPIE	0/ 3	0.00%	1/ 2	50.0%	1/ 5	20.0%
Class: 10 MSE (Depth/Area/Secchi)						
NORTHERN PIKE	61/ 85	71.8%	60/ 82	73.2%	121/167	72.5%
YELLOW PERCH	61/ 85	71.8%	57/ 82	69.5%	118/167	70.7%
BLACK CRAPPIE	43/ 85	50.6%	73/ 82	89.0%	116/167	69.5%
BLUEGILL	37/ 85	43.5%	73/ 82	89.0%	110/167	65.9%
WHITE SUCKER	46/ 85	54.1%	50/ 82	61.0%	96/167	57.5%
BROWN BULLHEAD	35/ 85	41.2%	43/ 82	52.4%	78/167	46.7%
LARGEMOUTH BASS	24/ 85	28.2%	45/ 82	54.9%	69/167	41.3%
CARP	1/ 85	1.18%	50/ 82	61.0%	51/167	30.5%
GOLDEN SHINER	10/ 85	11.8%	37/ 82	45.1%	47/167	28.1%
WALLEYE	23/ 85	27.1%	22/ 82	26.8%	45/167	26.9%
GREEN SUNFISH	2/ 85	2.35%	30/ 82	36.6%	32/167	19.2%
WHITE CRAPPIE	0/ 85	0.00%	27/ 82	32.9%	27/167	16.2%
FRESHWATER DRUM	0/ 85	0.00%	3/ 82	3.66%	3/167	1.80%
SMALLMOUTH BASS	1/ 85	1.18%	1/ 82	1.22%	2/167	1.20%
WHITE BASS	0/ 85	0.00%	1/ 82	1.22%	1/167	0.60%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 11 MSM (Depth/Area/Secchi)						
NORTHERN PIKE	246/350	70.3%	66/ 71	93.0%	312/421	74.1%
YELLOW PERCH	257/350	73.4%	50/ 71	70.4%	307/421	72.9%
WHITE SUCKER	199/350	56.9%	38/ 71	53.5%	237/421	56.3%
BLUEGILL	173/350	49.4%	63/ 71	88.7%	236/421	56.1%
BLACK CRAPPIE	162/350	46.3%	61/ 71	85.9%	223/421	53.0%
LARGEMOUTH BASS	150/350	42.9%	51/ 71	71.8%	201/421	47.7%
BROWN BULLHEAD	120/350	34.3%	47/ 71	66.2%	167/421	39.7%
WALLEYE	96/350	27.4%	22/ 71	31.0%	118/421	28.0%
GREEN SUNFISH	23/350	6.57%	39/ 71	54.9%	62/421	14.7%
GOLDEN SHINER	30/350	8.57%	23/ 71	32.4%	53/421	12.6%
CARP	3/350	0.86%	23/ 71	32.4%	26/421	6.18%
LAKE HERRING (CISCO)	22/350	6.29%	3/ 71	4.23%	25/421	5.94%
SMALLMOUTH BASS	12/350	3.43%	3/ 71	4.23%	15/421	3.56%
WHITE CRAPPIE	0/350	0.00%	13/ 71	18.3%	13/421	3.09%
LAKE TROUT	7/350	2.00%	1/ 71	1.41%	8/421	1.90%
LAKE WHITEFISH	6/350	1.71%	0/ 71	0.00%	6/421	1.43%
FRESHWATER DRUM	0/350	0.00%	1/ 71	1.41%	1/421	0.24%
Class: 12 MSO (Depth/Area/Secchi)						
YELLOW PERCH	50/ 76	65.8%	5/ 6	83.3%	55/ 82	67.1%
NORTHERN PIKE	41/ 76	53.9%	6/ 6	100%	47/ 82	57.3%
WHITE SUCKER	40/ 76	52.6%	3/ 6	50.0%	43/ 82	52.4%
LARGEMOUTH BASS	36/ 76	47.4%	6/ 6	100%	42/ 82	51.2%
BLUEGILL	35/ 76	46.1%	6/ 6	100%	41/ 82	50.0%
BLACK CRAPPIE	27/ 76	35.5%	6/ 6	100%	33/ 82	40.2%
BROWN BULLHEAD	17/ 76	22.4%	5/ 6	83.3%	22/ 82	26.8%
WALLEYE	17/ 76	22.4%	4/ 6	66.7%	21/ 82	25.6%
GREEN SUNFISH	10/ 76	13.2%	5/ 6	83.3%	15/ 82	18.3%
LAKE TROUT	8/ 76	10.5%	0/ 6	0.00%	8/ 82	9.76%
GOLDEN SHINER	6/ 76	7.89%	1/ 6	16.7%	7/ 82	8.54%
SMALLMOUTH BASS	7/ 76	9.21%	0/ 6	0.00%	7/ 82	8.54%
LAKE HERRING (CISCO)	4/ 76	5.26%	0/ 6	0.00%	4/ 82	4.88%
Class: 13 MME (Depth/Area/Secchi)						
NORTHERN PIKE	98/102	96.1%	135/142	95.1%	233/244	95.5%
YELLOW PERCH	96/102	94.1%	135/142	95.1%	231/244	94.7%
BLACK CRAPPIE	79/102	77.5%	136/142	95.8%	215/244	88.1%
WHITE SUCKER	92/102	90.2%	120/142	84.5%	212/244	86.9%
BLUEGILL	76/102	74.5%	136/142	95.8%	212/244	86.9%
WALLEYE	79/102	77.5%	111/142	78.2%	190/244	77.9%
BROWN BULLHEAD	65/102	63.7%	97/142	68.3%	162/244	66.4%
LARGEMOUTH BASS	51/102	50.0%	111/142	78.2%	162/244	66.4%
CARP	9/102	8.82%	106/142	74.6%	115/244	47.1%
GOLDEN SHINER	13/102	12.7%	80/142	56.3%	93/244	38.1%
GREEN SUNFISH	10/102	9.80%	64/142	45.1%	74/244	30.3%
WHITE CRAPPIE	0/102	0.00%	68/142	47.9%	68/244	27.9%
LAKE HERRING (CISCO)	22/102	21.6%	1/142	0.70%	23/244	9.43%
FRESHWATER DRUM	1/102	0.98%	19/142	13.4%	20/244	8.20%
WHITE BASS	0/102	0.00%	11/142	7.75%	11/244	4.51%
SMALLMOUTH BASS	6/102	5.88%	3/142	2.11%	9/244	3.69%
LAKE WHITEFISH	5/102	4.90%	1/142	0.70%	6/244	2.46%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 14 MMM (Depth/Area/Secchi)						
NORTHERN PIKE	509/531	95.9%	99/102	97.1%	608/633	96.1%
YELLOW PERCH	487/531	91.7%	98/102	96.1%	585/633	92.4%
WHITE SUCKER	461/531	86.8%	87/102	85.3%	548/633	86.6%
BLUEGILL	395/531	74.4%	101/102	99.0%	496/633	78.4%
WALLEYE	411/531	77.4%	79/102	77.5%	490/633	77.4%
BLACK CRAPPIE	382/531	71.9%	100/102	98.0%	482/633	76.1%
LARGEMOUTH BASS	357/531	67.2%	87/102	85.3%	444/633	70.1%
BROWN BULLHEAD	307/531	57.8%	78/102	76.5%	385/633	60.8%
LAKE HERRING (CISCO)	179/531	33.7%	14/102	13.7%	193/633	30.5%
GREEN SUNFISH	81/531	15.3%	62/102	60.8%	143/633	22.6%
GOLDEN SHINER	56/531	10.5%	33/102	32.4%	89/633	14.1%
CARP	22/531	4.14%	60/102	58.8%	82/633	13.0%
SMALLMOUTH BASS	69/531	13.0%	6/102	5.88%	75/633	11.8%
LAKE WHITEFISH	21/531	3.95%	0/102	0.00%	21/633	3.32%
WHITE CRAPPIE	0/531	0.00%	20/102	19.6%	20/633	3.16%
FRESHWATER DRUM	1/531	0.19%	6/102	5.88%	7/633	1.11%
LAKE TROUT	2/531	0.38%	0/102	0.00%	2/633	0.32%
WHITE BASS	0/531	0.00%	2/102	1.96%	2/633	0.32%
Class: 15 MMO (Depth/Area/Secchi)						
NORTHERN PIKE	71/ 78	91.0%	6/ 7	85.7%	77/ 85	90.6%
YELLOW PERCH	73/ 78	93.6%	4/ 7	57.1%	77/ 85	90.6%
WHITE SUCKER	67/ 78	85.9%	3/ 7	42.9%	70/ 85	82.4%
LARGEMOUTH BASS	62/ 78	79.5%	6/ 7	85.7%	68/ 85	80.0%
WALLEYE	61/ 78	78.2%	5/ 7	71.4%	66/ 85	77.6%
BLUEGILL	58/ 78	74.4%	6/ 7	85.7%	64/ 85	75.3%
BLACK CRAPPIE	51/ 78	65.4%	6/ 7	85.7%	57/ 85	67.1%
BROWN BULLHEAD	37/ 78	47.4%	5/ 7	71.4%	42/ 85	49.4%
LAKE HERRING (CISCO)	21/ 78	26.9%	0/ 7	0.00%	21/ 85	24.7%
SMALLMOUTH BASS	20/ 78	25.6%	0/ 7	0.00%	20/ 85	23.5%
GREEN SUNFISH	14/ 78	17.9%	4/ 7	57.1%	18/ 85	21.2%
CARP	3/ 78	3.85%	2/ 7	28.6%	5/ 85	5.88%
GOLDEN SHINER	2/ 78	2.56%	2/ 7	28.6%	4/ 85	4.71%
LAKE WHITEFISH	4/ 78	5.13%	0/ 7	0.00%	4/ 85	4.71%
LAKE TROUT	3/ 78	3.85%	0/ 7	0.00%	3/ 85	3.53%
WHITE CRAPPIE	0/ 78	0.00%	1/ 7	14.3%	1/ 85	1.18%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 16 MLE (Depth/Area/Secchi)						
BLACK CRAPPIE	14/ 14	100%	17/ 17	100%	31/ 31	100%
NORTHERN PIKE	14/ 14	100%	17/ 17	100%	31/ 31	100%
WALLEYE	14/ 14	100%	17/ 17	100%	31/ 31	100%
WHITE SUCKER	14/ 14	100%	17/ 17	100%	31/ 31	100%
YELLOW PERCH	14/ 14	100%	17/ 17	100%	31/ 31	100%
BLUEGILL	10/ 14	71.4%	16/ 17	94.1%	26/ 31	83.9%
LARGEMOUTH BASS	7/ 14	50.0%	14/ 17	82.4%	21/ 31	67.7%
BROWN BULLHEAD	9/ 14	64.3%	11/ 17	64.7%	20/ 31	64.5%
CARP	2/ 14	14.3%	15/ 17	88.2%	17/ 31	54.8%
GOLDEN SHINER	2/ 14	14.3%	11/ 17	64.7%	13/ 31	41.9%
WHITE CRAPPIE	0/ 14	0.00%	13/ 17	76.5%	13/ 31	41.9%
FRESHWATER DRUM	1/ 14	7.14%	10/ 17	58.8%	11/ 31	35.5%
LAKE HERRING (CISCO)	9/ 14	64.3%	1/ 17	5.88%	10/ 31	32.3%
GREEN SUNFISH	1/ 14	7.14%	6/ 17	35.3%	7/ 31	22.6%
SMALLMOUTH BASS	3/ 14	21.4%	2/ 17	11.8%	5/ 31	16.1%
WHITE BASS	0/ 14	0.00%	4/ 17	23.5%	4/ 31	12.9%
LAKE WHITEFISH	4/ 14	28.6%	0/ 17	0.00%	4/ 31	12.9%
Class: 17 MLM (Depth/Area/Secchi)						
NORTHERN PIKE	46/ 46	100%	5/ 5	100%	51/ 51	100%
YELLOW PERCH	46/ 46	100%	5/ 5	100%	51/ 51	100%
WALLEYE	45/ 46	97.8%	5/ 5	100%	50/ 51	98.0%
WHITE SUCKER	45/ 46	97.8%	5/ 5	100%	50/ 51	98.0%
BLACK CRAPPIE	38/ 46	82.6%	5/ 5	100%	43/ 51	84.3%
LAKE HERRING (CISCO)	38/ 46	82.6%	2/ 5	40.0%	40/ 51	78.4%
BLUEGILL	32/ 46	69.6%	5/ 5	100%	37/ 51	72.5%
BROWN BULLHEAD	31/ 46	67.4%	4/ 5	80.0%	35/ 51	68.6%
LARGEMOUTH BASS	28/ 46	60.9%	4/ 5	80.0%	32/ 51	62.7%
SMALLMOUTH BASS	15/ 46	32.6%	0/ 5	0.00%	15/ 51	29.4%
GREEN SUNFISH	9/ 46	19.6%	2/ 5	40.0%	11/ 51	21.6%
CARP	4/ 46	8.70%	5/ 5	100%	9/ 51	17.6%
LAKE WHITEFISH	7/ 46	15.2%	0/ 5	0.00%	7/ 51	13.7%
FRESHWATER DRUM	4/ 46	8.70%	0/ 5	0.00%	4/ 51	7.84%
GOLDEN SHINER	1/ 46	2.17%	1/ 5	20.0%	2/ 51	3.92%
WHITE CRAPPIE	0/ 46	0.00%	1/ 5	20.0%	1/ 51	1.96%
Class: 18 MLO (Depth/Area/Secchi)						
LAKE WHITEFISH	2/ 2	100%	0/ 0	****%	2/ 2	100%
NORTHERN PIKE	2/ 2	100%	0/ 0	****%	2/ 2	100%
WALLEYE	2/ 2	100%	0/ 0	****%	2/ 2	100%
WHITE SUCKER	2/ 2	100%	0/ 0	****%	2/ 2	100%
YELLOW PERCH	2/ 2	100%	0/ 0	****%	2/ 2	100%
BLACK CRAPPIE	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
BLUEGILL	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
BROWN BULLHEAD	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
CARP	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
FRESHWATER DRUM	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
GREEN SUNFISH	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
LARGEMOUTH BASS	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
SMALLMOUTH BASS	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%
LAKE HERRING (CISCO)	1/ 2	50.0%	0/ 0	****%	1/ 2	50.0%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 19 DSE (Depth/Area/Secchi)						
NORTHERN PIKE	6/ 6	100%	1/ 1	100%	7/ 7	100%
BLACK CRAPPIE	5/ 6	83.3%	0/ 1	0.00%	5/ 7	71.4%
BLUEGILL	4/ 6	66.7%	0/ 1	0.00%	4/ 7	57.1%
YELLOW PERCH	4/ 6	66.7%	0/ 1	0.00%	4/ 7	57.1%
BROWN BULLHEAD	3/ 6	50.0%	0/ 1	0.00%	3/ 7	42.9%
LARGEMOUTH BASS	3/ 6	50.0%	0/ 1	0.00%	3/ 7	42.9%
WHITE SUCKER	2/ 6	33.3%	0/ 1	0.00%	2/ 7	28.6%
WALLEYE	1/ 6	16.7%	0/ 1	0.00%	1/ 7	14.3%
Class: 20 DSM (Depth/Area/Secchi)						
NORTHERN PIKE	20/ 26	76.9%	7/ 7	100%	27/ 33	81.8%
BLUEGILL	17/ 26	65.4%	7/ 7	100%	24/ 33	72.7%
YELLOW PERCH	17/ 26	65.4%	6/ 7	85.7%	23/ 33	69.7%
LARGEMOUTH BASS	14/ 26	53.8%	7/ 7	100%	21/ 33	63.6%
BLACK CRAPPIE	12/ 26	46.2%	6/ 7	85.7%	18/ 33	54.5%
WHITE SUCKER	14/ 26	53.8%	2/ 7	28.6%	16/ 33	48.5%
BROWN BULLHEAD	10/ 26	38.5%	5/ 7	71.4%	15/ 33	45.5%
WALLEYE	5/ 26	19.2%	1/ 7	14.3%	6/ 33	18.2%
GREEN SUNFISH	1/ 26	3.85%	5/ 7	71.4%	6/ 33	18.2%
CARP	0/ 26	0.00%	5/ 7	71.4%	5/ 33	15.2%
GOLDEN SHINER	4/ 26	15.4%	1/ 7	14.3%	5/ 33	15.2%
LAKE HERRING (CISCO)	4/ 26	15.4%	1/ 7	14.3%	5/ 33	15.2%
SMALLMOUTH BASS	1/ 26	3.85%	1/ 7	14.3%	2/ 33	6.06%
LAKE TROUT	1/ 26	3.85%	0/ 7	0.00%	1/ 33	3.03%
Class: 21 DSO (Depth/Area/Secchi)						
WHITE SUCKER	18/ 26	69.2%	0/ 0	****%	18/ 26	69.2%
NORTHERN PIKE	15/ 26	57.7%	0/ 0	****%	15/ 26	57.7%
YELLOW PERCH	14/ 26	53.8%	0/ 0	****%	14/ 26	53.8%
BLUEGILL	13/ 26	50.0%	0/ 0	****%	13/ 26	50.0%
LARGEMOUTH BASS	13/ 26	50.0%	0/ 0	****%	13/ 26	50.0%
BLACK CRAPPIE	9/ 26	34.6%	0/ 0	****%	9/ 26	34.6%
LAKE TROUT	7/ 26	26.9%	0/ 0	****%	7/ 26	26.9%
BROWN BULLHEAD	5/ 26	19.2%	0/ 0	****%	5/ 26	19.2%
LAKE HERRING (CISCO)	4/ 26	15.4%	0/ 0	****%	4/ 26	15.4%
WALLEYE	4/ 26	15.4%	0/ 0	****%	4/ 26	15.4%
GREEN SUNFISH	2/ 26	7.69%	0/ 0	****%	2/ 26	7.69%
GOLDEN SHINER	1/ 26	3.85%	0/ 0	****%	1/ 26	3.85%
Class: 22 DME (Depth/Area/Secchi)						
BLACK CRAPPIE	3/ 3	100%	10/ 10	100%	13/ 13	100%
BLUEGILL	3/ 3	100%	10/ 10	100%	13/ 13	100%
NORTHERN PIKE	3/ 3	100%	10/ 10	100%	13/ 13	100%
WALLEYE	3/ 3	100%	10/ 10	100%	13/ 13	100%
WHITE SUCKER	3/ 3	100%	10/ 10	100%	13/ 13	100%
YELLOW PERCH	3/ 3	100%	10/ 10	100%	13/ 13	100%
LARGEMOUTH BASS	1/ 3	33.3%	9/ 10	90.0%	10/ 13	76.9%
BROWN BULLHEAD	1/ 3	33.3%	8/ 10	80.0%	9/ 13	69.2%
CARP	0/ 3	0.00%	9/ 10	90.0%	9/ 13	69.2%
GREEN SUNFISH	0/ 3	0.00%	5/ 10	50.0%	5/ 13	38.5%
LAKE HERRING (CISCO)	2/ 3	66.7%	2/ 10	20.0%	4/ 13	30.8%
GOLDEN SHINER	0/ 3	0.00%	4/ 10	40.0%	4/ 13	30.8%
WHITE CRAPPIE	0/ 3	0.00%	3/ 10	30.0%	3/ 13	23.1%
SMALLMOUTH BASS	1/ 3	33.3%	1/ 10	10.0%	2/ 13	15.4%

Table 12(Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 23 DMM (Depth/Area/Secchi)						
NORTHERN PIKE	96/103	93.2%	32/ 33	97.0%	128/136	94.1%
WHITE SUCKER	91/103	88.3%	31/ 33	93.9%	122/136	89.7%
YELLOW PERCH	81/103	78.6%	31/ 33	93.9%	112/136	82.4%
BLUEGILL	72/103	69.9%	33/ 33	100%	105/136	77.2%
BLACK CRAPPIE	72/103	69.9%	32/ 33	97.0%	104/136	76.5%
WALLEYE	74/103	71.8%	28/ 33	84.8%	102/136	75.0%
LARGEMOUTH BASS	70/103	68.0%	30/ 33	90.9%	100/136	73.5%
BROWN BULLHEAD	56/103	54.4%	29/ 33	87.9%	85/136	62.5%
LAKE HERRING (CISCO)	56/103	54.4%	16/ 33	48.5%	72/136	52.9%
GREEN SUNFISH	19/103	18.4%	22/ 33	66.7%	41/136	30.1%
CARP	8/103	7.77%	20/ 33	60.6%	28/136	20.6%
SMALLMOUTH BASS	16/103	15.5%	1/ 33	3.03%	17/136	12.5%
LAKE TROUT	15/103	14.6%	0/ 33	0.00%	15/136	11.0%
LAKE WHITEFISH	11/103	10.7%	1/ 33	3.03%	12/136	8.82%
GOLDEN SHINER	4/103	3.88%	8/ 33	24.2%	12/136	8.82%
FRESHWATER DRUM	2/103	1.94%	2/ 33	6.06%	4/136	2.94%
WHITE CRAPPIE	1/103	0.97%	1/ 33	3.03%	2/136	1.47%
Class: 24 DMO (Depth/Area/Secchi)						
WHITE SUCKER	63/ 69	91.3%	3/ 3	100%	66/ 72	91.7%
YELLOW PERCH	52/ 69	75.4%	3/ 3	100%	55/ 72	76.4%
NORTHERN PIKE	50/ 69	72.5%	3/ 3	100%	53/ 72	73.6%
BLUEGILL	35/ 69	50.7%	3/ 3	100%	38/ 72	52.8%
LARGEMOUTH BASS	32/ 69	46.4%	3/ 3	100%	35/ 72	48.6%
WALLEYE	33/ 69	47.8%	1/ 3	33.3%	34/ 72	47.2%
BLACK CRAPPIE	30/ 69	43.5%	3/ 3	100%	33/ 72	45.8%
LAKE HERRING (CISCO)	33/ 69	47.8%	0/ 3	0.00%	33/ 72	45.8%
LAKE TROUT	30/ 69	43.5%	0/ 3	0.00%	30/ 72	41.7%
SMALLMOUTH BASS	26/ 69	37.7%	1/ 3	33.3%	27/ 72	37.5%
BROWN BULLHEAD	17/ 69	24.6%	3/ 3	100%	20/ 72	27.8%
GREEN SUNFISH	12/ 69	17.4%	3/ 3	100%	15/ 72	20.8%
GOLDEN SHINER	5/ 69	7.25%	1/ 3	33.3%	6/ 72	8.33%
LAKE WHITEFISH	6/ 69	8.70%	0/ 3	0.00%	6/ 72	8.33%
CARP	1/ 69	1.45%	2/ 3	66.7%	3/ 72	4.17%
Class: 25 DLE (Depth/Area/Secchi)						
BLACK CRAPPIE	5/ 5	100%	5/ 5	100%	10/ 10	100%
NORTHERN PIKE	5/ 5	100%	5/ 5	100%	10/ 10	100%
WALLEYE	5/ 5	100%	5/ 5	100%	10/ 10	100%
WHITE SUCKER	5/ 5	100%	5/ 5	100%	10/ 10	100%
YELLOW PERCH	5/ 5	100%	5/ 5	100%	10/ 10	100%
LAKE HERRING (CISCO)	4/ 5	80.0%	4/ 5	80.0%	8/ 10	80.0%
BROWN BULLHEAD	3/ 5	60.0%	5/ 5	100%	8/ 10	80.0%
BLUEGILL	3/ 5	60.0%	5/ 5	100%	8/ 10	80.0%
LARGEMOUTH BASS	2/ 5	40.0%	5/ 5	100%	7/ 10	70.0%
CARP	1/ 5	20.0%	4/ 5	80.0%	5/ 10	50.0%
GREEN SUNFISH	1/ 5	20.0%	3/ 5	60.0%	4/ 10	40.0%
SMALLMOUTH BASS	1/ 5	20.0%	3/ 5	60.0%	4/ 10	40.0%
LAKE WHITEFISH	2/ 5	40.0%	1/ 5	20.0%	3/ 10	30.0%
WHITE CRAPPIE	0/ 5	0.00%	2/ 5	40.0%	2/ 10	20.0%
FRESHWATER DRUM	1/ 5	20.0%	0/ 5	0.00%	1/ 10	10.0%
GOLDEN SHINER	0/ 5	0.00%	1/ 5	20.0%	1/ 10	10.0%

Table 12 (Cont'd). Fish collected from 27 lake classes.

	NORTH		SOUTH		TOTAL	
Class: 26 DLM (Depth/Area/Secchi)						
NORTHERN PIKE	54/ 54	100%	6/ 6	100%	60/ 60	100%
WHITE SUCKER	54/ 54	100%	6/ 6	100%	60/ 60	100%
YELLOW PERCH	54/ 54	100%	6/ 6	100%	60/ 60	100%
WALLEYE	53/ 54	98.1%	6/ 6	100%	59/ 60	98.3%
LAKE HERRING (CISCO)	54/ 54	100%	4/ 6	66.7%	58/ 60	96.7%
BROWN BULLHEAD	45/ 54	83.3%	6/ 6	100%	51/ 60	85.0%
BLACK CRAPPIE	43/ 54	79.6%	6/ 6	100%	49/ 60	81.7%
BLUEGILL	40/ 54	74.1%	6/ 6	100%	46/ 60	76.7%
LARGEMOUTH BASS	40/ 54	74.1%	6/ 6	100%	46/ 60	76.7%
SMALLMOUTH BASS	17/ 54	31.5%	5/ 6	83.3%	22/ 60	36.7%
GREEN SUNFISH	15/ 54	27.8%	6/ 6	100%	21/ 60	35.0%
LAKE WHITEFISH	13/ 54	24.1%	0/ 6	0.00%	13/ 60	21.7%
CARP	8/ 54	14.8%	5/ 6	83.3%	13/ 60	21.7%
GOLDEN SHINER	3/ 54	5.56%	0/ 6	0.00%	3/ 60	5.00%
FRESHWATER DRUM	2/ 54	3.70%	0/ 6	0.00%	2/ 60	3.33%
LAKE TROUT	1/ 54	1.85%	0/ 6	0.00%	1/ 60	1.67%
Class: 27 DLO (Depth/Area/Secchi)						
WHITE SUCKER	17/ 17	100%	0/ 0	****%	17/ 17	100%
WALLEYE	16/ 17	94.1%	0/ 0	****%	16/ 17	94.1%
YELLOW PERCH	14/ 17	82.4%	0/ 0	****%	14/ 17	82.4%
NORTHERN PIKE	13/ 17	76.5%	0/ 0	****%	13/ 17	76.5%
SMALLMOUTH BASS	13/ 17	76.5%	0/ 0	****%	13/ 17	76.5%
LAKE HERRING (CISCO)	11/ 17	64.7%	0/ 0	****%	11/ 17	64.7%
LAKE TROUT	10/ 17	58.8%	0/ 0	****%	10/ 17	58.8%
LARGEMOUTH BASS	7/ 17	41.2%	0/ 0	****%	7/ 17	41.2%
LAKE WHITEFISH	7/ 17	41.2%	0/ 0	****%	7/ 17	41.2%
BLACK CRAPPIE	6/ 17	35.3%	0/ 0	****%	6/ 17	35.3%
BLUEGILL	6/ 17	35.3%	0/ 0	****%	6/ 17	35.3%
BROWN BULLHEAD	5/ 17	29.4%	0/ 0	****%	5/ 17	29.4%
GREEN SUNFISH	4/ 17	23.5%	0/ 0	****%	4/ 17	23.5%
CARP	1/ 17	5.88%	0/ 0	****%	1/ 17	5.88%
GOLDEN SHINER	1/ 17	5.88%	0/ 0	****%	1/ 17	5.88%

TABLE 13 a. COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS)
THERMAL AND DISSOLVED OXYGEN HABITAT, PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzero (day)	Z*jd (m day)	Z*jd Zm*GSL	Vol*jd A (m day)	Vol*jd Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	183	232	49	101	298	96	101	354	0.91	133	0.88
		mesotrophic	178	233	55	100	298	88	110	338	0.95	129	0.93
		oligotrophic	176	233	57	100	298	83	115	330	0.98	129	0.98
	MEDIUM (1.7)	eutrophic	179	233	54	101	298	88	109	341	0.96	125	0.94
		mesotrophic	176	233	57	100	298	83	115	329	0.98	122	0.97
		oligotrophic	175	241	66	100	299	81	118	324	0.99	121	0.99
	LARGE (10.0)	eutrophic	177	233	56	100	297	87	110	339	0.96	114	0.94
		mesotrophic	176	233	57	100	297	84	113	330	0.97	113	0.97
		oligotrophic	175	233	58	100	297	82	115	328	0.99	113	0.99
MEDIUM (13.0)	SMALL (0.2)	eutrophic	198	219	21	107	306	135	64	827	0.47	412	0.60
		mesotrophic	202	220	18	107	307	129	71	949	0.56	428	0.65
		oligotrophic	204	231	27	107	307	130	70	1160	0.68	439	0.67
	MEDIUM (1.7)	eutrophic	196	219	23	108	306	117	81	1080	0.71	409	0.73
		mesotrophic	198	223	25	107	306	114	85	1160	0.77	414	0.76
		oligotrophic	203	224	21	107	306	118	81	1220	0.79	409	0.72
	LARGE (10.0)	eutrophic	197	233	36	106	304	103	95	1160	0.86	373	0.82
		mesotrophic	198	233	35	106	304	102	96	1180	0.88	371	0.83
		oligotrophic	191	236	45	106	305	96	103	1140	0.91	370	0.88
DEEP (24.0)	SMALL (0.2)	eutrophic	204	232	28	112	308	153	43	801	0.22	633	0.43
		mesotrophic	200	232	32	112	309	162	35	952	0.24	701	0.45
		oligotrophic	0	0	0	112	311	199	0	1420	0.30	851	0.44
	MEDIUM (1.7)	eutrophic	204	231	27	114	311	139	58	1430	0.43	749	0.60
		mesotrophic	204	218	14	113	311	153	45	1690	0.46	803	0.58
		oligotrophic	0	0	0	113	312	199	0	2540	0.53	909	0.51
	LARGE (10.0)	eutrophic	0	0	0	111	309	121	77	2030	0.69	724	0.72
		mesotrophic	0	0	0	111	309	132	66	2390	0.75	752	0.69
		oligotrophic	0	0	0	111	310	159	40	2840	0.74	768	0.59

For acronyms see pages v - ix

TABLE 13 b. COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS)
THERMAL AND DISSOLVED OXYGEN HABITAT, PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW	SMALL	eutrophic	0	0	0	115	283	112	56	399	0.88	147	0.84
(4.0)	(0.2)	mesotrophic	0	0	0	111	284	102	71	379	0.92	143	0.89
		oligotrophic	0	0	0	110	284	97	77	375	0.96	145	0.94
	MEDIUM	eutrophic	0	0	0	115	283	102	66	385	0.94	138	0.89
	(1.7)	mesotrophic	0	0	0	110	284	98	76	380	0.96	140	0.94
		oligotrophic	0	0	0	110	284	91	83	364	0.99	136	0.99
	LARGE	eutrophic	0	0	0	111	282	101	70	386	0.95	130	0.93
	(10.0)	mesotrophic	0	0	0	110	283	97	76	375	0.96	127	0.94
		oligotrophic	0	0	0	110	284	92	82	368	0.99	127	0.99
MEDIUM	SMALL	eutrophic	0	0	0	123	290	163	4	861	0.40	459	0.56
(13.0)	(0.2)	mesotrophic	0	0	0	123	291	167	1	966	0.44	468	0.55
		oligotrophic	0	0	0	123	291	163	5	1230	0.58	482	0.58
	MEDIUM	eutrophic	0	0	0	124	289	138	27	1220	0.68	463	0.70
	(1.7)	mesotrophic	0	0	0	123	290	139	28	1310	0.72	466	0.70
		oligotrophic	0	0	0	123	290	123	44	1340	0.83	455	0.77
	LARGE	eutrophic	0	0	0	123	288	113	52	1310	0.88	417	0.84
	(10.0)	mesotrophic	0	0	0	123	288	109	56	1290	0.91	410	0.85
		oligotrophic	0	0	0	122	288	101	65	1240	0.94	405	0.91
DEEP	SMALL	eutrophic	0	0	0	130	294	162	2	834	0.21	693	0.44
(24.0)	(0.2)	mesotrophic	0	0	0	130	295	165	0	949	0.24	739	0.46
		oligotrophic	0	0	0	130	297	167	0	1440	0.36	900	0.56
	MEDIUM	eutrophic	0	0	0	131	296	165	0	1550	0.39	841	0.57
	(1.7)	mesotrophic	0	0	0	131	297	166	0	1790	0.45	891	0.60
		oligotrophic	0	0	0	131	298	167	0	2630	0.65	982	0.65
	LARGE	eutrophic	0	0	0	129	295	162	4	2240	0.57	826	0.62
	(10.0)	mesotrophic	0	0	0	128	295	167	0	2670	0.66	858	0.62
		oligotrophic	0	0	0	128	296	168	0	3150	0.78	864	0.62

Table 13 c. COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS)
THERMAL AND DISSOLVED OXYGEN HABITAT, PAST PERIOD 1955-1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW	SMALL	eutrophic	0	0	0	135	266	131	0	444	0.84	198	0.96
(4.0)	(0.2)	mesotrophic	0	0	0	135	267	132	0	525	0.99	206	0.99
		oligotrophic	0	0	0	135	267	132	0	527	0.99	206	0.99
	MEDIUM	eutrophic	0	0	0	135	266	131	0	507	0.96	195	0.99
	(1.7)	mesotrophic	0	0	0	135	266	131	0	524	0.99	196	0.99
		oligotrophic	0	0	0	134	267	133	0	532	0.99	199	0.99
	LARGE	eutrophic	0	0	0	135	266	131	0	523	0.99	180	0.99
	(10.0)	mesotrophic	0	0	0	135	266	131	0	524	0.99	180	0.99
		oligotrophic	0	0	0	135	266	131	0	524	0.99	180	0.99
MEDIUM	SMALL	eutrophic	0	0	0	137	272	135	0	501	0.28	422	0.61
(13.0)	(0.2)	mesotrophic	0	0	0	138	274	136	0	707	0.40	513	0.74
		oligotrophic	0	0	0	138	276	138	0	1090	0.60	612	0.87
	MEDIUM	eutrophic	0	0	0	139	273	134	0	839	0.48	514	0.80
	(1.7)	mesotrophic	0	0	0	138	273	135	0	1030	0.58	560	0.87
		oligotrophic	0	0	0	138	274	136	0	1400	0.79	616	0.95
	LARGE	eutrophic	0	0	0	138	272	134	0	1210	0.69	549	0.93
	(10.0)	mesotrophic	0	0	0	138	272	134	0	1570	0.89	572	0.97
		oligotrophic	0	0	0	138	272	134	0	1680	0.96	580	0.99
DEEP	SMALL	eutrophic	0	0	0	139	272	133	0	476	0.15	514	0.40
(24.0)	(0.2)	mesotrophic	0	0	0	140	274	134	0	658	0.20	654	0.50
		oligotrophic	0	0	0	141	278	137	0	998	0.30	856	0.64
	MEDIUM	eutrophic	0	0	0	141	276	135	0	725	0.22	675	0.56
	(1.7)	mesotrophic	0	0	0	142	277	135	0	892	0.27	771	0.63
		oligotrophic	0	0	0	142	279	137	0	1270	0.39	931	0.76
	LARGE	eutrophic	0	0	0	142	278	136	0	1400	0.43	891	0.79
	(10.0)	mesotrophic	0	0	0	142	279	137	0	1590	0.48	942	0.83
		oligotrophic	0	0	0	142	279	137	0	2220	0.67	1040	0.92

TABLE 13 d. COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS)
THERMAL AND DISSOLVED OXYGEN HABITAT, PAST PERIOD 1955-1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	149	252	103	0	381	0.92	158	0.97
		mesotrophic	0	0	0	149	252	103	0	412	0.99	162	1.00
		oligotrophic	0	0	0	149	252	103	0	416	1.00	163	1.00
	MEDIUM (1.7)	eutrophic	0	0	0	149	252	103	0	407	0.98	155	0.99
		mesotrophic	0	0	0	149	252	103	0	416	1.00	156	1.00
		oligotrophic	0	0	0	149	253	104	0	420	1.00	157	1.00
	LARGE (10.0)	eutrophic	0	0	0	149	252	103	0	407	0.98	141	0.99
		mesotrophic	0	0	0	149	252	103	0	416	1.00	143	1.00
		oligotrophic	0	0	0	149	252	103	0	416	1.00	143	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	155	255	100	0	400	0.30	330	0.65
		mesotrophic	0	0	0	155	256	101	0	542	0.41	390	0.76
		oligotrophic	0	0	0	155	258	103	0	808	0.60	461	0.88
	MEDIUM (1.7)	eutrophic	0	0	0	156	256	100	0	707	0.54	407	0.85
		mesotrophic	0	0	0	155	256	101	0	836	0.63	433	0.89
		oligotrophic	0	0	0	155	256	101	0	1160	0.88	469	0.97
	LARGE (10.0)	eutrophic	0	0	0	155	255	100	0	1100	0.84	426	0.97
		mesotrophic	0	0	0	155	255	100	0	1230	0.93	434	0.99
		oligotrophic	0	0	0	155	255	100	0	1270	0.97	438	0.99
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	159	256	97	0	342	0.15	372	0.39
		mesotrophic	0	0	0	159	257	98	0	471	0.20	472	0.50
		oligotrophic	0	0	0	161	260	99	0	659	0.28	590	0.61
	MEDIUM (1.7)	eutrophic	0	0	0	164	257	93	0	541	0.24	497	0.59
		mesotrophic	0	0	0	163	259	96	0	635	0.27	553	0.64
		oligotrophic	0	0	0	164	261	97	0	837	0.36	644	0.74
	LARGE (10.0)	eutrophic	0	0	0	164	260	96	0	1030	0.44	656	0.82
		mesotrophic	0	0	0	163	261	98	0	1180	0.50	695	0.86
		oligotrophic	0	0	0	163	262	99	0	1580	0.66	746	0.91

Table 13 e. WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, PAST 1955-1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	149	256	107	0	353	0.82	159	0.94
		mesotrophic	0	0	0	149	256	107	0	416	0.96	165	0.98
		oligotrophic	0	0	0	149	256	107	0	424	0.98	166	0.98
	MEDIUM (1.7)	eutrophic	0	0	0	149	256	107	0	405	0.94	157	0.97
		mesotrophic	0	0	0	149	256	107	0	423	0.98	159	0.98
		oligotrophic	0	0	0	149	256	107	0	424	0.98	159	0.98
	LARGE (10.0)	eutrophic	0	0	0	149	255	106	0	409	0.96	145	0.98
		mesotrophic	0	0	0	149	255	106	0	421	0.98	146	0.99
		oligotrophic	0	0	0	149	256	107	0	424	0.98	146	0.98
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	154	258	104	0	351	0.26	309	0.58
		mesotrophic	0	0	0	154	259	105	0	508	0.37	383	0.72
		oligotrophic	0	0	0	154	262	108	0	789	0.56	469	0.85
	MEDIUM (1.7)	eutrophic	0	0	0	154	259	105	0	568	0.41	387	0.77
		mesotrophic	0	0	0	154	261	107	0	733	0.52	430	0.84
		oligotrophic	0	0	0	154	261	107	0	1050	0.75	478	0.93
	LARGE (10.0)	eutrophic	0	0	0	154	258	104	0	927	0.68	425	0.93
		mesotrophic	0	0	0	154	258	104	0	1180	0.87	441	0.96
		oligotrophic	0	0	0	154	258	104	0	1280	0.94	449	0.98
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	154	257	103	0	322	0.13	358	0.36
		mesotrophic	0	0	0	154	259	105	0	454	0.18	467	0.46
		oligotrophic	0	0	0	155	262	107	0	652	0.25	601	0.58
	MEDIUM (1.7)	eutrophic	0	0	0	155	259	104	0	492	0.20	482	0.51
		mesotrophic	0	0	0	155	261	106	0	608	0.24	556	0.58
		oligotrophic	0	0	0	156	263	107	0	812	0.31	660	0.68
	LARGE (10.0)	eutrophic	0	0	0	156	262	106	0	885	0.35	660	0.75
		mesotrophic	0	0	0	156	263	107	0	990	0.38	695	0.78
		oligotrophic	0	0	0	156	264	108	0	1320	0.50	767	0.86

TABLE 13 f. WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, PAST 1955-1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW	SMALL	eutrophic	0	0	0	177	233	56	0	199	0.87	86.1	0.97
(4.0)	(0.2)	mesotrophic	0	0	0	177	234	57	0	228	0.98	90.1	0.99
		oligotrophic	0	0	0	177	234	57	0	230	0.99	90.3	1.00
	MEDIUM	eutrophic	0	0	0	177	233	56	0	225	0.99	85.2	1.00
	(1.7)	mesotrophic	0	0	0	176	234	58	0	232	0.98	88.1	1.00
		oligotrophic	0	0	0	176	241	65	0	244	0.92	91.5	0.92
	LARGE	eutrophic	0	0	0	177	233	56	0	226	0.99	78.4	1.00
	(10.0)	mesotrophic	0	0	0	176	233	57	0	230	0.99	79.8	1.00
		oligotrophic	0	0	0	176	233	57	0	232	1.00	79.9	1.00
MEDIUM	SMALL	eutrophic	0	0	0	179	235	56	0	173	0.23	158	0.55
(13.0)	(0.2)	mesotrophic	0	0	0	179	241	62	0	276	0.34	218	0.69
		oligotrophic	0	0	0	179	242	63	0	430	0.52	270	0.84
	MEDIUM	eutrophic	0	0	0	180	241	61	0	282	0.35	211	0.72
	(1.7)	mesotrophic	0	0	0	180	241	61	0	370	0.46	241	0.82
		oligotrophic	0	0	0	180	241	61	0	616	0.76	277	0.94
	LARGE	eutrophic	0	0	0	180	241	61	0	579	0.72	246	0.91
	(10.0)	mesotrophic	0	0	0	179	241	62	0	652	0.80	258	0.94
		oligotrophic	0	0	0	179	241	62	0	726	0.89	267	0.97
DEEP	SMALL	eutrophic	0	0	0	180	235	55	0	150	0.11	172	0.32
(24.0)	(0.2)	mesotrophic	0	0	0	181	241	60	0	217	0.15	235	0.40
		oligotrophic	0	0	0	185	242	57	0	316	0.23	304	0.55
	MEDIUM	eutrophic	0	0	0	182	240	58	0	220	0.16	228	0.43
	(1.7)	mesotrophic	0	0	0	185	241	56	0	278	0.20	270	0.53
		oligotrophic	0	0	0	186	242	56	0	378	0.28	328	0.64
	LARGE	eutrophic	0	0	0	186	241	55	0	369	0.28	314	0.68
	(10.0)	mesotrophic	0	0	0	186	242	56	0	415	0.30	338	0.72
		oligotrophic	0	0	0	186	244	58	0	535	0.38	386	0.80

TABLE 14 a. PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW	SMALL	eutrophic	155	254	99	76	308	97	135	290	0.74	117	0.77
(4.0)	(0.2)	mesotrophic	154	256	102	76	308	82	150	306	0.92	116	0.90
		oligotrophic	144	256	112	76	308	74	158	295	0.98	115	0.98
	MEDIUM	eutrophic	150	254	104	75	308	95	138	326	0.85	115	0.80
	(1.7)	mesotrophic	145	256	111	75	308	79	154	303	0.95	112	0.93
		oligotrophic	144	256	112	75	308	74	159	296	0.99	111	0.99
	LARGE	eutrophic	150	254	104	75	308	84	149	316	0.93	104	0.89
	(10.0)	mesotrophic	145	256	111	74	308	78	156	305	0.97	104	0.95
		oligotrophic	144	256	112	74	308	75	159	300	0.99	103	0.99
MEDIUM	SMALL	eutrophic	178	250	72	83	309	136	90	604	0.34	314	0.45
(13.0)	(0.2)	mesotrophic	182	253	71	84	309	130	95	646	0.38	327	0.49
		oligotrophic	178	253	75	85	309	118	106	755	0.49	351	0.58
	MEDIUM	eutrophic	180	251	71	84	308	107	117	667	0.48	322	0.63
	(1.7)	mesotrophic	181	248	67	85	308	109	114	726	0.51	335	0.64
		oligotrophic	181	261	80	85	308	110	113	945	0.66	353	0.67
	LARGE	eutrophic	177	258	81	84	308	98	126	892	0.69	332	0.77
	(10.0)	mesotrophic	178	259	81	84	308	100	124	1040	0.79	328	0.75
		oligotrophic	171	260	89	84	308	92	132	1000	0.83	318	0.78
DEEP	SMALL	eutrophic	159	255	96	85	311	165	61	951	0.24	547	0.34
(24.0)	(0.2)	mesotrophic	202	253	51	87	311	189	35	983	0.22	595	0.33
		oligotrophic	0	0	0	89	311	217	5	1240	0.24	713	0.34
	MEDIUM	eutrophic	175	250	75	87	311	132	92	1120	0.35	579	0.49
	(1.7)	mesotrophic	215	244	29	89	311	166	56	1210	0.30	626	0.42
		oligotrophic	0	0	0	90	311	194	27	1540	0.33	732	0.42
	LARGE	eutrophic	186	249	63	89	310	113	108	1240	0.45	589	0.63
	(10.0)	mesotrophic	207	248	41	89	310	124	97	1460	0.49	641	0.63
		oligotrophic	0	0	0	90	310	154	66	2280	0.61	705	0.55

TABLE 14 b. PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	207	218	11	99	299	109	91	376	0.86	134	0.78
		mesotrophic	174	232	58	99	299	85	115	333	0.97	128	0.95
		oligotrophic	173	232	59	89	300	93	118	341	0.91	132	0.90
	MEDIUM (1.7)	eutrophic	178	229	51	99	299	93	107	338	0.90	124	0.88
		mesotrophic	173	232	59	89	299	93	117	338	0.90	125	0.89
		oligotrophic	165	232	67	89	300	91	120	340	0.92	127	0.92
	LARGE (10.0)	eutrophic	177	229	52	89	298	97	112	336	0.86	113	0.84
		mesotrophic	173	232	59	89	298	91	118	331	0.90	113	0.89
		oligotrophic	165	232	67	89	298	89	120	332	0.92	114	0.92
MEDIUM (13.0)	SMALL (0.2)	eutrophic	199	202	3	104	307	148	55	656	0.34	387	0.51
		mesotrophic	204	218	14	104	307	143	60	801	0.43	414	0.57
		oligotrophic	202	219	17	103	307	140	64	1080	0.59	443	0.62
	MEDIUM (1.7)	eutrophic	218	219	1	104	306	130	72	977	0.57	408	0.66
		mesotrophic	205	207	2	104	306	122	80	1110	0.70	419	0.72
		oligotrophic	0	0	0	103	307	120	84	1260	0.80	433	0.75
	LARGE (10.0)	eutrophic	206	218	12	103	305	110	92	1110	0.77	386	0.80
		mesotrophic	206	230	24	103	305	110	92	1220	0.85	389	0.81
		oligotrophic	193	232	39	102	305	103	100	1210	0.90	381	0.84
DEEP (24.0)	SMALL (0.2)	eutrophic	190	223	33	107	309	164	38	598	0.15	557	0.35
		mesotrophic	0	0	0	107	311	189	15	793	0.17	666	0.36
		oligotrophic	0	0	0	107	313	206	0	1310	0.26	872	0.44
	MEDIUM (1.7)	eutrophic	214	218	4	109	312	162	41	1140	0.29	721	0.50
		mesotrophic	0	0	0	108	313	188	17	1410	0.31	818	0.48
		oligotrophic	0	0	0	108	314	206	0	2160	0.44	958	0.52
	LARGE (10.0)	eutrophic	0	0	0	108	311	134	69	1880	0.58	765	0.69
		mesotrophic	0	0	0	107	312	148	57	2380	0.67	825	0.68
		oligotrophic	0	0	0	107	312	198	7	3090	0.65	865	0.53

Table 14 c. PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	105	276	171	0	447	0.65	219	0.81
		mesotrophic	0	0	0	105	276	167	4	605	0.90	229	0.87
		oligotrophic	0	0	0	105	276	150	21	595	0.99	233	0.99
	MEDIUM (1.7)	eutrophic	0	0	0	105	276	171	0	534	0.78	220	0.85
		mesotrophic	0	0	0	105	276	155	16	597	0.96	219	0.94
		oligotrophic	0	0	0	105	276	146	25	583	0.99	218	0.99
	LARGE (10.0)	eutrophic	0	0	0	105	275	169	1	606	0.89	208	0.89
		mesotrophic	0	0	0	105	276	159	12	605	0.95	203	0.92
		oligotrophic	0	0	0	105	276	148	23	589	0.99	202	0.98
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	111	277	166	0	455	0.21	421	0.50
		mesotrophic	0	0	0	112	279	167	0	699	0.32	548	0.65
		oligotrophic	0	0	0	114	280	166	0	1060	0.49	642	0.76
	MEDIUM (1.7)	eutrophic	0	0	0	115	280	165	0	750	0.35	540	0.68
		mesotrophic	0	0	0	114	280	166	0	1000	0.46	618	0.78
		oligotrophic	0	0	0	114	280	166	0	1420	0.65	666	0.84
	LARGE (10.0)	eutrophic	0	0	0	114	279	165	0	1230	0.57	628	0.87
		mesotrophic	0	0	0	113	279	166	0	1610	0.74	658	0.90
		oligotrophic	0	0	0	113	279	166	0	1970	0.91	648	0.89
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	115	276	161	0	423	0.11	484	0.31
		mesotrophic	0	0	0	115	278	163	0	645	0.16	676	0.43
		oligotrophic	0	0	0	116	281	165	0	989	0.25	911	0.57
	MEDIUM (1.7)	eutrophic	0	0	0	116	279	163	0	631	0.16	647	0.44
		mesotrophic	0	0	0	117	280	163	0	828	0.21	785	0.54
		oligotrophic	0	0	0	118	282	164	0	1210	0.31	985	0.67
	LARGE (10.0)	eutrophic	0	0	0	118	282	164	0	1180	0.30	904	0.67
		mesotrophic	0	0	0	118	282	164	0	1360	0.34	984	0.73
		oligotrophic	0	0	0	119	283	164	0	1920	0.48	1140	0.84

TABLE 14 d. PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	133	266	133	0	498	0.93	205	0.98
		mesotrophic	0	0	0	133	266	133	0	528	0.99	209	1.00
		oligotrophic	0	0	0	133	266	133	0	536	1.00	210	1.00
	MEDIUM (1.7)	eutrophic	0	0	0	133	266	133	0	433	0.81	194	0.96
		mesotrophic	0	0	0	133	266	133	0	534	1.00	201	1.00
		oligotrophic	0	0	0	133	266	133	0	536	1.00	201	1.00
	LARGE (10.0)	eutrophic	0	0	0	133	265	132	0	493	0.93	181	0.99
		mesotrophic	0	0	0	133	265	132	0	531	1.00	183	1.00
		oligotrophic	0	0	0	133	265	132	0	532	1.00	183	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	135	270	135	0	402	0.23	367	0.53
		mesotrophic	0	0	0	136	272	136	0	631	0.35	483	0.70
		oligotrophic	0	0	0	137	274	137	0	1030	0.57	599	0.86
	MEDIUM (1.7)	eutrophic	0	0	0	136	271	135	0	637	0.36	453	0.70
		mesotrophic	0	0	0	137	272	135	0	900	0.51	531	0.82
		oligotrophic	0	0	0	137	272	135	0	1300	0.73	602	0.93
	LARGE (10.0)	eutrophic	0	0	0	137	271	134	0	987	0.56	515	0.88
		mesotrophic	0	0	0	137	271	134	0	1300	0.74	555	0.94
		oligotrophic	0	0	0	137	271	134	0	1670	0.95	581	0.99
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	137	270	133	0	373	0.12	422	0.33
		mesotrophic	0	0	0	138	273	135	0	567	0.17	587	0.45
		oligotrophic	0	0	0	141	277	136	0	885	0.27	796	0.60
	MEDIUM (1.7)	eutrophic	0	0	0	139	272	133	0	530	0.17	540	0.45
		mesotrophic	0	0	0	141	275	134	0	731	0.23	678	0.56
		oligotrophic	0	0	0	142	279	137	0	1100	0.33	865	0.70
	LARGE (10.0)	eutrophic	0	0	0	141	278	137	0	1070	0.32	777	0.69
		mesotrophic	0	0	0	141	278	137	0	1310	0.40	859	0.76
		oligotrophic	0	0	0	142	279	137	0	1870	0.57	985	0.87

Table 14 e. PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW	SMALL	eutrophic	0	0	0	126	272	146	0	415	0.71	209	0.91
(4.0)	(0.2)	mesotrophic	0	0	0	124	273	149	0	572	0.95	230	0.98
		oligotrophic	0	0	0	125	273	148	0	585	0.98	230	0.99
	MEDIUM	eutrophic	0	0	0	124	272	148	0	492	0.83	212	0.95
	(1.7)	mesotrophic	0	0	0	124	273	149	0	585	0.98	222	0.99
		oligotrophic	0	0	0	124	273	149	0	596	0.99	223	0.99
	LARGE	eutrophic	0	0	0	124	272	148	0	552	0.93	199	0.97
	(10.0)	mesotrophic	0	0	0	124	272	148	0	580	0.97	202	0.99
		oligotrophic	0	0	0	124	272	148	0	588	0.98	202	0.99
MEDIUM	SMALL	eutrophic	0	0	0	133	274	141	0	383	0.21	360	0.50
(13.0)	(0.2)	mesotrophic	0	0	0	134	274	140	0	596	0.33	475	0.67
		oligotrophic	0	0	0	134	275	141	0	942	0.51	591	0.82
	MEDIUM	eutrophic	0	0	0	134	274	140	0	607	0.33	458	0.68
	(1.7)	mesotrophic	0	0	0	134	275	141	0	853	0.46	536	0.79
		oligotrophic	0	0	0	135	275	140	0	1270	0.70	613	0.91
	LARGE	eutrophic	0	0	0	134	274	140	0	1090	0.59	543	0.88
	(10.0)	mesotrophic	0	0	0	134	274	140	0	1410	0.77	578	0.94
		oligotrophic	0	0	0	133	274	141	0	1720	0.93	603	0.97
DEEP	SMALL	eutrophic	0	0	0	135	274	139	0	340	0.10	395	0.29
(24.0)	(0.2)	mesotrophic	0	0	0	135	274	139	0	521	0.16	555	0.41
		oligotrophic	0	0	0	137	275	138	0	768	0.23	729	0.55
	MEDIUM	eutrophic	0	0	0	136	274	138	0	498	0.15	523	0.42
	(1.7)	mesotrophic	0	0	0	136	275	139	0	661	0.20	642	0.51
		oligotrophic	0	0	0	137	276	139	0	929	0.28	793	0.63
	LARGE	eutrophic	0	0	0	137	276	139	0	928	0.28	757	0.66
	(10.0)	mesotrophic	0	0	0	137	276	139	0	1070	0.32	818	0.71
		oligotrophic	0	0	0	137	276	139	0	1480	0.44	930	0.81

TABLE 14 f. PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS)
THERMAL AND DISSOLVED OXYGEN HABITAT, 2XCO2 CLIMATE SCENARIO GISS MODEL

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSB (day)	NSE (day)	NSL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	144	253	109	0	385	0.88	165	0.96
		mesotrophic	0	0	0	143	253	110	0	434	0.98	173	0.99
		oligotrophic	0	0	0	144	253	109	0	440	1.00	172	1.00
	MEDIUM (1.7)	eutrophic	0	0	0	143	253	110	0	366	0.82	160	0.96
		mesotrophic	0	0	0	142	253	111	0	444	0.99	168	1.00
		oligotrophic	0	0	0	143	253	110	0	444	1.00	166	1.00
	LARGE (10.0)	eutrophic	0	0	0	143	252	109	0	410	0.93	150	0.99
		mesotrophic	0	0	0	142	252	110	0	441	0.99	153	1.00
		oligotrophic	0	0	0	142	252	110	0	444	1.00	153	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	149	255	106	0	284	0.20	269	0.50
		mesotrophic	0	0	0	150	256	106	0	455	0.33	362	0.67
		oligotrophic	0	0	0	152	259	107	0	731	0.52	455	0.84
	MEDIUM (1.7)	eutrophic	0	0	0	150	256	106	0	411	0.30	331	0.65
		mesotrophic	0	0	0	152	257	105	0	602	0.44	399	0.79
		oligotrophic	0	0	0	153	257	104	0	965	0.71	460	0.92
	LARGE (10.0)	eutrophic	0	0	0	150	256	106	0	776	0.56	400	0.86
		mesotrophic	0	0	0	150	256	106	0	994	0.72	430	0.92
		oligotrophic	0	0	0	150	256	106	0	1270	0.91	454	0.97
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	150	255	105	0	245	0.10	286	0.28
		mesotrophic	0	0	0	154	256	102	0	372	0.15	401	0.40
		oligotrophic	0	0	0	155	260	105	0	582	0.23	555	0.54
	MEDIUM (1.7)	eutrophic	0	0	0	154	256	102	0	324	0.13	353	0.38
		mesotrophic	0	0	0	154	257	103	0	462	0.19	459	0.49
		oligotrophic	0	0	0	155	261	106	0	674	0.26	591	0.62
	LARGE (10.0)	eutrophic	0	0	0	155	258	103	0	597	0.24	529	0.62
		mesotrophic	0	0	0	155	260	105	0	737	0.29	601	0.69
		oligotrophic	0	0	0	156	262	106	0	1010	0.39	695	0.79

TABLE 15 a. PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day)	GSL (day)	Gzer (day)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	50	-25	10	21	34	-16	-12
		mesotrophic	47	-24	10	6	40	-13	-10
		oligotrophic	55	-24	10	-2	43	-14	-11
	MEDIUM (1.7)	eutrophic	50	-26	10	20	29	-10	-8
		mesotrophic	54	-25	10	4	39	-10	-8
		oligotrophic	46	-25	9	-1	41	-10	-8
	LARGE (10.0)	eutrophic	48	-25	11	9	39	-10	-9
		mesotrophic	54	-26	11	4	43	-9	-8
		oligotrophic	54	-26	11	1	44	-10	-9
MEDIUM (13.0)	SMALL (0.2)	eutrophic	51	-24	3	53	26	-98	-24
		mesotrophic	53	-23	2	46	24	-101	-24
		oligotrophic	48	-22	2	33	36	-88	-20
	MEDIUM (1.7)	eutrophic	48	-24	2	23	36	-87	-21
		mesotrophic	42	-22	2	24	29	-79	-19
		oligotrophic	59	-22	2	25	32	-56	-14
	LARGE (10.0)	eutrophic	45	-22	4	14	31	-41	-11
		mesotrophic	46	-22	4	16	28	-43	-12
		oligotrophic	44	-22	3	8	29	-52	-14
DEEP (24.0)	SMALL (0.2)	eutrophic	68	-27	3	80	18	-86	-14
		mesotrophic	19	-25	2	102	0	-106	-15
		oligotrophic	0	-23	0	128	5	-138	-16
	MEDIUM (1.7)	eutrophic	48	-27	0	45	34	-170	-23
		mesotrophic	15	-24	0	77	11	-177	-22
		oligotrophic	0	-23	-1	104	27	-177	-19
	LARGE (10.0)	eutrophic	63	-22	1	24	31	-135	-19
		mesotrophic	41	-22	1	35	31	-111	-15
		oligotrophic	0	-21	0	64	26	-63	-8

TABLE 15 b. PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day)	GSL (day)	Gzer (day)	Vol*jd A (m day)	Vol*jd A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	11	-16	16	-3	35	-13	-9
		mesotrophic	58	-12	15	-17	44	-15	-10
		oligotrophic	59	-21	16	-4	41	-13	-9
	MEDIUM (1.7)	eutrophic	51	-16	16	-9	41	-14	-10
		mesotrophic	59	-21	15	-5	41	-15	-11
		oligotrophic	67	-21	16	0	37	-9	-7
	LARGE (10.0)	eutrophic	52	-22	16	-4	42	-17	-13
		mesotrophic	59	-21	15	-6	42	-14	-11
		oligotrophic	67	-21	14	-3	38	-13	-10
MEDIUM (13.0)	SMALL (0.2)	eutrophic	3	-19	17	-15	51	-72	-16
		mesotrophic	14	-19	16	-24	59	-54	-12
		oligotrophic	17	-20	16	-23	59	-39	-8
	MEDIUM (1.7)	eutrophic	1	-20	17	-8	45	-55	-12
		mesotrophic	2	-19	16	-17	52	-47	-10
		oligotrophic	0	-20	17	-3	40	-22	-5
	LARGE (10.0)	eutrophic	12	-20	17	-3	40	-31	-7
		mesotrophic	24	-20	17	1	36	-21	-5
		oligotrophic	39	-20	17	2	35	-24	-6
DEEP (24.0)	SMALL (0.2)	eutrophic	33	-23	15	2	36	-136	-20
		mesotrophic	0	-23	16	24	15	-73	-10
		oligotrophic	0	-23	16	39	0	-28	-3
	MEDIUM (1.7)	eutrophic	4	-22	16	-3	41	-120	-14
		mesotrophic	0	-23	16	22	17	-73	-8
		oligotrophic	0	-23	16	39	0	-24	-2
	LARGE (10.0)	eutrophic	0	-21	16	-28	65	-61	-7
		mesotrophic	0	-21	17	-19	57	-33	-4
		oligotrophic	0	-21	16	30	7	1	0

TABLE 15 c. PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW	SMALL	eutrophic	0	-30	10	40	0	21	11
(4.0)	(0.2)	mesotrophic	0	-30	9	35	4	23	11
		oligotrophic	0	-30	9	18	21	27	13
	MEDIUM	eutrophic	0	-30	10	40	0	25	13
	(1.7)	mesotrophic	0	-30	10	24	16	23	12
		oligotrophic	0	-29	9	13	25	19	10
	LARGE	eutrophic	0	-30	9	38	1	28	16
	(10.0)	mesotrophic	0	-30	10	28	12	23	13
		oligotrophic	0	-30	10	17	23	22	12
MEDIUM	SMALL	eutrophic	0	-26	5	31	0	-1	-0
(13.0)	(0.2)	mesotrophic	0	-26	5	31	0	35	7
		oligotrophic	0	-24	4	28	0	30	5
	MEDIUM	eutrophic	0	-24	7	31	0	26	5
	(1.7)	mesotrophic	0	-24	7	31	0	58	10
		oligotrophic	0	-24	6	30	0	50	8
	LARGE	eutrophic	0	-24	7	31	0	79	14
	(10.0)	mesotrophic	0	-25	7	32	0	86	15
		oligotrophic	0	-25	7	32	0	68	12
DEEP	SMALL	eutrophic	0	-24	4	28	0	-30	-6
(24.0)	(0.2)	mesotrophic	0	-25	4	29	0	22	3
		oligotrophic	0	-25	3	28	0	55	6
	MEDIUM	eutrophic	0	-25	3	28	0	-28	-4
	(1.7)	mesotrophic	0	-25	3	28	0	14	2
		oligotrophic	0	-24	3	27	0	54	6
	LARGE	eutrophic	0	-24	4	28	0	13	1
	(10.0)	mesotrophic	0	-24	3	27	0	42	4
		oligotrophic	0	-23	4	27	0	100	10

TABLE 15 d. PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	-16	14	30	0	47	30
		mesotrophic	0	-16	14	30	0	47	29
		oligotrophic	0	-16	14	30	0	47	29
	MEDIUM (1.7)	eutrophic	0	-16	14	30	0	39	25
		mesotrophic	0	-16	14	30	0	45	29
		oligotrophic	0	-16	13	29	0	44	28
	LARGE (10.0)	eutrophic	0	-16	13	29	0	40	28
		mesotrophic	0	-16	13	29	0	40	28
		oligotrophic	0	-16	13	29	0	40	28
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-20	15	35	0	37	11
		mesotrophic	0	-19	16	35	0	93	24
		oligotrophic	0	-18	16	34	0	138	30
	MEDIUM (1.7)	eutrophic	0	-20	15	35	0	46	11
		mesotrophic	0	-18	16	34	0	98	23
		oligotrophic	0	-18	16	34	0	133	28
	LARGE (10.0)	eutrophic	0	-18	16	34	0	89	21
		mesotrophic	0	-18	16	34	0	121	28
		oligotrophic	0	-18	16	34	0	143	33
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-22	14	36	0	50	13
		mesotrophic	0	-21	16	37	0	115	24
		oligotrophic	0	-20	17	37	0	206	35
	MEDIUM (1.7)	eutrophic	0	-25	15	40	0	43	9
		mesotrophic	0	-22	16	38	0	125	23
		oligotrophic	0	-22	18	40	0	221	34
	LARGE (10.0)	eutrophic	0	-23	18	41	0	121	18
		mesotrophic	0	-22	17	39	0	164	24
		oligotrophic	0	-21	17	38	0	239	32

TABLE 15 e. PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Vol*jd A (m day)	Vol*jd A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	-23	16	39	0	50	31
		mesotrophic	0	-25	17	42	0	65	39
		oligotrophic	0	-24	17	41	0	64	39
	MEDIUM (1.7)	eutrophic	0	-25	16	41	0	55	35
		mesotrophic	0	-25	17	42	0	63	40
		oligotrophic	0	-25	17	42	0	64	40
	LARGE (10.0)	eutrophic	0	-25	17	42	0	54	37
		mesotrophic	0	-25	17	42	0	56	38
		oligotrophic	0	-25	16	41	0	56	38
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-21	16	37	0	51	17
		mesotrophic	0	-20	15	35	0	92	24
		oligotrophic	0	-20	13	33	0	122	26
	MEDIUM (1.7)	eutrophic	0	-20	15	35	0	71	18
		mesotrophic	0	-20	14	34	0	106	25
		oligotrophic	0	-19	14	33	0	135	28
	LARGE (10.0)	eutrophic	0	-20	16	36	0	118	28
		mesotrophic	0	-20	16	36	0	137	31
		oligotrophic	0	-21	16	37	0	154	34
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-19	17	36	0	37	10
		mesotrophic	0	-19	15	34	0	88	19
		oligotrophic	0	-18	13	31	0	128	21
	MEDIUM (1.7)	eutrophic	0	-19	15	34	0	41	9
		mesotrophic	0	-19	14	33	0	86	15
		oligotrophic	0	-19	13	32	0	133	20
	LARGE (10.0)	eutrophic	0	-19	14	33	0	97	15
		mesotrophic	0	-19	13	32	0	123	18
		oligotrophic	0	-19	12	31	0	163	21

TABLE 15 f. PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN NORTHERN MINNESOTA LAKES (REGIONAL ANALYSIS) DIFFERENCES (GISS-PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH					
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	NSL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Vol*jd A (m day)	Vol*jd A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	-33	20	53	0	79	92
		mesotrophic	0	-34	19	53	0	83	92
		oligotrophic	0	-33	19	52	0	82	90
	MEDIUM (1.7)	eutrophic	0	-34	20	54	0	75	88
		mesotrophic	0	-34	19	53	0	80	91
		oligotrophic	0	-33	12	45	0	75	81
	LARGE (10.0)	eutrophic	0	-34	19	53	0	72	91
		mesotrophic	0	-34	19	53	0	73	92
		oligotrophic	0	-34	19	53	0	73	91
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-30	20	50	0	111	70
		mesotrophic	0	-29	15	44	0	144	66
		oligotrophic	0	-27	17	44	0	185	69
	MEDIUM (1.7)	eutrophic	0	-30	15	45	0	120	57
		mesotrophic	0	-28	16	44	0	158	66
		oligotrophic	0	-27	16	43	0	183	66
	LARGE (10.0)	eutrophic	0	-30	15	45	0	154	63
		mesotrophic	0	-29	15	44	0	172	67
		oligotrophic	0	-29	15	44	0	187	70
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-30	20	50	0	114	66
		mesotrophic	0	-27	15	42	0	166	71
		oligotrophic	0	-30	18	48	0	251	83
	MEDIUM (1.7)	eutrophic	0	-28	16	44	0	125	55
		mesotrophic	0	-31	16	47	0	189	70
		oligotrophic	0	-31	19	50	0	263	80
	LARGE (10.0)	eutrophic	0	-31	17	48	0	215	68
		mesotrophic	0	-31	18	49	0	263	78
		oligotrophic	0	-30	18	48	0	309	80

TABLE 16 a. CHARACTERISTICS OF REGIONAL LAKES IN SOUTHERN MINNESOTA

LAKE CHARACTERISTICS							RELATIVE FREQUENCY BY		
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	VOLUME Million (m3)	TROPHIC STATUS	NUMBER OF LAKES	TOTAL SURFACE AREA (km2)	TOTAL VOLUME Million (m3)	NUMBER OF LAKES (%)	SURFACE AREA (%)	VOLUME (%)
SHALLOW	SMALL		eutrophic	45	9.0	14.1	5.8	0.6	0.3
4.0	0.2	0.31	mesotrophic	12	2.4	3.7	1.6	0.2	0.1
			oligotrophic	1	0.2	0.3	0.1	0.0	0.0
	MEDIUM		eutrophic	170	289.0	433.0	22.0	20.3	7.8
	1.7	2.55	mesotrophic	24	40.8	61.2	3.1	2.9	1.1
			oligotrophic	2	3.4	5.1	0.3	0.2	0.1
	LARGE		eutrophic	19	190.0	262.0	2.5	13.4	4.7
	10.0	13.80	mesotrophic	2	20.0	27.5	0.3	1.4	0.5
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
MEDIUM	SMALL		eutrophic	83	16.6	83.8	10.8	1.2	1.5
13.0	0.2	1.01	mesotrophic	70	14.0	70.7	9.1	1.0	1.3
			oligotrophic	6	1.2	6.1	0.8	0.1	0.1
	MEDIUM		eutrophic	142	241.0	1150.0	18.4	17.0	20.6
	1.7	8.09	mesotrophic	101	172.0	817.0	13.1	12.1	14.7
			oligotrophic	7	11.9	56.6	0.9	0.8	1.0
	LARGE		eutrophic	17	170.0	741.0	2.2	12.0	13.3
	10.0	43.60	mesotrophic	5	50.0	218.0	0.6	3.5	3.9
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
DEEP	SMALL		eutrophic	1	0.2	1.9	0.1	0.0	0.0
24.0	0.2	1.93	mesotrophic	7	1.4	13.5	0.9	0.1	0.2
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
	MEDIUM		eutrophic	10	17.0	152.0	1.3	1.2	2.7
	1.7	15.20	mesotrophic	33	56.1	501.0	4.3	3.9	9.0
			oligotrophic	3	5.1	45.6	0.4	0.4	0.8
	LARGE		eutrophic	5	50.0	410.0	0.6	3.5	7.4
	10.0	82.10	mesotrophic	6	60.0	492.0	0.8	4.2	8.8
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
			SUM =	771	1420.0	5570.0	100	100	100

TABLE 16 b. CHARACTERISTICS OF REGIONAL LAKES IN NORTHERN MINNESOTA

LAKE CHARACTERISTICS							RELATIVE FREQUENCY BY		
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	VOLUME Million (m3)	TROPHIC STATUS	NUMBER OF LAKES	TOTAL SURFACE AREA (km2)	TOTAL VOLUME Million (m3)	NUMBER OF LAKES (%)	SURFACE AREA (%)	VOLUME (%)
SHALLOW	SMALL		eutrophic	184	36.8	57.5	8.2	1.0	0.3
4.0	0.2	0.31	mesotrophic	187	37.4	58.5	8.4	1.0	0.3
			oligotrophic	2	0.4	0.6	0.1	0.0	0.0
	MEDIUM		eutrophic	151	257.0	385.0	6.8	7.2	2.1
	1.7	2.55	mesotrophic	100	170.0	255.0	4.5	4.8	1.4
			oligotrophic	2	3.4	5.1	0.1	0.1	0.0
	LARGE	13.80	eutrophic	7	70.0	96.4	0.3	2.0	0.5
	10.0		mesotrophic	3	30.0	41.3	0.1	0.8	0.2
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
MEDIUM	SMALL		eutrophic	84	16.8	84.8	3.8	0.5	0.5
13.0	0.2	1.01	mesotrophic	352	70.4	355.0	15.8	2.0	1.9
			oligotrophic	78	15.6	78.7	3.5	0.4	0.4
	MEDIUM		eutrophic	102	173.0	825.0	4.6	4.8	4.4
	1.7	8.09	mesotrophic	532	904.0	4300.0	23.8	25.3	22.9
			oligotrophic	76	129.0	614.0	3.4	3.6	3.3
	LARGE	43.60	eutrophic	14	140.0	610.0	0.6	3.9	3.3
	10.0		mesotrophic	45	450.0	1960.0	2.0	12.6	10.5
			oligotrophic	1	10.0	43.6	0.0	0.3	0.2
DEEP	SMALL		eutrophic	6	1.2	11.6	0.3	0.0	0.1
24.0	0.2	1.93	mesotrophic	26	5.2	50.1	1.2	0.1	0.3
			oligotrophic	26	5.2	50.1	1.2	0.1	0.3
	MEDIUM		eutrophic	3	5.1	45.6	0.1	0.1	0.2
	1.7	15.20	mesotrophic	104	177.0	1580.0	4.7	4.9	8.4
			oligotrophic	71	121.0	1080.0	3.2	3.4	5.8
	LARGE		eutrophic	5	50.0	410.0	0.2	1.4	2.2
	10.0	82.10	mesotrophic	53	530.0	4350.0	2.4	14.8	23.2
			oligotrophic	17	170.0	1400.0	0.8	4.8	7.4
			SUM =	2231	3580.0	18700.0	100	100	100

TABLE 16 c. CHARACTERISTICS OF REGIONAL LAKES IN MINNESOTA

LAKE CHARACTERISTICS							RELATIVE FREQUENCY BY		
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	VOLUME Million (m3)	TROPHIC STATUS	NUMBER OF LAKES	TOTAL SURFACE AREA (km2)	TOTAL VOLUME Million (m3)	NUMBER OF LAKES (%)	SURFACE AREA (%)	VOLUME (%)
SHALLOW	SMALL		eutrophic	229	45.8	71.6	7.6	0.9	0.3
4.0	0.2	0.31	mesotrophic	199	39.8	62.2	6.6	0.8	0.3
			oligotrophic	3	0.6	0.9	0.1	0.0	0.0
	MEDIUM		eutrophic	321	546.0	818.0	10.7	10.9	3.4
	1.7	2.55	mesotrophic	124	211.0	316.0	4.1	4.2	1.3
			oligotrophic	4	68.0	10.2	0.1	0.1	0.0
	LARGE		eutrophic	26	260.0	358.0	0.9	5.2	1.5
	10.0	13.80	mesotrophic	5	50.0	68.9	0.2	1.0	0.3
			oligotrophic	0	0.0	0.0	0.0	0.0	0.0
MEDIUM	SMALL		eutrophic	167	33.4	169.0	5.6	0.7	0.7
13.0	0.2	1.01	mesotrophic	422	84.4	426.0	14.1	1.7	1.8
			oligotrophic	84	16.8	84.8	2.8	0.3	0.3
	MEDIUM		eutrophic	244	415.0	1970.0	8.1	8.3	8.1
	1.7	8.09	mesotrophic	633	1080.0	5120.0	21.1	21.5	21.1
			oligotrophic	83	141.0	671.0	2.8	2.8	2.8
	LARGE	43.60	eutrophic	31	310.0	1350.0	1.0	6.2	5.6
	10.0		mesotrophic	50	500.0	2180.0	1.7	10.0	9.0
			oligotrophic	1	10.0	43.6	0.0	0.2	0.2
DEEP	SMALL		eutrophic	7	1.4	13.5	0.2	0.0	0.1
24.0	0.2	1.93	mesotrophic	33	6.6	63.5	1.1	0.1	0.3
			oligotrophic	26	5.2	50.1	0.9	0.1	0.2
	MEDIUM		eutrophic	13	22.1	198.0	0.4	0.4	0.8
	1.7	15.20	mesotrophic	137	233.0	2080.0	4.6	4.7	8.6
			oligotrophic	74	126.0	1120.0	2.5	2.5	4.6
	LARGE		eutrophic	10	100.0	821.0	0.3	2.0	3.4
	10.0	82.10	mesotrophic	59	590.0	4840.0	2.0	11.8	19.9
			oligotrophic	17	170.0	1400.0	0.6	3.4	5.7
			SUM =	3002	5000.0	24300.0	100	100	100

TABLE 17a. SUMMARY OF FISH PARAMETERS FOR ALL SOUTHERN MINNESOTA LAKES (771 LAKES)

CLIMATE	SURVIVAL (%)			LENGTH OF GOOD GROWTH SEASON (days)			LENGTH OF RESTRICTED GROWTH /STRESS SEASON (days)			TOTAL GOOD GROWTH VOLUME INTEGRAL OVER TIME (Billion m3*day)
	WEIGHTED BY			WEIGHTED BY			WEIGHTED BY			
	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	
				COLD WATER FISH						
1955-1979	1.8	8.0	17.1	144	131	130	56	69	67	85
2xCO2 GISS	0.4	0.3	0.8	194	194	194	27	27	27	4
DIFFERENCE	-1.4	-7.7	-16.3	50	63	64	-29	-42	-40	-81
				COOL WATER FISH						
1955-1979	100	100	100	134	133	134	0	0	0	631
2xCO2 GISS	100	100	100	167	167	165	0	0	0	684
DIFFERENCE	0	0	0	33	33	31	0	0	0	53
				WARM WATER FISH						
1955-1979	100	100	100	106	106	106	0	0	0	481
2xCO2 GISS	100	100	100	143	143	141	1	1	0	597
DIFFERENCE	0	0	0	37	37	35	1	1	0	116

DIFFERENCE = (2xCO2 GISS) - (1955-1979)

TABLE 17b. SUMMARY OF FISH PARAMETERS FOR ALL NORTHERN MINNESOTA LAKES (2231 LAKES)

CLIMATE	SURVIVAL (%)			LENGTH OF GOOD GROWTH SEASON (days)			LENGTH OF RESTRICTED GROWTH /STRESS SEASON (days)			TOTAL GOOD GROWTH VOLUME INTEGRAL OVER TIME (Billion m3*day)
	WEIGHTED BY			WEIGHTED BY			WEIGHTED BY			
	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	
				COLD WATER FISH						
1955-1979	100	100	100	138	136	147	30	31	20	1871
2xCO2 GISS	41.5	63.8	78.6	169	144	151	72	59	52	1102
DIFFERENCE	-58.5	-36.2	-21.4	31	8	4	42	28	32	-769
				COOL WATER FISH						
1955-1979	100	100	100	101	100	99	0	0	0	1627
2xCO2 GISS	100	100	100	135	135	135	0	0	0	2027
DIFFERENCE	0	0	0	34	35	36	0	0	0	400
				WARM WATER FISH						
1955-1979	100	100	100	59	59	59	0	0	0	869
2xCO2 GISS	100	100	100	106	106	105	0	0	0	1489
DIFFERENCE	0	0	0	47	47	46	0	0	0	620

TABLE 17c. SUMMARY OF FISH PARAMETERS FOR ALL MINNESOTA LAKES (3002 LAKES)

CLIMATE	SURVIVAL (%)			LENGTH OF GOOD GROWTH SEASON (days)			LENGTH OF RESTRICTED GROWTH /STRESS SEASON (days)			TOTAL GOOD GROWTH VOLUME INTEGRAL OVER TIME (Billion m3*day)
	WEIGHTED BY			WEIGHTED BY			WEIGHTED BY			
	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	NUMBER	SURFACE AREA	VOLUME	
				COLD WATER FISH						
1955-1979	75	74	81	140	135	143	37	42	31	1956
2xCO2 GISS	30.9	45.8	60.7	175	158	161	60	50	46	1106
DIFFERENCE	-43.9	-28.1	-20.2	36	24	18	24	8	16	-850
				COOL WATER FISH						
1955-1979	100	100	100	110	109	107	0	0	0	2258
2xCO2 GISS	100	100	100	143	144	142	0	0	0	2711
DIFFERENCE	0	0	0	34	35	35	0	0	0	453
				WARM WATER FISH						
1955-1979	100	100	100	71	72	70	0	0	0	1350
2xCO2 GISS	100	100	100	116	117	113	0	0	0	2086
DIFFERENCE	0	0	0	44	44	43	0	0	0	736
							ALL FISH			
1955-1979										5564
2xCO2 GISS										5903
DIFFERENCE										339

TABLE 18a. TOTAL WATER VOLUME INTEGRAL OVER TIME (billion m^3*day) FOR GOOD GROWTH IN ALL SOUTHERN MINNESOTA LAKES (771 LAKES)

LAKE CHARACTERISTICS				FISH GUILD								
MAX. DEPTH	SURF. AREA	TROPH. STAT.	NUMB. LAKES	COLD			COOL			WARM		
				PAST	GISS	DIFF	PAST	GISS	DIFF	PAST	GISS	DIFF
S	S	E	45				1.77	1.97	0.20	1.43	1.88	0.45
S	S	M	12				0.46	0.55	0.09	0.40	0.55	0.16
S	S	O	1				0.08	0.05	-0.03	0.03	0.05	0.01
S	M	E	170				56.4	63.6	7.22	45.4	61.3	15.9
S	M	M	24				8.02	8.93	0.91	6.48	9.05	2.57
S	M	O	2				0.69	0.74	0.05	0.54	0.76	0.22
S	L	E	19				34.2	39.5	5.30	27.5	37.7	10.2
S	L	M	2				3.62	4.07	0.45	2.93	4.05	1.12
S	L	O	0				0	0	0	0	0	0
M	S	E	83				7.01	6.99	-0.02	5.13	5.98	0.85
M	S	M	70				7.18	7.67	0.49	5.36	6.65	1.29
M	S	O	6				0.74	0.77	0.04	0.56	0.71	0.15
M	M	E	142				124.	130.	6.28	93.43	110.6	17.1
M	M	M	101				96.2	106.1	10.0	73.8	92.0	18.2
M	M	O	7				7.35	7.94	0.60	5.70	7.31	1.61
M	L	E	17				93.1	106.5	13.4	72.1	92.1	20.0
M	L	M	5				28.7	33.0	4.3	22.1	29.0	6.9
M	L	O	0				0	0	0	0	0	0
D	S	E	1				0.10	0.10	-0.01	0.07	0.08	0.01
D	S	M	7				0.92	0.95	0.03	0.66	0.78	0.12
D	S	O	0	0	0	0	0	0	0	0	0	0
D	M	E	10				11.5	11.02	-0.48	8.21	8.91	0.70
D	M	M	33				43.3	44.0	0.8	31.19	36.01	4.82
D	M	O	3	4.6	3.8	-0.8	4.76	5.04	0.28	3.37	4.05	0.68
D	L	E	5	36.3		-36.3	44.7	45.3	0.7	33.1	37.9	4.9
D	L	M	6	43.7		-43.7	56.6	59.2	2.5	41.8	49.2	7.4
D	L	O	0	0	0	0	0	0	0	0	0	0
SUM =			771	85	4	-81	631	684	53	481	597	115

SHADED BOXES INDICATE UNINHABITABLE CONDITIONS

DEPTH:
S = SHALLOW (4 m)
M = MEDIUM (13 m)
D = DEEP (24 m)

AREA:
S = SMALL ($0.2\ km^2$)
M = MEDIUM ($1.7\ km^2$)
L = LARGE ($10\ km^2$)

TROPHIC STATUS:
E = EUTROPHIC
M = MESOTROPHIC
O = OLIGOTROPHIC

TABLE 18b. TOTAL WATER VOLUME INTEGRAL OVER TIME (billion m^3*day) FOR GOOD GROWTH IN ALL NORTHERN MINNESOTA LAKES (2231 LAKES)

LAKE CHARACTERISTICS				FISH GUILD								
MAX. DEPTH	SURF. AREA	TROPH. STAT.	NUMB. LAKES	COLD			COOL			WARM		
				PAST	GISS	DIFF	PAST	GISS	DIFF	PAST	GISS	DIFF
S	S	E	184	5.41		-5.41	5.8	7.5	1.7	3.2	6.1	2.9
S	S	M	187	5.35		-5.35	6.1	7.8	1.7	3.4	6.5	3.1
S	S	O	2	0.06		-0.06	0.07	0.08	0.01	0.04	0.07	0.03
S	M	E	151	35.4		-35.4	39.8	49.8	10	21.9	41.1	19.2
S	M	M	100	23.8		-23.8	26.5	34.1	7.6	15.0	28.5	13.5
S	M	O	2	0.46		-0.46	0.54	0.69	0.1	0.31	0.57	0.26
S	L	E	7	8.99		-8.99	9.7	12.5	2.8	5.4	10.4	5.0
S	L	M	3	3.68		-3.68	4.1	5.3	1.2	2.3	4.4	2.1
S	L	O	0	0		0	0	0	0	0	0	0
M	S	E	84	7.72	4.53	-3.19	5.5	6.2	0.7	2.7	4.5	1.8
M	S	M	352	32.9		-32.9	27.5	34.0	6.5	15.3	25.5	10.2
M	S	O	78	7.53		-7.53	7.2	9.3	2.1	4.2	7.1	2.9
M	M	E	102	80.25	57.37	-22.9	70.5	78.5	8.0	36.6	57.4	20.8
M	M	M	532	421.5	360.9	-60.6	391.	480.	89.0	218.	360.	142.
M	M	O	76	58.85	59.5	0.65	60.7	77.9	17.2	35.8	59.5	23.7
M	L	E	14	58.6		-58.6	59.9	72.4	12.5	34.6	56.2	21.6
M	L	M	45	184.8		-184.	195.	250.	55.0	116.	193.	77.
M	L	O	1	3.61		-3.61	3.91	5.2	1.29	2.4	4.0	1.6
D	S	E	6	0.83		-0.83	0.45	0.51	0.06	0.21	0.34	0.13
D	S	M	26	3.86	2.09	-1.77	2.5	3.1	0.6	1.23	2.09	0.86
D	S	O	26	4.70	2.90	-1.80	3.1	4.2	1.1	1.59	2.90	1.31
D	M	E	3	4.15		-4.15	2.4	2.7	0.3	1.12	1.74	0.62
D	M	M	104	157.5	81.1	-76.4	97.7	119.	21.3	47.7	81.12	33.4
D	M	O	71	118.4	71.2	-47.1	77.7	104.	26.3	39.6	71.3	31.7
D	L	E	5	40.54	25.96	-14.5	32.2	38.1	5.9	15.4	25.9	10.5
D	L	M	53	455.6	319.1	-136.	369.	456.	87.0	179.	319.	140.
D	L	O	17	146.5	117.8	-28.7	126.	167.	41.0	65.4	117.	51.6
SUM =			2231	1871	1102	-769	1627	2027	400	869	1489	620

SHADED BOXES INDICATE UNINHABITABLE CONDITIONS

DEPTH:
S = SHALLOW (4 m)
M = MEDIUM (13 m)
D = DEEP (24 m)

AREA:
S = SMALL ($0.2\ km^2$)
M = MEDIUM ($1.7\ km^2$)
L = LARGE ($10\ km^2$)

TROPHIC STATUS:
E = EUTROPHIC
M = MESOTROPHIC
O = OLIGOTROPHIC

TABLE 18c. TOTAL WATER VOLUME INTEGRAL OVER TIME (billion m^3*day) FOR GOOD GROWTH IN ALL MINNESOTA LAKES (3002 LAKES)

LAKE CHARACTERISTICS				FISH GUILD								
MAX. DEPTH	SURF AREA	TROPH. STAT.	NUMB. LAKES	COLD			COOL			WARM		
				PAST	GISS	DIFF	PAST	GISS	DIFF	PAST	GISS	DIFF
S	S	E	229	5.4		-5.4	7.6	9.5	1.9	4.6	8.0	3.3
S	S	M	199	5.3		-5.3	6.6	8.4	1.8	3.8	7.1	3.3
S	S	O	3	0.06		-0.06	0.2	0.1	-0.1	0.1	0.1	0.0
S	M	E	321	35.4		-35.4	96.2	113.4	17.2	67.3	102.4	35.1
S	M	M	124	23.8		-23.8	34.5	43.0	8.5	21.5	37.6	16.1
S	M	O	4	0.5		-0.5	1.2	1.4	0.2	0.9	1.3	0.5
S	L	E	26	9.0		-9.0	43.9	52.0	8.1	32.9	48.1	15.2
S	L	M	5	3.7		-3.7	7.7	9.4	1.7	5.2	8.5	3.2
S	L	O	0	0		0	0	0	0	0	0	0
M	S	E	167	7.7	4.5	-3.1	12.5	13.2	0.7	7.8	10.5	2.7
M	S	M	422	32.9		-32.9	34.7	41.7	7.0	20.7	32.2	11.5
M	S	O	84	7.5		-7.5	7.9	10.1	2.1	4.8	7.8	3.0
M	M	E	244	80.2	57.4	-22.9	194.	208.	14.0	130.	168.	38.8
M	M	M	633	421.5	360.9	-60.6	487.	586.	98.9	292.	452.	160.
M	M	O	83	58.8	59.5	0.6	68.1	85.8	17.8	41.5	66.8	25.3
M	L	E	31	58.6		-58.6	153.	179.	26.0	107.	148.	41.6
M	L	M	50	184.8		-184.	224.	283.	59.3	138.	222.	83.9
M	L	O	1	3.6		-3.6	3.9	5.2	1.3	2.4	4.0	1.6
D	S	E	7	0.8		-0.8	0.6	0.6	0.0	0.3	0.4	0.1
D	S	M	33	3.9	2.1	-1.77	3.4	4.1	0.6	1.9	2.9	1.0
D	S	O	26	4.7	2.9	-1.80	3.1	4.2	1.1	1.6	2.9	1.3
D	M	E	13	4.1		-4.15	13.9	13.7	-0.2	9.3	10.7	1.3
D	M	M	137	157.5	81.1	-76.4	141.	163.	22.0	78.9	117.1	38.2
D	M	O	74	123.0	75.0	-47.9	82.5	109.	26.6	43.0	75.4	32.4
D	L	E	10	76.8	26.0	-50.9	76.9	83.4	6.5	48.5	63.8	15.3
D	L	M	59	499.3	319.1	-180.	425.	515.	90.0	221.	368.	147.
D	L	O	17	146.5	117.8	-28.7	126.	167.	41.0	65.4	117.	51.6
SUM =			3002	1956	1106	-850	2258	2711	453	1350	2086	736

SHADED BOXES INDICATE UNINHABITABLE CONDITIONS

DEPTH:
S = SHALLOW (4 m)
M = MEDIUM (13 m)
D = DEEP (24 m)

AREA:
S = SMALL ($0.2\ km^2$)
M = MEDIUM ($1.7\ km^2$)
L = LARGE ($10\ km^2$)

TROPHIC STATUS:
E = EUTROPHIC
M = MESOTROPHIC
O = OLIGOTROPHIC

APPENDIX A

Standard Operating Procedure for the Generation of Growth Thermal Criteria Values

STANDARD OPERATING PROCEDURE FOR THE GENERATION OF GROWTH THERMAL CRITERIA VALUES

Background Information, Data Sources, Rules of Precedence, and Calculation Methods Pertinent to the Estimation of Thermal Growth Criteria Values

Formulated 5-14-91

I. Background Information

The method uses the Maximum Growth Rate x Temperature ($G_{max}xT$) relationship to establish a temperature range of 'good growth' for fish. The good growth temperature range is an arbitrarily designated range that is intended to permit comparison of species or guild responses under different environmental temperature regimes. Attachment #6, pg A-11 illustrates a sample $G_{max}xT$ relationship. It is a range within which the most rapid growth should occur and therefore the length of time a population spends within this range is considered a measure of the temperature dependent fisheries production potential of a waterbody. The upper and lower bounds, or limits, of a good growth range are the endpoint values of the methodology and are important variables used in subsequent project modelling. The $G_{max}xT$ relationship assumes fish are fed a maximum ration. It should also be understood that the optimum growth temperature is, for the purposes of this paper, defined as the temperature at which the maximum rate of growth occurs.

II. Data Sources and Rules of Precedence.

Whenever possible, growth thermal criteria have been calculated using growth curve data sets generated by thermal growth experiments for the species. Since a paucity of experimental growth curve data exists for some species, that which produced the maximum rate of growth and has a curve that resembled the shape of a typical growth curve (Brett, in Hoar, et al., 1979) was selected for the purposes of this work. Since insufficient data values exceeding the growth optimum were not always available to generate a growth curve useful for the calculation of the upper growth limit, lower and upper growth optima were often generated from more than one dataset. Rules of precedence prioritizing the choice of data source were formulated.

1. Maximum Growth Temperature.

Primary - If more than one set of experimental growth curve data existed, the set producing the highest Optimum Growth Temperature was given precedence. Citations for experiments from which Optimum Growth Temperatures were derived are listed in Attachment #1, pg A-8.

Secondary - Optimum Growth Temperature values from Table 7, Hokanson (1990b). (See Attachment #2, pg. A-6)

Tertiary - Final Temperature Preferendum values were used in the case where no Optimum Temperature values were available.

Calculation - If derived from growth curve data, the Optimum Growth Temperature is considered to be the temperature providing for maximum growth rate on the G_{max}xT curve. This value is determined by calculating the point on the curve at which the slope of the tangent line is zero. The curve maximum may not correspond to the largest growth rate data value from the experiment; since the curve considers all data points, the error associated with one point is minimized. The generation of species growth curves is discussed below.

2. Lower Good Growth Limit.

Primary - If a growth experiment existed from which to calculate a curve-fitting polynomial, experimental growth curve data were used to calculate the lower growth limit. Specifically, the experimental growth curve, chosen to calculate the Optimum Growth Temperature (see #1 above) is utilized.

Secondary - Optimum Growth Temperature values from Table 7, Hokanson (1990b). (See Attachment #2, pg A-6)

Calculation - Growth curve equations were calculated for those species for which growth experiments produced a curve which closely fit the data and resembled a typical growth curve. The dataset of specific growth rates (in weight) was reviewed prior to the calculation of the growth curve equation and in one case (See Attachment #3, pg A-8, Brown Bullhead) a data value which was determined as an outlier was removed. To improve the fit of the resulting equations, a Lower Zero Net Growth point, often from another experiment, was added to the dataset. Third order polynomials fitted to the data produced curves that conformed to the shape of typical growth curves (Brett, in Hoar, et al., 1979) and are listed below.

Species	Source	Growth Curve Equation	50% Growth
Bluegill	Lemke (1977)	$G=-0.0008t^3+0.05t^2-0.7t+3.5$	19.8
Brook Trout	McCormick, et al. (1976)	$G=-0.001t^3+0.002t^2-0.7t-2.2$	6.4
Brown Bullhead	Keast (1985)	$G=-0.0006t^3+0.03t^2-0.4t+1.1$	17.7
Brown Trout	Elliott (1975)	$G=-0.001t^3+0.02t^2-0.09t+0.1$	
Chinook Salmon	Brett et al. (1982)	$G=-0.002t^3-0.06t^2-0.3t+0.45$	11.8
Northern Pike	Hokanson (1973)	$G=-0.0005t^3+0.02t^2-0.09t+0.1$	13.2
Rainbow Trout	Hokanson, et al. (1977)	$G=-0.004t^3+0.1t^2-0.4t+0.5$	9.2
Smallmouth Bass	Horning et al. (1973)	$G=-0.0006t^3+0.04t^2-0.7t+3.3$	20.2
Walleye	Hokanson (1986)	$G=-0.002t^3+0.1t^2-1.7t+9.5$	18.2
White Bass	McCormick, unpubl.	$G=-0.002t^3+0.06t^2-0.8t+3.1$	18.1
White Sucker	McCormick (1977)	$G=-0.005t^3+0.3t^2-2.7t+8.2$	16.0
Yellow Perch	McCormick (1976)	$G=-0.002t^3+0.09t^2-1.3t+5.1$	17.7

Using these equations, the Lower Growth Limit (defined as 50% of the Maximum Growth Temperature) were calculated as follows:

1. The highest point on the curve is determined by finding that point at which the slope of the curve = 0.

2. The highest point (maximum growth) is divided by 2, giving the point of lower 50% growth.

3. The temperature that corresponds to the lower 50% growth point is calculated from the species growth curve equation.

One exception to the procedure outlined above was in the case of the Largemouth Bass. Because the experiment was testing for optimum temperature, there were no data near the 50% growth temperature. A third degree polynomial would not fit the points, so a Cubic Spline interpolation was performed. The result is very close to that determined by Strawn (1961) for 50% growth in length (as opposed to weight, which was used in all other growth studies) for largemouth bass.

For the following species, the lower 50% good growth limits were calculated by taking the mean of the Optimum Temperature (the temperature where maximum growth was determined) and the experimentally derived Lower Zero Net Growth, LZNG, value:

$$G = \frac{OptT + LZNG}{2} .$$

Species	Opt. T, Reference	LZNG, Reference	50% Growth
Sockeye Salmon	17.4, Clarke (1978)	<1, Brett, et al. (1969)	9.2
Coho Salmon	17, Averett (1969)	3, USDI (1970)	10.0
Channel Catfish	30, Andrews & Stickney (1972)	15, Brown (1974)	22.5

3. Upper Good Growth Limit.

While the previous two growth criteria utilize only laboratory-derived growth rate data, the Upper Growth Limit values are calculated using formulas given in NAS 'Blue Book' (1974) and/or U.S. EPA 'Red Book' (1976). These formulas employ the thermal variables Optimum Growth Temperature, Upper Zero Net Growth (UZNG), and Ultimate Upper Incipient Lethal Temperature (UUILT).

Primary - Values were calculated (see below) using upper thermal criteria data (UZNGs) obtained in laboratory experiments and listed in Attachment #2, pg A-6 & 7.

Secondary - Values were calculated using UUILT. If only the Upper Incipient Lethal Temperature, UILT, existed for a given species, its UUILT was calculated by the linear regression formula relating UUILT to UILT (see below).

Calculation - Calculation of the Upper Good Growth Limit is given by one of two formulas, depending upon the availability of data values for the thermal variables, in the following precedence:

Primary $$\frac{OptT+UZNG}{2} \quad (1)$$

Secondary $$OptT+\frac{UUILT-OptT}{3} \quad (2)$$

Formulas (1), (2) given in NAS 'Blue Book' (1974) and/or U.S. EPA 'Red Book' (1976).

Not all species have experimentally-derived UUILT values, used in Equation (2). A linear regression method has been used by Hokanson to relate UUILT values to known UILT values. The method calculates the linear regression equation from a set of known species UUILT and UILT values (see graph, attachment #5, pg A-11). The resulting regression equation, (3) below, was then used to compute UUILT values for those species which a UILT value but no UUILT value was known.

$$UUILT=1.12(UILT)-1.68 \quad , r^2 = .9477 \quad (3)$$

The set of known species UUILT and UILT values used to calculate the regression equation and the set of unknown UUILT values calculated using the regression equation are given in Attachment #4, pg A-10.

Attachment 1

Citations for Calculation of Optimum Growth Rate.

Species	Reference
Pink Salmon	Kepshire (1976)
Chinook Salmon	Brett et al. (1982)
Chum Salmon	Kepshire (1971; 1976)
Brown Trout	Elliott (1975)[2]
Rainbow Trout	Hokanson et al. (1977)[2]
Lake Trout	Goddard et al. (1974)[1]
Brook Trout	McCormick et al. (1976)[2]
Lake Herring	
Mountain Whitefish	
Northern Pike	Hokanson (1973)[2]
Muskellunge	Ferguson (1958)
White Sucker	McCormick (1977)[2]
Black Crappie	
White Crappie	
Yellow Perch	McCormick (1976)[2]
Sauger	
Walleye	Hokanson (1986)[2]
Lake Sturgeon	
Gizzard Shad	Gammon(1973); Neill(1971); Spigarelli(1975)[1]
Carp	Tatarko (1966)
Golden Shiner	Cincotta & Stauffer (1984)[1]
Channel Catfish	Andrews & Stickney (1972)
Brown Bullhead	Keast (1985)[2]
White Bass	McCormick, unpubl. (1975)[2]
Largemouth Bass	McCormick (1981)[2]
Smallmouth Bass	Horning et al. (1973)[2]
Green Sunfish	Jude (1973)
Bluegill	Lemke (1977)[2]
Rock Bass	Cherry et al. (1977)[1]
Freshwater Drum	Reutter & Herendorf (1974)[1]

[1] Final Temperature Preferendum used for Optimum Temperature
[2] Maximum Temperature as derived from growth equation.

Attachment #2

TABLE 7. THERMAL CRITERIA FOR GROWTH OF SELECTED FRESHWATER FISHES (from Hokanson, 1990b)

Species	Optimum Temp (C)		Zero Net Biomass Change (C)		
	Maximum	Reference	Lowest	Highest	Reference
White Sucker	26.1 26.9	Koenst & Smith (1982) McCormick et al. (1977)	 10.3	30.2 29.9	Koenst & Smith (1982) McCormick et al. (1977)
Carp	30	Tatarko (1966)			
Northern Pike	25.7	Hokanson et al. (1973)	7 <2.9	 28	Hokanson et al. (1973a) Cassleman (1978)
Channel Catfish	30	Jude (1973)			
Bluegill	31	Beitinger & Magnuson (1979)	 10	>36	Lemke (1977) Anderson (1959)
Smallmouth Bass	29	Peek (1965)	 10	35.0	Horning & Pearson (1973) Hubbs & Bailey (1938)
Largemouth Bass	32.0	McCormick & Wegner (1981)	9.1	 35.5	Lee (1969) Coutant & Cox (1976)
White Bass	30	McCormick (1979a)	9.7	35	McCormick (1979a)
Pink Salmon	18.3	Kepshire (1976)			
Chum Salmon	12.7	Kepshire (1971; 1976)			
Coho Salmon	17	Averett (1969)	3	22 >23	USDI Averett (1969)
Sockeye Salmon	17.4	Clarke (1978)	<1	23	Brett et al. (1969)
Chinook Salmon	17.4 15.6	Seymour (1956) Banks et al.	4.5	19.1	Seymour (1956)
Yellow Perch	28	McCormick (1976)	<8	32.1	McCormick (1976)

Mountain Whitefish	>12	Stalnaker & Cresswell (1974)			
Rainbow Trout	17.2	Hokanson et al. (1977)	<3	23	Hokanson et al. (1977) Goryczko (1972)
Brown Trout	16 >16.4	Brown (1946b) Wingfield (1940)	<2.0	>21.1	Swift (1972) Nicholls (1957)
Brook Trout	16.1	Hokanson et al. (1973)	3.1	>21	McCormick et al. (1972) Hokanson et al. (1973b)
Sauger	22.0	Smith & Koenst (1975)			
Walleye	26	Hokanson & Koenst (1986)		>30	Hokanson & Koenst (1986)

Attachment 3: Specific growth rates used in creating growth curves:

Bluegill (Lemke, 1977)

T	G
20.04	1.24
22.02	1.57
23.99	1.71
26.05	1.57
28.02	1.92
30.1	2.35
31.8	1.81
34	1.89
35.97	1.17

Brook Trout (McCormick, et al., 1972)

T	G
3.1	0
7.1	2.4
9.8	3.8
12.4	4.5
15.4	4.5
21.0	0[1]

[1]UZNG (Hokanson et al., 1973b)

Brown Bullhead (Keast, 1985)
(Growth rates derived from table 1)

T	G
5	-0.256
10	.355
15	.8514
20	1.096
25	1.427[1]
30	2.714
37	0[2]

[1]Initial wet weight larger than other test groups; data discarded.
[2]UILT (Brett, 1944)

Brown Trout (Elliott, 1975)

T	G[1]
2	0[2]
3.8	.276
7.1	.2975
12.2	.644
15.1	.655
17.8	.252

[1]average of 6 replicates of different types of food
[2]LZNG (Swift, 1961)

Chinook Salmon (Brett et al., 1982)

T	G
4.5	0[1]
14	2.98
16	3.42
18	3
19	3.25
20	3.37
20	3.46
21	3.11
22	3.23
23	2.58
24	1.78
24	1.84

[1]LZNG (Seymour, 1956)

Largemouth Bass (McCormick, 1981)

T	G
9.1	0[1]
28	3.87
30	4.24
32	4.5
34	4.29
35	3.67
36	1.43

[1]LZNG (Lee, 1969)

Northern Pike (Hokanson, 1973)

T	G
2.9	0[1]
7.5	1.82
9.8	6.27
12.55	9.18
15.5	13.22
17.95	17.42
20.8	19.14
25.65	20.04
28.0	0[2]

[1]LZNG (Cassleman, 1978)
[2]UZNG (Cassleman, 1978)

Rainbow Trout (Hokanson et al., 1977)

T	G
3.0	0[1]
8.1	2.29
11.8	3.66
14.8	4.36
17.2	5.12
18.6	4.83
21.2	4.49
22.3	3.94

[1]LZNG (Goryczko, 1972)

Smallmouth Bass (Horning, et al., 1973)

T	G
10	0[1]
16	0.15
23	0.7
26	1.23
29	1.02

[1]LZNG (Hubbs & Bailey, 1938)

Walleye (Hokanson, 1986)

T	G
16	0.6
18	1.16
20.1	1.58
22.1	1.83
24.0	1.83
26.0	2.15
28.0	2.07
29.9	1.06

White Bass (McCormick, 1975; unpublished)

T	G
9.7	0[1]
12	.556
15	1.064
18	1.898
21	2.721
24	3.504
26	3.623
28	3.624
30	3.621
32	2.901
34	1.452

[1]LZNG (McCormick, 1979a)

White Sucker (McCormick, 1977)

T	G
10	.9
15.7	7.4
17.9	9.7
20.8	12.0
23.9	13.2
26.9	14.8
29.7	9.2

Yellow Perch (McCormick, 1976)

T	G
6	0
8	.31
12	.66
16	1.34
18	1.37
20	2.24
22	2.67
24	2.77
26	3.5
28	3.77
30	3.47
32.1	0

Attachment #4

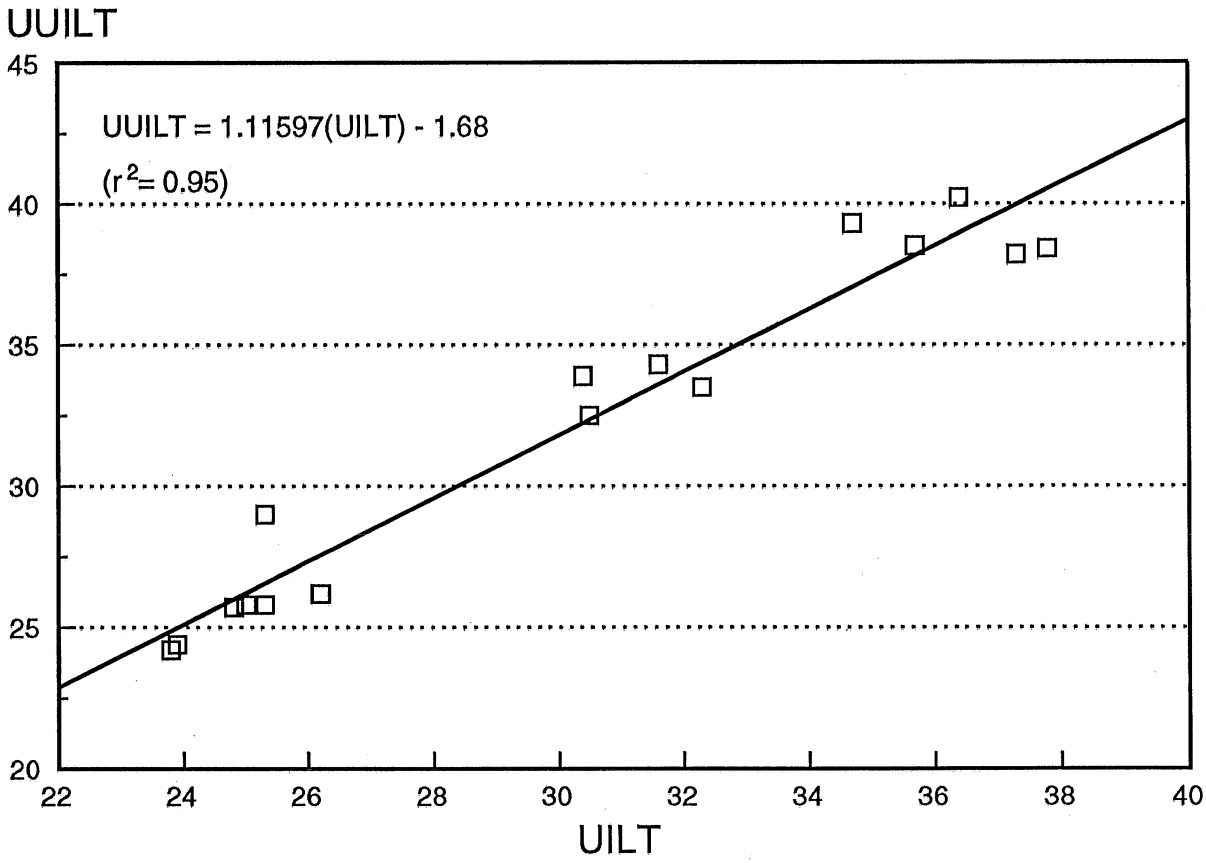
Data set used to calculate regression equation.

Species	UILT	UUILT
Pink Salmon	23.9	24.4
Sockeye Salmon	24.8	24.8
Chinook Salmon	23.8	24.2
Coho Salmon	25.0	25.8
Brown Trout	25.3	29.0
Rainbow Trout	26.2	26.2
Brook Trout	25.3	25.8
White Sucker	30.5	32.5
Yellow Perch	32.3	33.5
Sauger	30.4	33.9
Walleye	31.6	34.3
Carp	35.7	38.5
Golden Shiner	34.7	39.3
Channel Catfish	37.8	38.4
Largemouth Bass	36.4	40.2
Bluegill	37.3	38.2

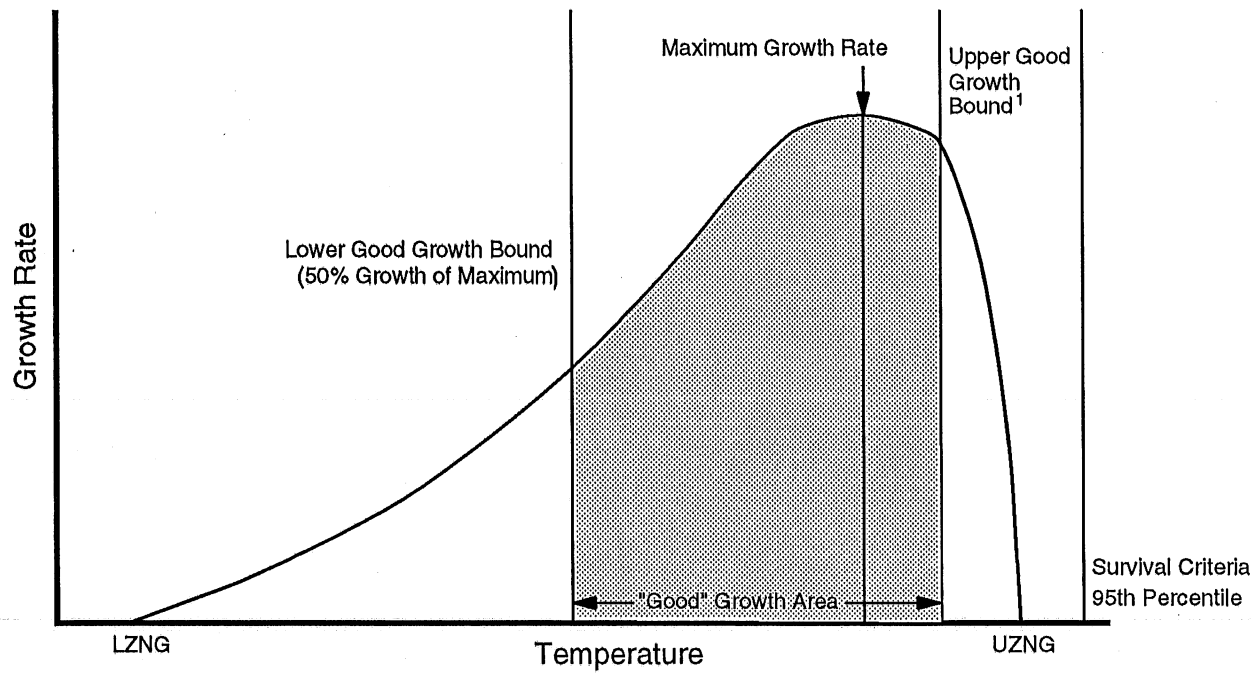
UUILT values calculated from regression equation.

Species	UILT	UUILT Calculated
Chinook Salmon	25.1	26.3
Lake Herring	26.0	27.3
Northern Pike	33.0	35.1
Black Crappie	32.5	34.6
White Crappie	32.8	34.9
Gizzard Shad	36.5	39.1
Brown Bullhead	37.5	40.1
White Bass	33.5	35.7
Rock Bass	36.0	38.5
Smallmouth Bass	38.0	40.7
Green Sunfish	35.4	37.8
Freshwater Drum	32.8	34.9

Attachment #5 - UILT/UUILT Regression Graph; Sample Growth Curve



Attachment #6 - Maximum Growth Rate x Temperature Relationship



[1] See calculation procedure, pg A-3

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APPENDIX B

Standard Operating Procedure for the Determination of Dissolved Oxygen Criteria Values

STANDARD OPERATING PROCEDURE FOR THE DETERMINATION OF DISSOLVED OXYGEN CRITERIA VALUES

Formulated 7-31-91

Background:

The dissolved oxygen criteria established by this Standard Operating Procedure, SOP, are intended solely for application within the US EPA - University of Minnesota cooperative Global Climate Change, GCC, project. The GCC dissolved oxygen criteria are used in conjunction with thermal growth and survival criteria to establish habitable waterbody volumes for fish species. The criteria established are particularily appropriate to those hypolimnetic waters which serve as potential refugia for fish during extended time intervals of elevated temperatures in the waterbody.

The GCC dissolved oxygen criteria were determined using the authority of existing EPA Dissolved Oxygen Criteria documents and the expert opinion of agency personnel.

The EPA dissolved oxygen criteria document "Ambient Aquatic Life Quality Criteria of Dissolved Oxygen" (Chapman 1986) was thoroughly reviewed. Consultations with the author, Dr. Gary Chapman, Environmental Research Laboratory, Corvallis, OR, helped establish the document criteria applicable to the project's particular needs.

GCC Project Dissolved Oxygen Criteria:

1. The criteria developed by this SOP document are dissolved oxygen survival values for freshwater fish guilds as applied within the Global Climate Change project. These criteria are dissolved oxygen concentrations at which detectable lethality is expected, as distinguished from (1) levels which assure protection, or non-lethality, to fish populations and (2) levels at which complete non-survival of fish populations is assured in a short period of time (i.e. several hours to several days). The criteria are applied to the freshwater fish guilds of coldwater fish, coolwater fish, and warmwater fish. Guild definitions are to be found in the GCC Project Thermal Criteria SOP.

2. Dissolved oxygen criteria for non-salmonid species (i.e. cool- and warmwater species) were determined by a consideration of Figure 1, page 14, of the referenced criteria document, in consultation with the author. It was determined that detectable lethalities in 96 hour exposures for representative cool- and warmwater species, occur between the values of 2.5 mg/l and 4.5 mg/l, and that appropriate criteria values are 2.5 mg/l for warmwater species and 3.0 mg/l for cool-water species.

3. Dissolved oxygen criteria for coldwater species were established from data contained in Table 8, page 34, of the critria document, modified by other criteria document information and consultation with the author. The "1 Day Minimum" line of Table 8 shows that acute lethality in other-than-early life stages occurs at the values of 4.0 mg/l for coldwater species. However, page 33 of the same document provides the following rationale for lowering the coldwater criteria value:

"Although the acute lethal limit for salmonids is at or below 3 mg/l, the coldwater minimum has been established at 4 mg/l because a significant proportion of the insect species common to salmonid habits are less tolerant of acute exposures to low dissolved oxygen than are salmonids."

4. In consideration of the above-listed available data and expert consultation, the following project dissolved oxygen criteria were established:

RECOMMENDED DISSOLVED OXYGEN SURVIVAL CRITERIA FOR FRESHWATER FISH GUILDS

Coldwater	Coolwater	Warmwater
3.0 mg/l	**3.0 mg/l**	**2.5 mg/l**

APPENDIX C

Fish Survival and Growth Parameters in Five Minnesota Streams for Five Climate Conditions Computed from Simulated Average Daily Water Temperatures

REGIONAL FISH SURVIVAL AND GROWTH PARAMETERS IN MINNESOTA STREAMS
THERMAL HABITAT

SCB - Earliest Julian date when the water temperature exceeds the survival temperature.

SCE - Latest Julian date when the water temperature exceeds the survival temperature.

SCL - Total number of days when the stream water temperature exceeds the survival temperature.

GSB - Earliest Julian date when the water temperature exceeds the lower bound growth criterion.

GSE - Latest Julian date when the water temperature exceeds the lower bound growth criterion.

GSL - Total number of days when the stream water temperature is within lower and upper growth limits.

GZER - Total number of days when the upper bound growth temperature is exceeded. This is the midsummer no-growth period due to excessive temperature.

RIVER : STRAIGHT
SCENARIO: PAST

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout			0	103	296	140	52
Brown Trout			0	107	290	138	37
Coho Salmon			0	123	276	136	5
Rainbow Trout			0	123	281	147	9
Lake Herring			0	115	281	121	37
Chinook Salmon			0	153	263	105	0
Chum Salmon			0	115	281	100	58
Mountain Whitefish			0	115	281	121	37
Pink Salmon			0	115	281	156	2
Lake Trout			0	115	281	93	65
Sockeye Salmon			0	123	281	111	45
●Guild (Cold)			0	115	281	121	37
Northern Pike			0	154	250	93	0
Sauger			0	177	242	60	0
White Sucker			0	177	242	62	0
Yellow Perch			0	179	233	51	0
Walleye			0	180	233	40	0
Muskellunge			0	177	242	60	0
Black Crappie			0	177	242	60	0
White Crappie			0	177	242	60	0
●Guild (Cool)			0	177	242	60	0
Smallmouth Bass			0	206	208	2	0
Brown Bullhead			0	179	233	51	0
Carp			0	198	219	8	0
Freshwater Drum			0	198	219	8	0
Gizzard Shad			0	198	219	8	0
Golden Shiner			0	198	219	8	0
Green Sunfish			0	198	219	8	0
White Bass			0	180	233	45	0
Lake Sturgeon			0	198	219	8	0
Rock Bass			0	198	219	8	0
Channel Catfish			0			0	0
Largemouth Bass			0	206	208	2	0
Bluegill			0	199	209	6	0
●Guild (Warm)			0	198	219	8	0

All numbers in this and the following tables give number of days for each parameter.

RIVER : STRAIGHT
SCENARIO: GISS

FISH	SCB	SCE	SCL*	GSB	GSE	GSL	GZER
Brook Trout	180	222	28	89	306	117	92
Brown Trout			0	99	297	119	79
Coho Salmon	204	219	6	102	295	135	56
Rainbow Trout	207	208	1	100	296	137	59
Lake Herring	205	209	4	100	296	117	79
Chinook Salmon	206	208	2	107	285	120	47
Chum Salmon	180	220	23	100	296	97	99
Mountain Whitefish	205	208	3	100	296	117	79
Pink Salmon	180	220	23	100	296	142	54
Lake Trout	205	209	4	100	296	91	105
Sockeye Salmon	204	219	6	100	296	113	83
●Guild (Cold)	205	209	4	100	296	117	79
Northern Pike			0	115	281	136	0
Sauger			0	154	253	99	0
White Sucker			0	154	263	103	0
Yellow Perch			0	155	248	86	0
Walleye			0	164	247	82	0
Muskellunge			0	154	253	99	0
Black Crappie			0	154	253	99	0
White Crappie			0	154	253	99	0
●Guild (Cool)			0	154	253	99	0
Smallmouth Bass			0	177	233	54	0
Brown Bullhead			0	155	248	86	0
Carp			0	177	234	57	0
Freshwater Drum			0	177	234	57	0
Gizzard Shad			0	177	234	57	0
Golden Shiner			0	177	234	57	0
Green Sunfish			0	177	234	57	0
White Bass			0	164	248	83	0
Lake Sturgeon			0	177	234	57	0
Rock Bass			0	177	234	57	0
Channel Catfish			0	180	219	16	0
Largemouth Bass			0	177	234	55	0
Bluegill			0	177	234	57	0
●Guild (Warm)			0	177	234	57	0

*SCL values in excess of 7 days are considered cause to expect absence of a species from a habitat unless a refuge is present and accessible.

RIVER : STRAIGHT
DIFFERENCES : [GISS-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	180	222	28	-14	10	-23	40
Brown Trout	0	0	0	-8	7	-19	42
Coho Salmon	204	219	6	-21	19	-1	51
Rainbow Trout	207	208	1	-23	15	-10	50
Lake Herring	205	209	4	-15	15	-4	42
Chinook Salmon	206	208	2	-46	22	15	47
Chum Salmon	180	220	23	-15	15	-3	41
Mountain Whitefish	205	208	3	-15	15	-4	42
Pink Salmon	180	220	23	-15	15	-14	52
Lake Trout	205	209	4	-15	15	-2	40
Sockeye Salmon	204	219	6	-23	15	2	38
● Guild (Cold)	205	209	4	-15	15	-4	42
Northern Pike	0	0	0	-39	31	43	0
Sauger	0	0	0	-23	11	39	0
White Sucker	0	0	0	-23	21	41	0
Yellow Perch	0	0	0	-24	15	35	0
Walleye	0	0	0	-16	14	42	0
Muskellunge	0	0	0	-23	11	39	0
Black Crappie	0	0	0	-23	11	39	0
White Crappie	0	0	0	-23	11	39	0
● Guild (Cool)	0	0	0	-23	11	39	0
Smallmouth Bass	0	0	0	-29	25	52	0
Brown Bullhead	0	0	0	-24	15	35	0
Carp	0	0	0	-21	15	49	0
Freshwater Drum	0	0	0	-21	15	49	0
Gizzard Shad	0	0	0	-21	15	49	0
Golden Shiner	0	0	0	-21	15	49	0
Green Sunfish	0	0	0	-21	15	49	0
White Bass	0	0	0	-16	15	38	0
Lake Sturgeon	0	0	0	-21	15	49	0
Rock Bass	0	0	0	-21	15	49	0
Channel Catfish	0	0	0			16	0
Largemouth Bass	0	0	0	-29	26	53	0
Bluegill	0	0	0	-22	25	51	0
● Guild (Warm)	0	0	0	-21	15	49	0

RIVER : STRAIGHT
SCENARIO: GFDL

FISH	SCB	SCE	SCL*	GSB	GSE	GSL	GZER
Brook Trout	180	230	27	71	316	144	98
Brown Trout			0	76	312	137	88
Coho Salmon	192	208	7	81	306	144	61
Rainbow Trout	207	208	1	78	306	148	66
Lake Herring	206	208	2	78	307	128	88
Chinook Salmon	206	208	2	89	296	138	49
Chum Salmon	180	219	25	78	307	110	106
Mountain Whitefish	206	208	2	78	307	128	88
Pink Salmon	180	219	24	78	307	159	57
Lake Trout	206	208	2	78	307	94	122
Sockeye Salmon	192	208	7	78	306	124	90
● Guild (Cold)	206	208	2	78	307	128	88
Northern Pike			0	115	285	161	0
Sauger			0	154	264	107	0
White Sucker			0	153	279	110	0
Yellow Perch			0	155	253	94	0
Walleye			0	160	252	88	0
Muskellunge			0	154	264	107	0
Black Crappie			0	154	264	107	0
White Crappie			0	154	264	107	0
● Guild (Cool)			0	154	264	107	0
Smallmouth Bass			0	177	247	57	0
Brown Bullhead			0	155	253	94	0
Carp			0	177	247	63	0
Freshwater Drum			0	177	247	63	0
Gizzard Shad			0	177	247	63	0
Golden Shiner			0	177	247	63	0
Green Sunfish			0	177	247	63	0
White Bass			0	159	253	90	0
Lake Sturgeon			0	177	247	63	0
Rock Bass			0	177	247	63	0
Channel Catfish			0	180	219	20	0
Largemouth Bass			0	177	247	60	0
Bluegill			0	177	247	61	0
● Guild (Warm)			0	177	247	63	0

RIVER : STRAIGHT
DIFFERENCES : [GFDL-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	180	230	27	-32	20	4	46
Brown Trout	0	0	0	-31	22	-1	51
Coho Salmon	192	208	7	-42	30	8	56
Rainbow Trout	207	208	1	-45	25	1	57
Lake Herring	206	208	2	-37	26	7	51
Chinook Salmon	206	208	2	-64	33	33	49
Chum Salmon	180	219	25	-37	26	10	48
Mountain Whitefish	206	208	2	-37	26	7	51
Pink Salmon	180	219	24	-37	26	3	55
Lake Trout	206	208	2	-37	26	1	57
Sockeye Salmon	192	208	7	-45	25	13	45
● Guild (Cold)	206	208	2	-37	26	7	51
Northern Pike	0	0	0	-39	35	68	0
Sauger	0	0	0	-23	22	47	0
White Sucker	0	0	0	-24	37	48	0
Yellow Perch	0	0	0	-24	20	43	0
Walleye	0	0	0	-20	19	48	0
Muskellunge	0	0	0	-23	22	47	0
Black Crappie	0	0	0	-23	22	47	0
White Crappie	0	0	0	-23	22	47	0
● Guild (Cool)	0	0	0	-23	22	47	0
Smallmouth Bass	0	0	0	-29	39	55	0
Brown Bullhead	0	0	0	-24	20	43	0
Carp	0	0	0	-21	28	55	0
Freshwater Drum	0	0	0	-21	28	55	0
Gizzard Shad	0	0	0	-21	28	55	0
Golden Shiner	0	0	0	-21	28	55	0
Green Sunfish	0	0	0	-21	28	55	0
White Bass	0	0	0	-21	20	45	0
Lake Sturgeon	0	0	0	-21	28	55	0
Rock Bass	0	0	0	-21	28	55	0
Channel Catfish	0	0	0			20	0
Largemouth Bass	0	0	0	-29	39	58	0
Bluegill	0	0	0	-22	38	55	0
● Guild (Warm)	0	0	0	-21	28	55	0

RIVER : STRAIGHT
SCENARIO: UKMO

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	177	279	87	72	323	72	179
Brown Trout	192	246	30	77	318	91	150
Coho Salmon	179	262	75	86	312	103	123
Rainbow Trout	180	252	71	79	314	107	127
Lake Herring	179	253	74	79	314	85	150
Chinook Salmon	179	252	73	95	307	116	96
Chum Salmon	177	276	84	79	314	43	192
Mountain Whitefish	179	253	74	79	314	85	150
Pink Salmon	177	263	81	79	314	119	116
Lake Trout	179	253	74	79	314	38	197
Sockeye Salmon	179	262	75	79	314	70	164
● Guild (Cold)	179	253	74	79	314	85	150
Northern Pike			0	99	306	203	2
Sauger			0	103	306	190	3
White Sucker	214	230	5	102	306	183	12
Yellow Perch	218	219	1	111	296	167	4
Walleye	218	219	1	111	294	156	3
Muskellunge			0	103	306	190	3
Black Crappie			0	103	306	190	3
White Crappie			0	103	306	190	3
● Guild (Cool)			0	103	306	190	3
Smallmouth Bass	217	219	2	164	285	116	0
Brown Bullhead			0	111	296	171	0
Carp			0	154	285	125	0
Freshwater Drum			0	154	285	125	0
Gizzard Shad			0	154	285	125	0
Golden Shiner			0	154	285	125	0
Green Sunfish			0	154	285	125	0
White Bass			0	111	295	160	0
Lake Sturgeon			0	154	285	125	0
Rock Bass			0	154	285	125	0
Channel Catfish			0	178	263	80	0
Largemouth Bass			0	164	285	117	0
Bluegill			0	155	285	124	0
● Guild (Warm)			0	154	285	125	0

RIVER : STRAIGHT
DIFFERENCES : [UKMO-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout			87	-31	27	-68	127
Brown Trout			30	-30	28	-47	113
Coho Salmon			75	-37	36	-33	118
Rainbow Trout			71	-44	33	-40	118
Lake Herring			74	-36	33	-36	113
Chinook Salmon			73	-58	44	11	96
Chum Salmon			84	-36	33	-57	134
Mountain Whitefish			74	-36	33	-36	113
Pink Salmon			81	-36	33	-37	114
Lake Trout			74	-36	33	-55	132
Sockeye Salmon			75	-44	33	-41	119
●Guild (Cold)			74	-36	33	-36	113
Northern Pike			0	-55	56	110	2
Sauger			0	-74	64	130	3
White Sucker			5	-75	64	121	12
Yellow Perch			1	-68	63	116	4
Walleye			1	-69	61	116	3
Muskellunge			0	-74	64	130	3
Black Crappie			0	-74	64	130	3
White Crappie			0	-74	64	130	3
●Guild (Cool)			0	-74	64	130	3
Smallmouth Bass			2	-42	77	114	0
Brown Bullhead			0	-68	63	120	0
Carp			0	-44	66	117	0
Freshwater Drum			0	-44	66	117	0
Gizzard Shad			0	-44	66	117	0
Golden Shiner			0	-44	66	117	0
Green Sunfish			0	-44	66	117	0
White Bass			0	-69	62	115	0
Lake Sturgeon			0	-44	66	117	0
Rock Bass			0	-44	66	117	0
Channel Catfish			0			80	0
Largemouth Bass			0	-42	77	115	0
Bluegill			0	-44	76	118	0
●Guild (Warm)			0	-44	66	117	0

RIVER : STRAIGHT
SCENARIO: OSU

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	191	220	24	100	301	115	84
Brown Trout			0	101	297	125	71
Coho Salmon	199	209	5	111	291	118	58
Rainbow Trout	207	208	1	107	296	126	60
Lake Herring	206	208	2	106	296	119	71
Chinook Salmon	207	208	1	123	281	111	45
Chum Salmon	191	220	24	106	296	97	93
Mountain Whitefish	206	208	2	106	296	119	71
Pink Salmon	191	219	20	106	296	138	52
Lake Trout	206	208	2	106	296	90	100
Sockeye Salmon	199	209	5	107	296	106	80
● Guild (Cold)	206	208	2	106	296	119	71
Northern Pike			0	123	276	135	0
Sauger			0	154	249	95	0
White Sucker			0	154	252	98	0
Yellow Perch			0	164	247	83	0
Walleye			0	165	247	78	0
Muskellunge			0	154	249	95	0
Black Crappie			0	154	249	95	0
White Crappie			0	154	249	95	0
● Guild (Cool)			0	154	249	95	0
Smallmouth Bass			0	178	233	53	0
Brown Bullhead			0	164	247	83	0
Carp			0	177	242	60	0
Freshwater Drum			0	177	242	60	0
Gizzard Shad			0	177	242	60	0
Golden Shiner			0	177	242	60	0
Green Sunfish			0	177	242	60	0
White Bass			0	164	247	80	0
Lake Sturgeon			0	177	242	60	0
Rock Bass			0	177	242	60	0
Channel Catfish			0	192	219	14	0
Largemouth Bass			0	178	233	54	0
Bluegill			0	178	242	58	0
● Guild (Warm)			0	177	242	60	0

RIVER : STRAIGHT
DIFFERENCES : [OSU-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout			24	-3	5	-25	32
Brown Trout			0	-6	7	-13	34
Coho Salmon			5	-12	15	-18	53
Rainbow Trout			1	-16	15	-21	51
Lake Herring			2	-9	15	-2	34
Chinook Salmon			1	-30	18	6	45
Chum Salmon			24	-9	15	-3	35
Mountain Whitefish			2	-9	15	-2	34
Pink Salmon			20	-9	15	-18	50
Lake Trout			2	-9	15	-3	35
Sockeye Salmon			5	-16	15	-5	35
● Guild (Cold)			2	-9	15	-2	34
Northern Pike			0	-31	26	42	0
Sauger			0	-23	7	35	0
White Sucker			0	-23	10	36	0
Yellow Perch			0	-15	14	32	0
Walleye			0	-15	14	38	0
Muskellunge			0	-23	7	35	0
Black Crappie			0	-23	7	35	0
White Crappie			0	-23	7	35	0
● Guild (Cool)			0	-23	7	35	0
Smallmouth Bass			0	-28	25	51	0
Brown Bullhead			0	-15	14	32	0
Carp			0	-21	23	52	0
Freshwater Drum			0	-21	23	52	0
Gizzard Shad			0	-21	23	52	0
Golden Shiner			0	-21	23	52	0
Green Sunfish			0	-21	23	52	0
White Bass			0	-16	14	35	0
Lake Sturgeon			0	-21	23	52	0
Rock Bass			0	-21	23	52	0
Channel Catfish			0			14	0
Largemouth Bass			0	-28	25	52	0
Bluegill			0	-21	33	52	0
● Guild (Warm)			0	-21	23	52	0

RIVER : BAPTISM
SCENARIO: PAST

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	188	219	25	100	296	114	82
Brown Trout			0	103	292	127	62
Coho Salmon	198	209	7	121	282	107	54
Rainbow Trout	207	208	1	107	285	114	55
Lake Herring	206	209	3	107	286	113	62
Chinook Salmon	206	208	2	126	271	105	39
Chum Salmon	188	219	24	107	286	86	89
Mountain Whitefish	206	209	3	107	286	113	62
Pink Salmon	191	219	21	107	286	122	53
Lake Trout	206	209	3	107	286	76	99
Sockeye Salmon	198	209	7	107	285	97	72
● Guild (Cold)	206	209	3	107	286	113	62
Northern Pike			0	136	265	129	0
Sauger			0	155	248	91	0
White Sucker			0	155	252	95	0
Yellow Perch			0	166	247	76	0
Walleye			0	173	246	69	0
Muskellunge			0	155	248	91	0
Black Crappie			0	155	248	91	0
White Crappie			0	155	248	91	0
● Guild (Cool)			0	155	248	91	0
Smallmouth Bass			0	179	233	54	0
Brown Bullhead			0	166	247	76	0
Carp			0	179	233	54	0
Freshwater Drum			0	179	233	54	0
Gizzard Shad			0	179	233	54	0
Golden Shiner			0	179	233	54	0
Green Sunfish			0	179	233	54	0
White Bass			0	171	246	71	0
Lake Sturgeon			0	179	233	54	0
Rock Bass			0	179	233	54	0
Channel Catfish			0	192	219	14	0
Largemouth Bass			0	179	233	54	0
Bluegill			0	179	233	54	0
● Guild (Warm)			0	179	233	54	0

RIVER : BAPTISM
SCENARIO: GISS

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	177	234	57	86	306	113	107
Brown Trout			0	89	302	108	100
Coho Salmon	178	233	55	100	296	108	88
Rainbow Trout	180	230	42	99	297	103	95
Lake Herring	179	232	50	97	297	100	100
Chinook Salmon	179	230	47	104	290	117	66
Chum Salmon	177	234	57	97	297	88	112
Mountain Whitefish	179	232	49	97	297	100	100
Pink Salmon	177	233	56	97	297	117	83
Lake Trout	179	232	50	97	297	70	130
Sockeye Salmon	178	233	55	99	297	95	103
●Guild (Cold)	179	232	50	97	297	100	100
Northern Pike			0	108	281	160	0
Sauger			0	142	265	115	0
White Sucker			0	141	270	121	0
Yellow Perch			0	154	263	105	0
Walleye			0	154	256	102	0
Muskellunge			0	142	265	115	0
Black Crappie			0	142	265	115	0
White Crappie			0	142	265	115	0
●Guild (Cool)			0	142	265	115	0
Smallmouth Bass			0	160	247	83	0
Brown Bullhead			0	154	263	105	0
Carp			0	156	252	90	0
Freshwater Drum			0	156	252	90	0
Gizzard Shad			0	156	252	90	0
Golden Shiner			0	156	252	90	0
Green Sunfish			0	156	252	90	0
White Bass			0	154	263	103	0
Lake Sturgeon			0	156	252	90	0
Rock Bass			0	156	252	90	0
Channel Catfish			0	177	233	56	0
Largemouth Bass			0	160	247	84	0
Bluegill			0	159	248	88	0
●Guild (Warm)			0	156	252	90	0

RIVER : BAPTISM
DIFFERENCES : [GISS-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-11	15	32	-14	10	-1	25
Brown Trout			0	-14	10	-19	38
Coho Salmon	-20	24	48	-21	14	1	34
Rainbow Trout	-27	22	41	-8	12	-11	40
Lake Herring	-27	23	47	-10	11	-13	38
Chinook Salmon	-27	22	45	-22	19	12	27
Chum Salmon	-11	15	33	-10	11	2	23
Mountain Whitefish	-27	23	46	-10	11	-13	38
Pink Salmon	-14	14	35	-10	11	-5	30
Lake Trout	-27	23	47	-10	11	-6	31
Sockeye Salmon	-20	24	48	-8	12	-2	31
●Guild (Cold)	-27	23	47	-10	11	-13	38
Northern Pike			0	-28	16	31	0
Sauger			0	-13	17	24	0
White Sucker			0	-14	18	26	0
Yellow Perch			0	-12	16	29	0
Walleye			0	-19	10	33	0
Muskellunge			0	-13	17	24	0
Black Crappie			0	-13	17	24	0
White Crappie			0	-13	17	24	0
●Guild (Cool)			0	-13	17	24	0
Smallmouth Bass			0	-19	14	29	0
Brown Bullhead			0	-12	16	29	0
Carp			0	-23	19	36	0
Freshwater Drum			0	-23	19	36	0
Gizzard Shad			0	-23	19	36	0
Golden Shiner			0	-23	19	36	0
Green Sunfish			0	-23	19	36	0
White Bass			0	-17	17	32	0
Lake Sturgeon			0	-23	19	36	0
Rock Bass			0	-23	19	36	0
Channel Catfish			0	-15	14	42	0
Largemouth Bass			0	-19	14	30	0
Bluegill			0	-20	15	34	0
●Guild (Warm)			0	-23	19	36	0

RIVER : BAPTISM
SCENARIO: GFDL

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	177	247	61	67	318	126	125
Brown Trout	198	209	7	69	315	137	109
Coho Salmon	178	246	56	77	307	119	98
Rainbow Trout	179	232	50	74	308	127	103
Lake Herring	179	233	54	73	309	123	109
Chinook Salmon	179	233	54	80	297	128	77
Chum Salmon	177	247	60	73	309	95	137
Mountain Whitefish	179	233	54	73	309	123	109
Pink Salmon	177	247	58	73	309	136	96
Lake Trout	179	233	54	73	309	85	147
Sockeye Salmon	178	246	56	74	308	115	115
●Guild (Cold)	179	233	54	73	309	123	109
Northern Pike			0	87	294	178	0
Sauger			0	136	281	140	0
White Sucker			0	136	281	142	0
Yellow Perch			0	142	270	121	0
Walleye			0	153	265	112	0
Muskellunge			0	136	281	140	0
Black Crappie			0	136	281	140	0
White Crappie			0	136	281	140	0
●Guild (Cool)			0	136	281	140	0
Smallmouth Bass			0	159	255	96	0
Brown Bullhead			0	142	270	121	0
Carp			0	155	263	101	0
Freshwater Drum			0	155	263	101	0
Gizzard Shad			0	155	263	101	0
Golden Shiner			0	155	263	101	0
Green Sunfish			0	155	263	101	0
White Bass			0	143	265	113	0
Lake Sturgeon			0	155	263	101	0
Rock Bass			0	155	263	101	0
Channel Catfish			0	177	247	58	0
Largemouth Bass			0	159	255	96	0
Bluegill			0	155	263	101	0
●Guild (Warm)			0	155	263	101	0

RIVER : BAPTISM
DIFFERENCES : [GFDL-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-11	28	36	-33	22	12	43
Brown Trout			7	-34	23	10	47
Coho Salmon	-20	37	49	-44	25	12	44
Rainbow Trout	-28	24	49	-33	23	13	48
Lake Herring	-27	24	51	-34	23	10	47
Chinook Salmon	-27	25	52	-46	26	23	38
Chum Salmon	-11	28	36	-34	23	9	48
Mountain Whitefish	-27	24	51	-34	23	10	47
Pink Salmon	-14	28	37	-34	23	14	43
Lake Trout	-27	24	51	-34	23	9	48
Sockeye Salmon	-20	37	49	-33	23	18	43
● Guild (Cold)	-27	24	51	-34	23	10	47
Northern Pike			0	-49	29	49	0
Sauger			0	-19	33	49	0
White Sucker			0	-19	29	47	0
Yellow Perch			0	-24	23	45	0
Walleye			0	-20	19	43	0
Muskellunge			0	-19	33	49	0
Black Crappie			0	-19	33	49	0
White Crappie			0	-19	33	49	0
● Guild (Cool)			0	-19	33	49	0
Smallmouth Bass			0	-20	22	42	0
Brown Bullhead			0	-24	23	45	0
Carp			0	-24	30	47	0
Freshwater Drum			0	-24	30	47	0
Gizzard Shad			0	-24	30	47	0
Golden Shiner			0	-24	30	47	0
Green Sunfish			0	-24	30	47	0
White Bass			0	-28	19	42	0
Lake Sturgeon			0	-24	30	47	0
Rock Bass			0	-24	30	47	0
Channel Catfish			0	-15	28	44	0
Largemouth Bass			0	-20	22	42	0
Bluegill			0	-24	30	47	0
● Guild (Warm)			0	-24	30	47	0

RIVER : BAPTISM
SCENARIO: UKMO

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	143	281	124	68	322	59	195
Brown Trout	180	252	71	72	318	57	189
Coho Salmon	165	270	101	78	312	80	154
Rainbow Trout	173	265	92	76	314	76	162
Lake Herring	166	270	97	75	314	50	189
Chinook Salmon	171	270	95	82	308	79	144
Chum Salmon	155	281	121	75	314	42	197
Mountain Whitefish	166	270	97	75	314	50	189
Pink Salmon	155	281	119	75	314	89	150
Lake Trout	166	270	97	75	314	39	200
Sockeye Salmon	165	270	101	76	314	45	193
● Guild (Cold)	166	270	97	75	314	50	189
Northern Pike	217	219	2	89	307	173	45
Sauger	217	219	2	100	297	146	51
White Sucker	186	247	53	99	298	145	54
Yellow Perch	187	246	44	102	296	142	52
Walleye	188	246	43	103	296	142	51
Muskellunge	206	230	13	100	297	146	51
Black Crappie			0	100	297	146	51
White Crappie			0	100	297	146	51
● Guild (Cool)	206	230	13	100	297	146	51
Smallmouth Bass	187	246	46	135	286	151	0
Brown Bullhead	204	230	19	102	296	192	2
Carp			0	128	290	154	0
Freshwater Drum			0	128	290	154	0
Gizzard Shad			0	128	290	154	0
Golden Shiner	206	229	10	128	290	154	0
Green Sunfish	217	219	2	128	290	154	0
White Bass			0	103	296	168	25
Lake Sturgeon	217	219	2	128	290	154	0
Rock Bass	217	219	2	128	290	154	0
Channel Catfish	218	219	1	155	281	117	0
Largemouth Bass	217	219	2	135	286	151	0
Bluegill	218	219	1	128	290	153	1
● Guild (Warm)	217	219	2	128	290	154	0

RIVER : BAPTISM
DIFFERENCES : [UKMO-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-45	62	99	-32	26	-55	113
Brown Trout			71	-31	26	-70	127
Coho Salmon	-33	61	94	-43	30	-27	100
Rainbow Trout	-34	57	91	-31	29	-38	107
Lake Herring	-40	61	94	-32	28	-63	127
Chinook Salmon	-35	62	93	-44	37	-26	105
Chum Salmon	-33	62	97	-32	28	-44	108
Mountain Whitefish	-40	61	94	-32	28	-63	127
Pink Salmon	-36	62	98	-32	28	-33	97
Lake Trout	-40	61	94	-32	28	-37	101
Sockeye Salmon	-33	61	94	-31	29	-52	121
●Guild (Cold)	-40	61	94	-32	28	-63	127
Northern Pike			2	-47	42	44	45
Sauger			2	-55	49	55	51
White Sucker			53	-56	46	50	54
Yellow Perch			44	-64	49	66	52
Walleye			43	-70	50	73	51
Muskellunge			13	-55	49	55	51
Black Crappie			0	-55	49	55	51
White Crappie			0	-55	49	55	51
●Guild (Cool)			13	-55	49	55	51
Smallmouth Bass			46	-44	53	97	0
Brown Bullhead			19	-64	49	116	2
Carp			0	-51	57	100	0
Freshwater Drum			0	-51	57	100	0
Gizzard Shad			0	-51	57	100	0
Golden Shiner			10	-51	57	100	0
Green Sunfish			2	-51	57	100	0
White Bass			0	-68	50	97	25
Lake Sturgeon			2	-51	57	100	0
Rock Bass			2	-51	57	100	0
Channel Catfish			1	-37	62	103	0
Largemouth Bass			2	-44	53	97	0
Bluegill			1	-51	57	99	1
●Guild (Warm)			2	-51	57	100	0

RIVER : BAPTISM
SCENARIO: OSU

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	177	242	59	88	303	97	115
Brown Trout	206	208	2	99	298	100	99
Coho Salmon	179	233	54	104	295	103	88
Rainbow Trout	180	233	50	102	296	101	93
Lake Herring	179	233	54	101	296	96	99
Chinook Salmon	180	233	51	121	286	92	73
Chum Salmon	177	242	58	101	296	68	127
Mountain Whitefish	179	233	53	101	296	96	99
Pink Salmon	178	234	56	101	296	110	85
Lake Trout	179	233	54	101	296	63	132
Sockeye Salmon	179	233	54	102	296	92	102
● Guild (Cold)	179	233	54	101	296	96	99
Northern Pike			0	124	281	157	0
Sauger			0	136	265	129	0
White Sucker			0	136	270	130	0
Yellow Perch			0	142	263	106	0
Walleye			0	154	255	101	0
Muskellunge			0	136	265	129	0
Black Crappie			0	136	265	129	0
White Crappie			0	136	265	129	0
● Guild (Cool)			0	136	265	129	0
Smallmouth Bass			0	159	247	87	0
Brown Bullhead			0	142	263	106	0
Carp			0	155	248	91	0
Freshwater Drum			0	155	248	91	0
Gizzard Shad			0	155	248	91	0
Golden Shiner			0	155	248	91	0
Green Sunfish			0	155	248	91	0
White Bass			0	154	255	101	0
Lake Sturgeon			0	155	248	91	0
Rock Bass			0	155	248	91	0
Channel Catfish			0	178	233	55	0
Largemouth Bass			0	159	247	88	0
Bluegill			0	156	248	90	0
● Guild (Warm)			0	155	248	91	0

RIVER : BAPTISM
DIFFERENCES : [OSU-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-11	23	34	-12	7	-17	33
Brown Trout			2	-4	6	-27	37
Coho Salmon	-19	24	47	-17	13	-4	34
Rainbow Trout	-27	25	49	-5	11	-13	38
Lake Herring	-27	24	51	-6	10	-17	37
Chinook Salmon	-26	25	49	-5	15	-13	34
Chum Salmon	-11	23	34	-6	10	-18	38
Mountain Whitefish	-27	24	50	-6	10	-17	37
Pink Salmon	-13	15	35	-6	10	-12	32
Lake Trout	-27	24	51	-6	10	-13	33
Sockeye Salmon	-19	24	47	-5	11	-5	30
● Guild (Cold)	-27	24	51	-6	10	-17	37
Northern Pike			0	-12	16	28	0
Sauger			0	-19	17	38	0
White Sucker			0	-19	18	35	0
Yellow Perch			0	-24	16	30	0
Walleye			0	-19	9	32	0
Muskellunge			0	-19	17	38	0
Black Crappie			0	-19	17	38	0
White Crappie			0	-19	17	38	0
● Guild (Cool)			0	-19	17	38	0
Smallmouth Bass			0	-20	14	33	0
Brown Bullhead			0	-24	16	30	0
Carp			0	-24	15	37	0
Freshwater Drum			0	-24	15	37	0
Gizzard Shad			0	-24	15	37	0
Golden Shiner			0	-24	15	37	0
Green Sunfish			0	-24	15	37	0
White Bass			0	-17	9	30	0
Lake Sturgeon			0	-24	15	37	0
Rock Bass			0	-24	15	37	0
Channel Catfish			0	-14	14	41	0
Largemouth Bass			0	-20	14	34	0
Bluegill			0	-23	15	36	0
● Guild (Warm)			0	-24	15	37	0

RIVER : CLEARWATER
SCENARIO: PAST

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	198	220	20	115	292	97	80
Brown Trout			0	121	289	101	67
Coho Salmon	206	208	2	126	279	101	52
Rainbow Trout			0	123	280	99	58
Lake Herring			0	123	280	90	67
Chinook Salmon			0	129	269	106	34
Chum Salmon	198	219	18	123	280	68	89
Mountain Whitefish			0	123	280	90	67
Pink Salmon	198	219	14	123	280	112	45
Lake Trout			0	123	280	61	96
Sockeye Salmon	206	208	2	123	280	88	69
● Guild (Cold)			0	123	280	90	67
Northern Pike			0	135	265	130	0
Sauger			0	158	250	92	0
White Sucker			0	157	251	94	0
Yellow Perch			0	173	244	71	0
Walleye			0	174	243	69	0
Muskellunge			0	158	250	92	0
Black Crappie			0	158	250	92	0
White Crappie			0	158	250	92	0
● Guild (Cool)			0	158	250	92	0
Smallmouth Bass			0	187	234	47	0
Brown Bullhead			0	173	244	71	0
Carp			0	180	237	55	0
Freshwater Drum			0	180	237	55	0
Gizzard Shad			0	180	237	55	0
Golden Shiner			0	180	237	55	0
Green Sunfish			0	180	237	55	0
White Bass			0	174	243	69	0
Lake Sturgeon			0	180	237	55	0
Rock Bass			0	180	237	55	0
Channel Catfish			0	199	214	11	0
Largemouth Bass			0	187	234	47	0
Bluegill			0	180	237	55	0
● Guild (Warm)			0	180	237	55	0

RIVER : CLEARWATER
SCENARIO: GISS

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	174	247	73	97	302	85	119
Brown Trout	217	220	3	103	298	85	110
Coho Salmon	179	243	62	117	296	80	99
Rainbow Trout	187	241	53	107	296	85	104
Lake Herring	179	242	59	105	297	82	110
Chinook Salmon	180	242	57	122	291	86	83
Chum Salmon	175	247	72	105	297	58	134
Mountain Whitefish	179	242	59	105	297	82	110
Pink Salmon	175	247	72	105	297	96	96
Lake Trout	179	242	59	105	297	50	142
Sockeye Salmon	179	243	62	107	296	77	112
● Guild (Cold)	179	242	59	105	297	82	110
Northern Pike			0	126	282	156	0
Sauger			0	136	271	135	0
White Sucker			0	134	272	138	0
Yellow Perch			0	154	267	113	0
Walleye			0	155	266	111	0
Muskellunge			0	136	271	135	0
Black Crappie			0	136	271	135	0
White Crappie			0	136	271	135	0
● Guild (Cool)			0	136	271	135	0
Smallmouth Bass			0	158	256	98	0
Brown Bullhead			0	154	267	113	0
Carp			0	157	263	103	0
Freshwater Drum			0	157	263	103	0
Gizzard Shad			0	157	263	103	0
Golden Shiner			0	157	263	103	0
Green Sunfish			0	157	263	103	0
White Bass			0	154	266	112	0
Lake Sturgeon			0	157	263	103	0
Rock Bass			0	157	263	103	0
Channel Catfish			0	177	247	70	0
Largemouth Bass			0	158	256	98	0
Bluegill			0	157	263	101	0
● Guild (Warm)			0	157	263	103	0

RIVER : CLEARWATER
DIFFERENCES : [GISS-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-24	27	53	-18	10	-12	39
Brown Trout			3	-18	9	-16	43
Coho Salmon	-27	35	60	-9	17	-21	47
Rainbow Trout			53	-16	16	-14	46
Lake Herring			59	-18	17	-8	43
Chinook Salmon			57	-7	22	-20	49
Chum Salmon	-23	28	54	-18	17	-10	45
Mountain Whitefish			59	-18	17	-8	43
Pink Salmon	-23	28	58	-18	17	-16	51
Lake Trout			59	-18	17	-11	46
Sockeye Salmon	-27	35	60	-16	16	-11	43
● Guild (Cold)			59	-18	17	-8	43
Northern Pike			0	-9	17	26	0
Sauger			0	-22	21	43	0
White Sucker			0	-23	21	44	0
Yellow Perch			0	-19	23	42	0
Walleye			0	-19	23	42	0
Muskellunge			0	-22	21	43	0
Black Crappie			0	-22	21	43	0
White Crappie			0	-22	21	43	0
● Guild (Cool)			0	-22	21	43	0
Smallmouth Bass			0	-29	22	51	0
Brown Bullhead			0	-19	23	42	0
Carp			0	-23	26	48	0
Freshwater Drum			0	-23	26	48	0
Gizzard Shad			0	-23	26	48	0
Golden Shiner			0	-23	26	48	0
Green Sunfish			0	-23	26	48	0
White Bass			0	-20	23	43	0
Lake Sturgeon			0	-23	26	48	0
Rock Bass			0	-23	26	48	0
Channel Catfish			0	-22	33	59	0
Largemouth Bass			0	-29	22	51	0
Bluegill			0	-23	26	46	0
● Guild (Warm)			0	-23	26	48	0

RIVER : CLEARWATER
SCENARIO: GFDL

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	180	242	60	82	307	109	110
Brown Trout			0	89	298	96	100
Coho Salmon	187	234	47	121	295	91	83
Rainbow Trout	189	226	37	118	296	85	93
Lake Herring	188	230	42	117	296	79	100
Chinook Salmon	188	229	40	126	290	97	67
Chum Salmon	180	242	60	117	296	59	120
Mountain Whitefish	188	230	41	117	296	79	100
Pink Salmon	180	241	57	117	296	102	77
Lake Trout	188	230	42	117	296	46	133
Sockeye Salmon	187	234	47	118	296	74	104
● Guild (Cold)	188	230	42	117	296	79	100
Northern Pike			0	128	281	153	0
Sauger			0	142	267	123	0
White Sucker			0	139	267	128	0
Yellow Perch			0	155	264	107	0
Walleye			0	155	262	103	0
Muskellunge			0	142	267	123	0
Black Crappie			0	142	267	123	0
White Crappie			0	142	267	123	0
● Guild (Cool)			0	142	267	123	0
Smallmouth Bass			0	173	251	78	0
Brown Bullhead			0	155	264	107	0
Carp			0	159	252	92	0
Freshwater Drum			0	159	252	92	0
Gizzard Shad			0	159	252	92	0
Golden Shiner			0	159	252	92	0
Green Sunfish			0	159	252	92	0
White Bass			0	155	263	104	0
Lake Sturgeon			0	159	252	92	0
Rock Bass			0	159	252	92	0
Channel Catfish			0	186	238	52	0
Largemouth Bass			0	170	251	80	0
Bluegill			0	160	251	88	0
● Guild (Warm)			0	159	252	92	0

RIVER : CLEARWATER
DIFFERENCES : [GFDL-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-18	22	40	-33	15	12	30
Brown Trout			0	-32	9	-5	33
Coho Salmon	-19	26	45	-5	16	-10	31
Rainbow Trout			37	-5	16	-14	35
Lake Herring			42	-6	16	-11	33
Chinook Salmon			40	-3	21	-9	33
Chum Salmon	-18	23	42	-6	16	-9	31
Mountain Whitefish			41	-6	16	-11	33
Pink Salmon	-18	22	43	-6	16	-10	32
Lake Trout			42	-6	16	-15	37
Sockeye Salmon	-19	26	45	-5	16	-14	35
● Guild (Cold)			42	-6	16	-11	33
Northern Pike			0	-7	16	23	0
Sauger			0	-16	17	31	0
White Sucker			0	-18	16	34	0
Yellow Perch			0	-18	20	36	0
Walleye			0	-19	19	34	0
Muskellunge			0	-16	17	31	0
Black Crappie			0	-16	17	31	0
White Crappie			0	-16	17	31	0
● Guild (Cool)			0	-16	17	31	0
Smallmouth Bass			0	-14	17	31	0
Brown Bullhead			0	-18	20	36	0
Carp			0	-21	15	37	0
Freshwater Drum			0	-21	15	37	0
Gizzard Shad			0	-21	15	37	0
Golden Shiner			0	-21	15	37	0
Green Sunfish			0	-21	15	37	0
White Bass			0	-19	20	35	0
Lake Sturgeon			0	-21	15	37	0
Rock Bass			0	-21	15	37	0
Channel Catfish			0	-13	24	41	0
Largemouth Bass			0	-17	17	33	0
Bluegill			0	-20	14	33	0
● Guild (Warm)			0	-21	15	37	0

RIVER : CLEARWATER
SCENARIO: UKMO

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	156	278	115	78	314	69	167
Brown Trout	186	251	65	83	311	65	163
Coho Salmon	159	266	104	91	308	68	149
Rainbow Trout	173	265	92	89	309	68	152
Lake Herring	160	265	97	89	309	57	163
Chinook Salmon	173	265	92	94	307	80	133
Chum Salmon	156	278	115	89	309	45	175
Mountain Whitefish	170	265	94	89	309	57	163
Pink Salmon	156	278	114	89	309	73	147
Lake Trout	160	265	97	89	309	34	186
Sockeye Salmon	159	266	104	89	309	56	164
● Guild (Cold)	160	265	97	89	309	57	163
Northern Pike	217	220	3	100	306	158	44
Sauger	217	220	3	120	296	125	51
White Sucker	188	246	55	118	296	122	56
Yellow Perch	198	241	40	126	291	111	54
Walleye	198	241	40	127	291	113	51
Muskellunge	214	226	9	120	296	125	51
Black Crappie			0	120	296	125	51
White Crappie			0	120	296	125	51
● Guild (Cool)	214	226	9	120	296	125	51
Smallmouth Bass	193	242	46	134	281	147	0
Brown Bullhead	206	229	15	126	291	163	2
Carp			0	133	288	151	0
Freshwater Drum			0	133	288	151	0
Gizzard Shad			0	133	288	151	0
Golden Shiner	214	222	8	133	288	151	0
Green Sunfish	217	220	3	133	288	151	0
White Bass			0	127	291	146	18
Lake Sturgeon	217	219	2	133	288	151	0
Rock Bass	217	221	4	133	288	151	0
Channel Catfish			0	157	268	111	0
Largemouth Bass	217	220	3	134	281	147	0
Bluegill			0	133	287	150	0
● Guild (Warm)	217	219	2	133	288	151	0

RIVER : CLEARWATER
DIFFERENCES : [UKMO-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-42	58	95	-37	22	-28	87
Brown Trout			65	-38	22	-36	96
Coho Salmon	-47	58	102	-35	29	-33	97
Rainbow Trout			92	-34	29	-31	94
Lake Herring			97	-34	29	-33	96
Chinook Salmon			92	-35	38	-26	99
Chum Salmon	-42	59	97	-34	29	-23	86
Mountain Whitefish			94	-34	29	-33	96
Pink Salmon	-42	59	100	-34	29	-39	102
Lake Trout			97	-34	29	-27	90
Sockeye Salmon	-47	58	102	-34	29	-32	95
● Guild (Cold)			97	-34	29	-33	96
Northern Pike			3	-35	41	28	44
Sauger			3	-38	46	33	51
White Sucker			55	-39	45	28	56
Yellow Perch			40	-47	47	40	54
Walleye			40	-47	48	44	51
Muskellunge			9	-38	46	33	51
Black Crappie			0	-38	46	33	51
White Crappie			0	-38	46	33	51
● Guild (Cool)			9	-38	46	33	51
Smallmouth Bass			46	-53	47	100	0
Brown Bullhead			15	-47	47	92	2
Carp			0	-47	51	96	0
Freshwater Drum			0	-47	51	96	0
Gizzard Shad			0	-47	51	96	0
Golden Shiner			8	-47	51	96	0
Green Sunfish			3	-47	51	96	0
White Bass			0	-47	48	77	18
Lake Sturgeon			2	-47	51	96	0
Rock Bass			4	-47	51	96	0
Channel Catfish			0	-42	54	100	0
Largemouth Bass			3	-53	47	100	0
Bluegill			0	-47	50	95	0
● Guild (Warm)			2	-47	51	96	0

RIVER : CLEARWATER
SCENARIO: OSU

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	173	243	70	103	297	77	117
Brown Trout	206	208	2	107	295	87	101
Coho Salmon	178	242	63	121	288	73	94
Rainbow Trout	180	237	52	119	290	76	95
Lake Herring	179	241	59	118	291	72	101
Chinook Salmon	179	237	54	124	280	72	84
Chum Salmon	174	243	69	118	291	44	129
Mountain Whitefish	179	241	57	118	291	72	101
Pink Salmon	174	243	69	118	291	84	89
Lake Trout	179	241	59	118	291	38	135
Sockeye Salmon	178	242	63	119	290	68	103
● Guild (Cold)	179	241	59	118	291	72	101
Northern Pike			0	126	278	150	0
Sauger			0	135	266	131	0
White Sucker			0	134	266	132	0
Yellow Perch			0	153	263	107	0
Walleye			0	154	256	102	0
Muskellunge			0	135	266	131	0
Black Crappie			0	135	266	131	0
White Crappie			0	135	266	131	0
● Guild (Cool)			0	135	266	131	0
Smallmouth Bass			0	157	250	91	0
Brown Bullhead			0	153	263	107	0
Carp			0	156	251	95	0
Freshwater Drum			0	156	251	95	0
Gizzard Shad			0	156	251	95	0
Golden Shiner			0	156	251	95	0
Green Sunfish			0	156	251	95	0
White Bass			0	154	256	102	0
Lake Sturgeon			0	156	251	95	0
Rock Bass			0	156	251	95	0
Channel Catfish			0	175	243	68	0
Largemouth Bass			0	157	250	91	0
Bluegill			0	156	250	94	0
● Guild (Warm)			0	156	251	95	0

RIVER : CLEARWATER
DIFFERENCES : [OSU-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-25	23	50	-12	5	-20	37
Brown Trout			2	-14	6	-14	34
Coho Salmon	-28	34	61	-5	9	-28	42
Rainbow Trout			52	-4	10	-23	37
Lake Herring			59	-5	11	-18	34
Chinook Salmon			54	-5	11	-34	50
Chum Salmon	-24	24	51	-5	11	-24	40
Mountain Whitefish			57	-5	11	-18	34
Pink Salmon	-24	24	55	-5	11	-28	44
Lake Trout			59	-5	11	-23	39
Sockeye Salmon	-28	34	61	-4	10	-20	34
●Guild (Cold)			59	-5	11	-18	34
Northern Pike			0	-9	13	20	0
Sauger			0	-23	16	39	0
White Sucker			0	-23	15	38	0
Yellow Perch			0	-20	19	36	0
Walleye			0	-20	13	33	0
Muskellunge			0	-23	16	39	0
Black Crappie			0	-23	16	39	0
White Crappie			0	-23	16	39	0
●Guild (Cool)			0	-23	16	39	0
Smallmouth Bass			0	-30	16	44	0
Brown Bullhead			0	-20	19	36	0
Carp			0	-24	14	40	0
Freshwater Drum			0	-24	14	40	0
Gizzard Shad			0	-24	14	40	0
Golden Shiner			0	-24	14	40	0
Green Sunfish			0	-24	14	40	0
White Bass			0	-20	13	33	0
Lake Sturgeon			0	-24	14	40	0
Rock Bass			0	-24	14	40	0
Channel Catfish			0	-24	29	57	0
Largemouth Bass			0	-30	16	44	0
Bluegill			0	-24	13	39	0
●Guild (Warm)			0	-24	14	40	0

RIVER : ZUMBRO
SCENARIO: PAST

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	178	235	57	96	305	100	109
Brown Trout			0	100	297	99	98
Coho Salmon	180	230	48	102	292	97	92
Rainbow Trout	181	220	31	101	294	100	93
Lake Herring	180	226	44	101	295	96	98
Chinook Salmon	180	221	40	106	288	107	68
Chum Salmon	178	235	57	101	295	76	118
Mountain Whitefish	180	226	43	101	295	96	98
Pink Salmon	178	235	57	101	295	104	90
Lake Trout	180	226	44	101	295	72	122
Sockeye Salmon	180	230	48	101	294	92	101
● Guild (Cold)	180	226	44	101	295	96	98
Northern Pike			0	116	279	152	0
Sauger			0	138	257	119	0
White Sucker			0	138	257	119	0
Yellow Perch			0	146	254	106	0
Walleye			0	150	253	101	0
Muskellunge			0	138	257	119	0
Black Crappie			0	138	257	119	0
White Crappie			0	138	257	119	0
● Guild (Cool)			0	138	257	119	0
Smallmouth Bass			0	155	247	90	0
Brown Bullhead			0	146	254	106	0
Carp			0	155	247	92	0
Freshwater Drum			0	155	247	92	0
Gizzard Shad			0	155	247	92	0
Golden Shiner			0	155	247	92	0
Green Sunfish			0	155	247	92	0
White Bass			0	150	253	101	0
Lake Sturgeon			0	155	247	92	0
Rock Bass			0	155	247	92	0
Channel Catfish			0	179	234	55	0
Largemouth Bass			0	155	247	91	0
Bluegill			0	155	247	92	0
● Guild (Warm)			0	155	247	92	0

RIVER : ZUMBRO
SCENARIO: GISS

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	154	264	110	83	316	84	149
Brown Trout	179	247	40	89	311	85	137
Coho Salmon	155	262	103	96	308	84	126
Rainbow Trout	155	256	101	95	309	81	133
Lake Herring	155	257	102	95	309	77	137
Chinook Salmon	155	256	101	100	306	84	114
Chum Salmon	154	263	109	95	309	47	167
Mountain Whitefish	155	257	102	95	309	77	137
Pink Salmon	154	263	109	95	309	91	123
Lake Trout	155	257	102	95	309	39	175
Sockeye Salmon	155	262	103	95	309	73	141
● Guild (Cold)	155	257	102	95	309	77	137
Northern Pike			0	101	293	192	0
Sauger			0	106	280	168	2
White Sucker	217	220	3	106	280	167	7
Yellow Perch			0	116	275	141	3
Walleye			0	117	275	138	2
Muskellunge			0	106	280	168	2
Black Crappie			0	106	280	168	2
White Crappie			0	106	280	168	2
● Guild (Cool)			0	106	280	168	2
Smallmouth Bass	218	219	1	145	271	125	0
Brown Bullhead			0	116	275	144	0
Carp			0	139	271	129	0
Freshwater Drum			0	139	271	129	0
Gizzard Shad			0	139	271	129	0
Golden Shiner			0	139	271	129	0
Green Sunfish			0	139	271	129	0
White Bass			0	117	275	140	0
Lake Sturgeon			0	139	271	129	0
Rock Bass			0	139	271	129	0
Channel Catfish			0	154	263	107	0
Largemouth Bass			0	145	271	126	0
Bluegill			0	145	271	126	0
● Guild (Warm)			0	139	271	129	0

RIVER : ZUMBRO
DIFFERENCES : [GISS-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-24	29	53	-13	11	-16	40
Brown Trout			40	-11	14	-14	39
Coho Salmon	-25	32	55	-6	16	-13	34
Rainbow Trout	-26	36	70	-6	15	-19	40
Lake Herring	-25	31	58	-6	14	-19	39
Chinook Salmon	-25	35	61	-6	18	-23	46
Chum Salmon	-24	28	52	-6	14	-29	49
Mountain Whitefish	-25	31	59	-6	14	-19	39
Pink Salmon	-24	28	52	-6	14	-13	33
Lake Trout	-25	31	58	-6	14	-33	53
Sockeye Salmon	-25	32	55	-6	15	-19	40
● Guild (Cold)	-25	31	58	-6	14	-19	39
Northern Pike			0	-15	14	40	0
Sauger			0	-32	23	49	2
White Sucker			3	-32	23	48	7
Yellow Perch			0	-30	21	35	3
Walleye			0	-33	22	37	2
Muskellunge			0	-32	23	49	2
Black Crappie			0	-32	23	49	2
White Crappie			0	-32	23	49	2
● Guild (Cool)			0	-32	23	49	2
Smallmouth Bass			1	-10	24	35	0
Brown Bullhead			0	-30	21	38	0
Carp			0	-16	24	37	0
Freshwater Drum			0	-16	24	37	0
Gizzard Shad			0	-16	24	37	0
Golden Shiner			0	-16	24	37	0
Green Sunfish			0	-16	24	37	0
White Bass			0	-33	22	39	0
Lake Sturgeon			0	-16	24	37	0
Rock Bass			0	-16	24	37	0
Channel Catfish			0	-25	29	52	0
Largemouth Bass			0	-10	24	35	0
Bluegill			0	-10	24	34	0
● Guild (Warm)			0	-16	24	37	0

RIVER : ZUMBRO
SCENARIO: GFDL

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	154	256	102	68	325	104	153
Brown Trout	179	221	42	69	322	118	135
Coho Salmon	155	253	97	75	316	111	126
Rainbow Trout	155	252	91	72	317	116	128
Lake Herring	155	253	97	71	317	110	135
Chinook Salmon	155	252	95	82	311	111	110
Chum Salmon	154	255	101	71	317	72	173
Mountain Whitefish	155	253	97	71	317	110	135
Pink Salmon	154	255	101	71	317	126	119
Lake Trout	155	253	97	71	317	60	185
Sockeye Salmon	155	253	97	72	317	104	140
● Guild (Cold)	155	253	97	71	317	110	135
Northern Pike			0	89	308	199	3
Sauger			0	112	289	163	11
White Sucker	192	209	14	106	291	164	16
Yellow Perch	199	204	3	133	281	131	13
Walleye			0	134	280	127	11
Muskellunge			0	112	289	163	11
Black Crappie			0	112	289	163	11
White Crappie			0	112	289	163	11
● Guild (Cool)			0	112	289	163	11
Smallmouth Bass	199	204	3	138	263	124	0
Brown Bullhead			0	133	281	144	0
Carp			0	138	264	126	0
Freshwater Drum			0	138	264	126	0
Gizzard Shad			0	138	264	126	0
Golden Shiner			0	138	264	126	0
Green Sunfish			0	138	264	126	0
White Bass			0	134	280	139	0
Lake Sturgeon			0	138	264	126	0
Rock Bass			0	138	264	126	0
Channel Catfish			0	154	255	101	0
Largemouth Bass			0	138	263	125	0
Bluegill			0	138	264	126	0
● Guild (Warm)			0	138	264	126	0

RIVER : ZUMBRO
DIFFERENCES : [GFDL-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-24	21	45	-28	20	4	44
Brown Trout			42	-31	25	19	37
Coho Salmon	-25	23	49	-27	24	14	34
Rainbow Trout	-26	32	60	-29	23	16	35
Lake Herring	-25	27	53	-30	22	14	37
Chinook Salmon	-25	31	55	-24	23	4	42
Chum Salmon	-24	20	44	-30	22	-4	55
Mountain Whitefish	-25	27	54	-30	22	14	37
Pink Salmon	-24	20	44	-30	22	22	29
Lake Trout	-25	27	53	-30	22	-12	63
Sockeye Salmon	-25	23	49	-29	23	12	39
● Guild (Cold)	-25	27	53	-30	22	14	37
Northern Pike			0	-27	29	47	3
Sauger			0	-26	32	44	11
White Sucker			14	-32	34	45	16
Yellow Perch			3	-13	27	25	13
Walleye			0	-16	27	26	11
Muskellunge			0	-26	32	44	11
Black Crappie			0	-26	32	44	11
White Crappie			0	-26	32	44	11
● Guild (Cool)			0	-26	32	44	11
Smallmouth Bass			3	-17	16	34	0
Brown Bullhead			0	-13	27	38	0
Carp			0	-17	17	34	0
Freshwater Drum			0	-17	17	34	0
Gizzard Shad			0	-17	17	34	0
Golden Shiner			0	-17	17	34	0
Green Sunfish			0	-17	17	34	0
White Bass			0	-16	27	38	0
Lake Sturgeon			0	-17	17	34	0
Rock Bass			0	-17	17	34	0
Channel Catfish			0	-25	21	46	0
Largemouth Bass			0	-17	16	34	0
Bluegill			0	-17	17	34	0
● Guild (Warm)			0	-17	17	34	0

RIVER : ZUMBRO
SCENARIO: UKMO

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	106	289	164	68	328	53	207
Brown Trout	155	262	90	70	325	57	198
Coho Salmon	116	281	143	76	320	52	192
Rainbow Trout	138	280	132	73	322	55	194
Lake Herring	116	281	142	73	323	52	198
Chinook Salmon	117	280	137	85	316	52	178
Chum Salmon	106	289	164	73	323	42	208
Mountain Whitefish	117	281	141	73	323	52	198
Pink Salmon	111	289	163	73	323	59	191
Lake Trout	116	281	142	73	323	39	211
Sockeye Salmon	116	281	143	73	322	49	200
● Guild (Cold)	116	281	142	73	323	52	198
Northern Pike	188	235	38	92	312	147	73
Sauger	188	235	37	99	308	134	75
White Sucker	178	255	77	98	308	133	77
Yellow Perch	180	253	73	100	307	129	77
Walleye	180	253	73	101	306	124	75
Muskellunge	184	247	54	99	308	134	75
Black Crappie	199	230	14	99	308	134	75
White Crappie	214	230	11	99	308	134	75
● Guild (Cool)	184	247	54	99	308	134	75
Smallmouth Bass	179	253	74	105	306	170	21
Brown Bullhead	183	247	58	100	307	171	35
Carp	199	230	14	105	306	188	4
Freshwater Drum	199	230	14	105	306	184	8
Gizzard Shad	218	219	1	105	306	181	11
Golden Shiner	188	247	49	105	306	181	11
Green Sunfish	188	235	37	105	306	186	6
White Bass	199	230	14	101	306	140	60
Lake Sturgeon	192	235	35	105	306	181	11
Rock Bass	188	246	41	105	306	179	13
Channel Catfish	193	234	29	112	288	151	4
Largemouth Bass	188	235	38	105	306	191	0
Bluegill	199	234	26	105	306	164	28
● Guild (Warm)	192	235	35	105	306	181	11

RIVER : ZUMBRO
DIFFERENCES : [UKMO-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-72	54	107	-28	23	-47	98
Brown Trout			90	-30	28	-42	100
Coho Salmon	-64	51	95	-26	28	-45	100
Rainbow Trout	-43	60	101	-28	28	-45	101
Lake Herring	-64	55	98	-28	28	-44	100
Chinook Salmon	-63	59	97	-21	28	-55	110
Chum Salmon	-72	54	107	-28	28	-34	90
Mountain Whitefish	-63	55	98	-28	28	-44	100
Pink Salmon	-67	54	106	-28	28	-45	101
Lake Trout	-64	55	98	-28	28	-33	89
Sockeye Salmon	-64	51	95	-28	28	-43	99
● Guild (Cold)	-64	55	98	-28	28	-44	100
Northern Pike			38	-24	33	-5	73
Sauger			37	-39	51	15	75
White Sucker			77	-40	51	14	77
Yellow Perch			73	-46	53	23	77
Walleye			73	-49	53	23	75
Muskellunge			54	-39	51	15	75
Black Crappie			14	-39	51	15	75
White Crappie			11	-39	51	15	75
● Guild (Cool)			54	-39	51	15	75
Smallmouth Bass			74	-50	59	80	21
Brown Bullhead			58	-46	53	65	35
Carp			14	-50	59	96	4
Freshwater Drum			14	-50	59	92	8
Gizzard Shad			1	-50	59	89	11
Golden Shiner			49	-50	59	89	11
Green Sunfish			37	-50	59	94	6
White Bass			14	-49	53	39	60
Lake Sturgeon			35	-50	59	89	11
Rock Bass			41	-50	59	87	13
Channel Catfish			29	-67	54	96	4
Largemouth Bass			38	-50	59	100	0
Bluegill			26	-50	59	72	28
● Guild (Warm)			35	-50	59	89	11

RIVER : ZUMBRO
SCENARIO: OSU

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	154	252	98	88	308	90	130
Brown Trout	180	230	45	96	306	86	124
Coho Salmon	155	247	92	100	297	87	110
Rainbow Trout	155	246	82	98	305	92	112
Lake Herring	155	247	91	97	305	82	124
Chinook Salmon	155	247	89	101	293	93	99
Chum Salmon	154	252	98	97	305	68	138
Mountain Whitefish	155	247	90	97	305	82	124
Pink Salmon	154	252	96	97	305	99	107
Lake Trout	155	247	91	97	305	50	156
Sockeye Salmon	155	247	92	98	305	77	127
●Guild (Cold)	155	247	91	97	305	82	124
Northern Pike	1000	0	0	106	289	183	0
Sauger	1000	0	0	123	271	139	4
White Sucker	199	219	7	122	271	137	10
Yellow Perch	1000	0	0	135	264	124	5
Walleye	1000	0	0	136	263	123	4
Muskellunge	1000	0	0	123	271	139	4
Black Crappie	1000	0	0	123	271	139	4
White Crappie	1000	0	0	123	271	139	4
●Guild (Cool)	1000	0	0	123	271	139	4
Smallmouth Bass	1000	0	0	146	256	108	0
Brown Bullhead	1000	0	0	135	264	129	0
Carp	1000	0	0	145	256	111	0
Freshwater Drum	1000	0	0	145	256	111	0
Gizzard Shad	1000	0	0	145	256	111	0
Golden Shiner	1000	0	0	145	256	111	0
Green Sunfish	1000	0	0	145	256	111	0
White Bass	1000	0	0	136	263	127	0
Lake Sturgeon	1000	0	0	145	256	111	0
Rock Bass	1000	0	0	145	256	111	0
Channel Catfish	1000	0	0	154	248	94	0
Largemouth Bass	1000	0	0	145	256	110	0
Bluegill	1000	0	0	145	256	110	0
●Guild (Warm)	1000	0	0	145	256	111	0

RIVER : ZUMBRO
DIFFERENCES : [OSU-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-24	17	41	-8	3	-10	21
Brown Trout			45	-4	9	-13	26
Coho Salmon	-25	17	44	-2	5	-10	18
Rainbow Trout	-26	26	51	-3	11	-8	19
Lake Herring	-25	21	47	-4	10	-14	26
Chinook Salmon	-25	26	49	-5	5	-14	31
Chum Salmon	-24	17	41	-4	10	-8	20
Mountain Whitefish	-25	21	47	-4	10	-14	26
Pink Salmon	-24	17	39	-4	10	-5	17
Lake Trout	-25	21	47	-4	10	-22	34
Sockeye Salmon	-25	17	44	-3	11	-15	26
● Guild (Cold)	-25	21	47	-4	10	-14	26
Northern Pike			0	-10	10	31	0
Sauger			0	-15	14	20	4
White Sucker			7	-16	14	18	10
Yellow Perch			0	-11	10	18	5
Walleye			0	-14	10	22	4
Muskellunge			0	-15	14	20	4
Black Crappie			0	-15	14	20	4
White Crappie			0	-15	14	20	4
● Guild (Cool)			0	-15	14	20	4
Smallmouth Bass			0	-9	9	18	0
Brown Bullhead			0	-11	10	23	0
Carp			0	-10	9	19	0
Freshwater Drum			0	-10	9	19	0
Gizzard Shad			0	-10	9	19	0
Golden Shiner			0	-10	9	19	0
Green Sunfish			0	-10	9	19	0
White Bass			0	-14	10	26	0
Lake Sturgeon			0	-10	9	19	0
Rock Bass			0	-10	9	19	0
Channel Catfish			0	-25	14	39	0
Largemouth Bass			0	-10	9	19	0
Bluegill			0	-10	9	18	0
● Guild (Warm)			0	-10	9	19	0

RIVER : MISSISSIPPI
SCENARIO: PAST

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	154	250	96	96	303	77	130
Brown Trout	179	230	45	100	297	76	121
Coho Salmon	155	247	90	103	292	76	113
Rainbow Trout	156	242	80	101	294	75	118
Lake Herring	155	247	88	101	295	73	121
Chinook Salmon	156	247	85	107	281	73	101
Chum Salmon	154	250	96	101	295	56	138
Mountain Whitefish	155	247	88	101	295	73	121
Pink Salmon	154	250	96	101	295	83	111
Lake Trout	155	247	88	101	295	51	143
Sockeye Salmon	155	247	90	101	294	67	126
● Guild (Cold)	155	247	88	101	295	73	121
Northern Pike			0	115	280	158	7
Sauger			0	125	265	130	10
White Sucker	192	208	12	124	266	121	21
Yellow Perch	199	208	6	135	262	115	12
Walleye	203	207	2	135	262	115	10
Muskellunge			0	125	265	130	10
Black Crappie			0	125	265	130	10
White Crappie			0	125	265	130	10
● Guild (Cool)			0	125	265	130	10
Smallmouth Bass	199	208	7	144	255	111	0
Brown Bullhead			0	135	262	127	0
Carp			0	138	256	118	0
Freshwater Drum			0	138	256	118	0
Gizzard Shad			0	138	256	118	0
Golden Shiner			0	138	256	118	0
Green Sunfish			0	138	256	118	0
White Bass			0	135	262	126	0
Lake Sturgeon			0	138	256	118	0
Rock Bass			0	138	256	118	0
Channel Catfish			0	155	248	92	0
Largemouth Bass			0	144	255	111	0
Bluegill			0	139	255	116	0
● Guild (Warm)			0	138	256	118	0

RIVER : MISSISSIPPI
SCENARIO: GISS

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	139	256	114	82	311	67	162
Brown Trout	155	247	85	86	308	77	145
Coho Salmon	149	256	107	97	298	71	130
Rainbow Trout	153	255	101	90	306	82	133
Lake Herring	150	255	105	90	307	72	145
Chinook Salmon	150	255	103	100	295	70	125
Chum Salmon	139	256	114	90	307	52	165
Mountain Whitefish	150	255	105	90	307	72	145
Pink Salmon	144	256	112	90	307	87	130
Lake Trout	150	255	105	90	307	43	174
Sockeye Salmon	149	256	107	90	306	64	151
● Guild (Cold)	150	255	105	90	307	72	145
Northern Pike	180	208	9	102	292	138	52
Sauger	180	208	7	112	280	99	68
White Sucker	156	234	75	111	280	93	76
Yellow Perch	177	230	51	117	278	87	69
Walleye	177	230	50	124	277	80	68
Muskellunge	179	219	17	112	280	99	68
Black Crappie			0	112	280	99	68
White Crappie			0	112	280	99	68
● Guild (Cool)	179	219	17	112	280	99	68
Smallmouth Bass	176	230	54	135	265	130	0
Brown Bullhead	179	219	20	117	278	154	2
Carp			0	134	265	131	0
Freshwater Drum			0	134	265	131	0
Gizzard Shad			0	134	265	131	0
Golden Shiner	180	208	13	134	265	131	0
Green Sunfish	180	208	7	134	265	131	0
White Bass			0	124	277	115	33
Lake Sturgeon	181	207	2	134	265	131	0
Rock Bass	180	208	9	134	265	131	0
Channel Catfish			0	144	256	112	0
Largemouth Bass	180	208	9	135	265	130	0
Bluegill			0	135	265	130	0
● Guild (Warm)	181	207	2	134	265	131	0

RIVER : MISSISSIPPI
DIFFERENCES : [GISS-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-15	6	18	-14	8	-10	32
Brown Trout	-24	17	40	-14	11	1	24
Coho Salmon	-6	9	17	-6	6	-5	17
Rainbow Trout	-3	13	21	-11	12	7	15
Lake Herring	-5	8	17	-11	12	-1	24
Chinook Salmon	-6	8	18	-7	14	-3	24
Chum Salmon	-15	6	18	-11	12	-4	27
Mountain Whitefish	-5	8	17	-11	12	-1	24
Pink Salmon	-10	6	16	-11	12	4	19
Lake Trout	-5	8	17	-11	12	-8	31
Sockeye Salmon	-6	9	17	-11	12	-3	25
● Guild (Cold)	-5	8	17	-11	12	-1	24
Northern Pike			9	-13	12	-20	45
Sauger			7	-13	15	-31	58
White Sucker	-36	26	63	-13	14	-28	55
Yellow Perch	-22	22	45	-18	16	-28	57
Walleye	-26	23	48	-11	15	-35	58
Muskellunge			17	-13	15	-31	58
Black Crappie			0	-13	15	-31	58
White Crappie			0	-13	15	-31	58
● Guild (Cool)			17	-13	15	-31	58
Smallmouth Bass	-23	22	47	-9	10	19	0
Brown Bullhead			20	-18	16	27	2
Carp			0	-4	9	13	0
Freshwater Drum			0	-4	9	13	0
Gizzard Shad			0	-4	9	13	0
Golden Shiner			13	-4	9	13	0
Green Sunfish			7	-4	9	13	0
White Bass			0	-11	15	-11	33
Lake Sturgeon			2	-4	9	13	0
Rock Bass			9	-4	9	13	0
Channel Catfish			0	-11	8	20	0
Largemouth Bass			9	-9	10	19	0
Bluegill			0	-4	10	14	0
● Guild (Warm)			2	-4	9	13	0

RIVER : MISSISSIPPI
SCENARIO: GFDL

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	137	262	124	68	321	92	161
Brown Trout	155	247	81	71	317	95	151
Coho Salmon	143	256	113	79	312	94	134
Rainbow Trout	149	255	106	75	314	100	137
Lake Herring	144	256	112	75	315	87	151
Chinook Salmon	146	255	107	83	308	81	128
Chum Salmon	137	262	122	75	315	73	165
Mountain Whitefish	145	256	111	75	315	87	151
Pink Salmon	138	257	119	75	315	106	132
Lake Trout	144	256	112	75	315	61	177
Sockeye Salmon	143	256	113	75	314	81	156
● Guild (Cold)	144	256	112	75	315	87	151
Northern Pike	179	182	3	89	306	150	43
Sauger	180	182	2	116	281	101	64
White Sucker	156	230	66	112	282	97	71
Yellow Perch	157	219	41	121	280	93	65
Walleye	165	219	34	123	279	89	64
Muskellunge	178	204	7	116	281	101	64
Black Crappie			0	116	281	101	64
White Crappie			0	116	281	101	64
● Guild (Cool)	178	204	7	116	281	101	64
Smallmouth Bass	157	220	49	133	265	131	1
Brown Bullhead	178	207	10	121	280	156	2
Carp			0	132	266	134	0
Freshwater Drum			0	132	266	134	0
Gizzard Shad			0	132	266	134	0
Golden Shiner	179	182	3	132	266	134	0
Green Sunfish	180	182	2	132	266	134	0
White Bass			0	122	279	141	13
Lake Sturgeon	180	182	2	132	266	134	0
Rock Bass	179	182	3	132	266	134	0
Channel Catfish	180	182	2	138	256	118	0
Largemouth Bass	179	182	3	133	265	132	0
Bluegill	180	182	2	132	266	132	2
● Guild (Warm)	180	182	2	132	266	134	0

RIVER : MISSISSIPPI
DIFFERENCES : [GFDL-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-17	12	28	-28	18	15	31
Brown Trout	-24	17	36	-29	20	19	30
Coho Salmon	-12	9	23	-24	20	18	21
Rainbow Trout	-7	13	26	-26	20	25	19
Lake Herring	-11	9	24	-26	20	14	30
Chinook Salmon	-10	8	22	-24	27	8	27
Chum Salmon	-17	12	26	-26	20	17	27
Mountain Whitefish	-10	9	23	-26	20	14	30
Pink Salmon	-16	7	23	-26	20	23	21
Lake Trout	-11	9	24	-26	20	10	34
Sockeye Salmon	-12	9	23	-26	20	14	30
● Guild (Cold)	-11	9	24	-26	20	14	30
Northern Pike			3	-26	26	-8	36
Sauger			2	-9	16	-29	54
White Sucker	-36	22	54	-12	16	-24	50
Yellow Perch	-42	11	35	-14	18	-22	53
Walleye	-38	12	32	-12	17	-26	54
Muskellunge			7	-9	16	-29	54
Black Crappie			0	-9	16	-29	54
White Crappie			0	-9	16	-29	54
● Guild (Cool)			7	-9	16	-29	54
Smallmouth Bass	-42	12	42	-11	10	20	1
Brown Bullhead			10	-14	18	29	2
Carp			0	-6	10	16	0
Freshwater Drum			0	-6	10	16	0
Gizzard Shad			0	-6	10	16	0
Golden Shiner			3	-6	10	16	0
Green Sunfish			2	-6	10	16	0
White Bass			0	-13	17	15	13
Lake Sturgeon			2	-6	10	16	0
Rock Bass			3	-6	10	16	0
Channel Catfish			2	-17	8	26	0
Largemouth Bass			3	-11	10	21	0
Bluegill			2	-7	11	16	2
● Guild (Warm)			2	-6	10	16	0

RIVER : MISSISSIPPI
SCENARIO: UKMO

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	127	288	155	69	324	58	197
Brown Trout	149	265	114	73	321	57	191
Coho Salmon	134	281	147	82	316	52	182
Rainbow Trout	135	280	142	78	317	55	184
Lake Herring	135	281	145	78	317	48	191
Chinook Salmon	135	280	143	88	310	48	174
Chum Salmon	128	282	152	78	317	37	202
Mountain Whitefish	135	280	144	78	317	48	191
Pink Salmon	132	282	150	78	317	61	178
Lake Trout	135	281	145	78	317	32	207
Sockeye Salmon	134	281	147	78	317	46	193
● Guild (Cold)	135	281	145	78	317	48	191
Northern Pike	179	252	72	93	309	118	98
Sauger	179	252	72	100	307	101	102
White Sucker	155	262	106	100	307	99	107
Yellow Perch	156	256	96	105	306	88	105
Walleye	156	256	92	106	306	90	102
Muskellunge	178	255	76	100	307	101	102
Black Crappie	181	250	63	100	307	101	102
White Crappie	182	248	59	100	307	101	102
● Guild (Cool)	178	255	76	100	307	101	102
Smallmouth Bass	156	256	98	112	292	114	64
Brown Bullhead	178	255	77	105	306	124	69
Carp	181	250	63	111	293	129	53
Freshwater Drum	181	250	63	111	293	127	55
Gizzard Shad	184	247	43	111	293	124	58
Golden Shiner	178	252	73	111	293	124	58
Green Sunfish	179	252	72	111	293	128	54
White Bass	181	250	63	105	306	115	78
Lake Sturgeon	180	252	69	111	293	124	58
Rock Bass	179	252	72	111	293	119	63
Channel Catfish	180	251	68	132	281	96	53
Largemouth Bass	179	252	72	112	292	163	16
Bluegill	180	251	67	111	293	114	68
● Guild (Warm)	180	252	69	111	293	124	58

RIVER : MISSISSIPPI
DIFFERENCES : [UKMO-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-27	38	59	-27	21	-19	67
Brown Trout	-30	35	69	-27	24	-19	70
Coho Salmon	-21	34	57	-21	24	-24	69
Rainbow Trout	-21	38	62	-23	23	-20	66
Lake Herring	-20	34	57	-23	22	-25	70
Chinook Salmon	-21	33	58	-19	29	-25	73
Chum Salmon	-26	32	56	-23	22	-19	64
Mountain Whitefish	-20	33	56	-23	22	-25	70
Pink Salmon	-22	32	54	-23	22	-22	67
Lake Trout	-20	34	57	-23	22	-19	64
Sockeye Salmon	-21	34	57	-23	23	-21	67
● Guild (Cold)	-20	34	57	-23	22	-25	70
Northern Pike			72	-22	29	-40	91
Sauger			72	-25	42	-29	92
White Sucker	-37	54	94	-24	41	-22	86
Yellow Perch	-43	48	90	-30	44	-27	93
Walleye	-47	49	90	-29	44	-25	92
Muskellunge			76	-25	42	-29	92
Black Crappie			63	-25	42	-29	92
White Crappie			59	-25	42	-29	92
● Guild (Cool)			76	-25	42	-29	92
Smallmouth Bass	-43	48	91	-32	37	3	64
Brown Bullhead			77	-30	44	-3	69
Carp			63	-27	37	11	53
Freshwater Drum			63	-27	37	9	55
Gizzard Shad			43	-27	37	6	58
Golden Shiner			73	-27	37	6	58
Green Sunfish			72	-27	37	10	54
White Bass			63	-30	44	-11	78
Lake Sturgeon			69	-27	37	6	58
Rock Bass			72	-27	37	1	63
Channel Catfish			68	-23	33	4	53
Largemouth Bass			72	-32	37	52	16
Bluegill			67	-28	38	-2	68
● Guild (Warm)			69	-27	37	6	58

RIVER : MISSISSIPPI
SCENARIO: OSU

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	138	256	118	85	307	74	148
Brown Trout	155	247	90	90	305	70	141
Coho Salmon	149	255	106	100	297	68	129
Rainbow Trout	150	252	100	99	298	67	132
Lake Herring	149	255	105	99	298	58	141
Chinook Salmon	150	252	100	105	293	65	123
Chum Salmon	139	256	116	99	298	41	158
Mountain Whitefish	150	255	104	99	298	58	141
Pink Salmon	139	256	114	99	298	71	128
Lake Trout	149	255	105	99	298	35	164
Sockeye Salmon	149	255	106	99	298	53	146
● Guild (Cold)	149	255	105	99	298	58	141
Northern Pike	192	220	14	106	291	126	57
Sauger	198	219	12	121	279	97	61
White Sucker	157	242	68	121	279	86	72
Yellow Perch	177	234	57	123	271	85	63
Walleye	178	234	56	124	270	83	61
Muskellunge	180	230	36	121	279	97	61
Black Crappie			0	121	279	97	61
White Crappie			0	121	279	97	61
● Guild (Cool)	180	230	36	121	279	97	61
Smallmouth Bass	177	234	57	135	263	126	2
Brown Bullhead	180	230	43	123	271	138	10
Carp			0	133	265	132	0
Freshwater Drum			0	133	265	132	0
Gizzard Shad			0	133	265	132	0
Golden Shiner	180	221	33	133	265	132	0
Green Sunfish	198	219	12	133	265	132	0
White Bass			0	124	270	95	50
Lake Sturgeon	199	219	10	133	265	132	0
Rock Bass	192	220	17	133	265	132	0
Channel Catfish	199	208	7	144	256	112	0
Largemouth Bass	192	220	14	135	264	129	0
Bluegill	199	208	7	134	265	124	7
● Guild (Warm)	199	219	10	133	265	132	0

RIVER : MISSISSIPPI
DIFFERENCES : [OSU-PAST]

FISH	SCB	SCE	SCL	GSB	GSE	GSL	GZER
Brook Trout	-16	6	22	-11	4	-3	18
Brown Trout	-24	17	45	-10	8	-6	20
Coho Salmon	-6	8	16	-3	5	-8	16
Rainbow Trout	-6	10	20	-2	4	-8	14
Lake Herring	-6	8	17	-2	3	-15	20
Chinook Salmon	-6	5	15	-2	12	-8	22
Chum Salmon	-15	6	20	-2	3	-15	20
Mountain Whitefish	-5	8	16	-2	3	-15	20
Pink Salmon	-15	6	18	-2	3	-12	17
Lake Trout	-6	8	17	-2	3	-16	21
Sockeye Salmon	-6	8	16	-2	4	-14	20
● Guild (Cold)	-6	8	17	-2	3	-15	20
Northern Pike			14	-9	11	-32	50
Sauger			12	-4	14	-33	51
White Sucker	-35	34	56	-3	13	-35	51
Yellow Perch	-22	26	51	-12	9	-30	51
Walleye	-25	27	54	-11	8	-32	51
Muskellunge			36	-4	14	-33	51
Black Crappie			0	-4	14	-33	51
White Crappie			0	-4	14	-33	51
● Guild (Cool)			36	-4	14	-33	51
Smallmouth Bass	-22	26	50	-9	8	15	2
Brown Bullhead			43	-12	9	11	10
Carp			0	-5	9	14	0
Freshwater Drum			0	-5	9	14	0
Gizzard Shad			0	-5	9	14	0
Golden Shiner			33	-5	9	14	0
Green Sunfish			12	-5	9	14	0
White Bass			0	-11	8	-31	50
Lake Sturgeon			10	-5	9	14	0
Rock Bass			17	-5	9	14	0
Channel Catfish			7	-11	8	20	0
Largemouth Bass			14	-9	9	18	0
Bluegill			7	-5	10	8	7
● Guild (Warm)			10	-5	9	14	0

	Observed fish species				
FISH	STRAIGHT	BAPTISM	CLEARWATER	ZUMBRO	MISSISSIPPI
Brook Trout		1/7			
Brown Trout	22/22	2/7	11/13	1/50	
Coho Salmon					
Rainbow Trout	5/22	7/10	11/13	4/50	
Lake Herring					
Chinook Salmon		5/7			
Chum Salmon					
Mountain Whitefish					
Pink Salmon					
Lake Trout					
Sockeye Salmon					
Guild (Cold)					
Northern Pike	8/32		5/18	6/50	*
Sauger				17/50	
White Sucker	13/39	2/7	8/18	16/67	*
Yellow Perch	3/22	3/7	2/13	4/50	*
Walleye	1/22		3/18	14/54	*
Muskellunge					
Black Crappie	2/7			15/50	*
White Crappie				10/50	
Guild (Cool)					
Smallmouth Bass				35/54	*
Brown Bullhead			1/13		
Carp			1/13	11/50	*
Freshwater Drum			2/13	5/50	
Gizzard Shad				2/50	
Golden Shiner	1/22				
Green Sunfish	1/22		1/13	5/50	
White Bass				16/63	
Lake Sturgeon					
Rock Bass	2/22		6/18		*
Channel Catfish			2/13	16/63	
Largemouth Bass	5/22			25/50	*
Bluegill	1/22		1/13	14/50	*
Guild (Warm)					

Example : 5/22 means fish species observed in 5 of 22 surveys.
* designates species collected from river reach modeled (unknown number of surveys).

APPENDIX D

Fish Survival and Growth Parameters Based on Water Temperature (only) in 27 Southern Minnesota Lake Classes for Two Climate Scenarios (1955–79 and 2x CO_2 GISS)

PROJECTED FISH SURVIVAL AND GROWTH PARAMETERS IN MINNESOTA LAKES
THERMAL HABITAT

SCB - Earliest Julian date when the lowest temperature in the vertical lake temperature profile exceeds the survival temperature.

SCE - Latest Julian date when the lowest temperature in the vertical lake temperature profile exceeds the survival temperature.

SCL - Total number of days when the lowest temperature in lake temperature profile exceeds the suvirval temperature.

GSB - Earliest Julian date when any value in the vertical lake temperature profile exceeds the lower bound for good growth.

GSE - Latest Julian date when any value in the vertical lake temperature profile exceeds the lower bound for good growth.

GSL - Total number of days when temperature at same depth in the lake temerature temperature profile falls between the lower and upper bound for good growth.

Gzer - Total number of days when the lowest temperature in the lake temperature profile exceeds the upper bound for good growth. This is the midsumer no growth period due to excessive temperature in the temperature profile.

Z*jd - Integration of depths over time for those depths (m) and times (days) where and when water temperatures are within the upper and lower good growth limits. Integration begins at the first exceedance of the lower growth limit. This is the summation of possible good growth depths over growing season.

$\frac{Z*jd}{Zm*GSL}$ - Previous interpretation normalized by maximum lake depth Zm and length of the season for good growth GSL. Indicates what fraction of the maximum depth would be available for growth during the entire growing season. Range of values from 0 to 1.

$\frac{Vol*jd}{A}$ - Integration of volumes over time for those volumes (m3) and times (days) where and when water temperatures are within the upper and lower good growth temperature limits. Integration begins at the first exceedance of the lower limit for good growth. This is the summation of possible good growth volumes over growing season divided by surface area.

$\frac{Vol*jd}{Vtot*GSL}$ Previous integration normalized by average depth (Vtot/A) and length of good growth season GSL. Indicates what fraction of average depth would be available for good growth during the entire good growing season. Range of values from 0 to 1.

COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	192	223	31	101	298	98	99	357	0.90	133	0.86
		mesotrophic	178	233	55	100	298	88	110	338	0.95	129	0.93
		oligotrophic	176	233	57	100	298	83	115	330	0.98	129	0.98
	MEDIUM (1.7)	eutrophic	179	233	54	101	298	88	109	341	0.96	125	0.94
		mesotrophic	176	233	57	100	298	83	115	329	0.98	122	0.97
		oligotrophic	175	241	66	100	299	81	118	324	0.99	121	0.99
	LARGE (10.0)	eutrophic	177	233	56	100	297	87	110	339	0.96	114	0.94
		mesotrophic	176	233	57	100	297	84	113	330	0.97	113	0.97
		oligotrophic	175	233	58	100	297	82	115	328	0.99	113	0.99
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	107	306	199	0	2010	0.77	618	0.61
		mesotrophic	0	0	0	107	307	200	0	1870	0.72	554	0.55
		oligotrophic	0	0	0	107	307	200	0	1590	0.61	478	0.47
	MEDIUM (1.7)	eutrophic	0	0	0	108	306	186	12	1680	0.69	468	0.53
		mesotrophic	0	0	0	107	306	163	36	1500	0.71	443	0.57
		oligotrophic	0	0	0	107	306	125	74	1260	0.77	412	0.69
	LARGE (10.0)	eutrophic	207	233	26	106	304	106	92	1210	0.87	375	0.81
		mesotrophic	201	233	32	106	304	102	96	1180	0.88	371	0.83
		oligotrophic	191	236	45	106	305	96	103	1140	0.91	370	0.88
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	112	308	196	0	1630	0.35	1040	0.55
		mesotrophic	0	0	0	112	309	197	0	1580	0.33	974	0.51
		oligotrophic	0	0	0	112	311	199	0	1800	0.38	951	0.49
	MEDIUM (1.7)	eutrophic	0	0	0	114	311	197	0	3650	0.77	1150	0.65
		mesotrophic	0	0	0	113	311	198	0	3560	0.75	1090	0.61
		oligotrophic	0	0	0	113	312	199	0	3430	0.71	1000	0.56
	LARGE (10.0)	eutrophic	0	0	0	111	309	198	0	3370	0.71	832	0.51
		mesotrophic	0	0	0	111	309	198	0	3280	0.69	813	0.50
		oligotrophic	0	0	0	111	300	173	26	2960	0.71	773	0.54

PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
2XCO2 CLIMATE SCENARIO GISS-model

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	177	254	77	76	308	105	127	333	0.79	121	0.73
		mesotrophic	154	256	102	76	308	82	150	306	0.92	116	0.90
		oligotrophic	144	256	112	76	308	74	158	295	0.98	115	0.98
	MEDIUM (1.7)	eutrophic	156	254	98	75	308	95	138	328	0.85	115	0.80
		mesotrophic	145	256	111	75	308	79	154	303	0.95	112	0.93
		oligotrophic	144	256	112	75	308	74	159	296	0.99	111	0.99
	LARGE (10.0)	eutrophic	154	254	100	75	308	84	149	316	0.93	104	0.89
		mesotrophic	145	256	111	74	308	78	156	305	0.97	104	0.95
		oligotrophic	144	256	112	74	308	75	159	300	0.99	103	0.99
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	83	309	226	0	1030	0.35	488	0.43
		mesotrophic	0	0	0	84	309	225	0	1240	0.42	462	0.41
		oligotrophic	0	0	0	85	309	224	0	1430	0.49	427	0.38
	MEDIUM (1.7)	eutrophic	0	0	0	84	308	224	0	1760	0.60	479	0.45
		mesotrophic	0	0	0	85	308	190	33	1480	0.60	419	0.46
		oligotrophic	224	261	37	85	308	134	89	1160	0.66	368	0.57
	LARGE (10.0)	eutrophic	198	258	60	84	308	113	111	1160	0.78	349	0.70
		mesotrophic	188	259	71	84	308	104	120	1080	0.79	330	0.72
		oligotrophic	171	260	89	84	308	92	132	1000	0.83	318	0.78
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	85	311	226	0	1210	0.22	754	0.35
		mesotrophic	0	0	0	87	311	224	0	1250	0.23	761	0.35
		oligotrophic	0	0	0	89	311	222	0	1490	0.28	811	0.38
	MEDIUM (1.7)	eutrophic	0	0	0	87	311	224	0	2040	0.38	967	0.48
		mesotrophic	0	0	0	89	311	222	0	2080	0.39	914	0.46
		oligotrophic	0	0	0	90	311	221	0	2460	0.46	883	0.45
	LARGE (10.0)	eutrophic	0	0	0	89	310	221	0	3300	0.62	844	0.46
		mesotrophic	0	0	0	89	310	218	3	3170	0.60	804	0.45
		oligotrophic	0	0	0	90	310	193	27	2810	0.60	735	0.46

PROJECTED COLD-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
DIFFERENCIES (GISS- PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCL (day)	GSB (day)	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd (%)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	46	-25	10	7	28	-24	-7	-12	-9
		mesotrophic	47	-24	10	-6	40	-32	-9	-13	-10
		oligotrophic	55	-24	10	-9	43	-35	-11	-14	-11
	MEDIUM (1.7)	eutrophic	44	-26	10	7	29	-13	-4	-10	-8
		mesotrophic	54	-25	10	-4	39	-26	-8	-10	-8
		oligotrophic	46	-25	9	-7	41	-28	-9	-10	-8
	LARGE (10.0)	eutrophic	44	-25	11	-3	39	-23	-7	-10	-9
		mesotrophic	54	-26	11	-6	43	-25	-8	-9	-8
		oligotrophic	54	-26	11	-7	44	-28	-9	-10	-9
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-24	3	27	0	-980	-49	-130	-21
		mesotrophic	0	-23	2	25	0	-630	-34	-92	-17
		oligotrophic	0	-22	2	24	0	-160	-10	-51	-11
	MEDIUM (1.7)	eutrophic	0	-24	2	38	-12	80	5	11	2
		mesotrophic	0	-22	2	27	-3	-20	-1	-24	-5
		oligotrophic	37	-22	2	9	15	-100	-8	-44	-11
	LARGE (10.0)	eutrophic	34	-22	4	7	19	-50	-4	-26	-7
		mesotrophic	39	-22	4	2	24	-100	-8	-41	-11
		oligotrophic	44	-22	3	-4	29	-140	-12	-52	-14
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-27	3	30	0	-420	-26	-286	-28
		mesotrophic	0	-25	2	27	0	-330	-21	-213	-22
		oligotrophic	0	-23	0	23	0	-310	-17	-140	-15
	MEDIUM (1.7)	eutrophic	0	-27	0	27	0	-1610	-44	-183	-16
		mesotrophic	0	-24	0	24	0	-1480	-42	-176	-16
		oligotrophic	0	-23	-1	22	0	-970	-28	-117	-12
	LARGE (10.0)	eutrophic	0	-22	1	23	0	-70	-2	12	1
		mesotrophic	0	-22	1	20	3	-110	-3	-9	-1
		oligotrophic	0	-21	10	20	1	-150	-5	-38	-5

COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	135	266	131	0	511	0.97	203	0.99
		mesotrophic	0	0	0	135	267	132	0	525	0.99	206	0.99
		oligotrophic	0	0	0	135	267	132	0	527	0.99	206	0.99
	MEDIUM (1.7)	eutrophic	0	0	0	135	266	131	0	521	0.99	196	0.99
		mesotrophic	0	0	0	135	266	131	0	524	0.99	196	0.99
		oligotrophic	0	0	0	134	267	133	0	532	0.99	199	0.99
	LARGE (10.0)	eutrophic	0	0	0	135	266	131	0	523	0.99	180	0.99
		mesotrophic	0	0	0	135	266	131	0	524	0.99	180	0.99
		oligotrophic	0	0	0	135	266	131	0	524	0.99	180	0.99
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	137	272	135	0	595	0.34	465	0.68
		mesotrophic	0	0	0	138	274	136	0	803	0.45	543	0.79
		oligotrophic	0	0	0	138	276	138	0	1310	0.72	639	0.91
	MEDIUM (1.7)	eutrophic	0	0	0	139	273	134	0	1290	0.73	580	0.90
		mesotrophic	0	0	0	138	273	135	0	1400	0.79	601	0.93
		oligotrophic	0	0	0	138	274	136	0	1590	0.89	628	0.96
	LARGE (10.0)	eutrophic	0	0	0	138	272	134	0	1610	0.92	569	0.97
		mesotrophic	0	0	0	138	272	134	0	1640	0.93	574	0.98
		oligotrophic	0	0	0	138	272	134	0	1680	0.96	580	0.99
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	139	272	133	0	526	0.16	554	0.43
		mesotrophic	0	0	0	140	274	134	0	693	0.21	677	0.52
		oligotrophic	0	0	0	141	278	137	0	1000	0.30	858	0.65
	MEDIUM (1.7)	eutrophic	0	0	0	141	276	135	0	862	0.26	751	0.62
		mesotrophic	0	0	0	142	277	135	0	991	0.30	817	0.67
		oligotrophic	0	0	0	142	279	137	0	1290	0.39	935	0.76
	LARGE (10.0)	eutrophic	0	0	0	142	278	136	0	2160	0.66	995	0.89
		mesotrophic	0	0	0	142	279	137	0	2230	0.67	1010	0.89
		oligotrophic	0	0	0	142	279	137	0	2460	0.74	1050	0.92

PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
2XCO2 CLIMATE SCENARIO GISS - model

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	105	276	171	0	610	0.89	235	0.87
		mesotrophic	0	0	0	105	276	167	4	608	0.90	229	0.87
		oligotrophic	0	0	0	105	276	150	21	595	0.99	233	0.99
	MEDIUM (1.7)	eutrophic	0	0	0	105	276	171	0	630	0.92	226	0.88
		mesotrophic	0	0	0	105	276	155	16	597	0.96	219	0.94
		oligotrophic	0	0	0	105	276	146	25	583	0.99	218	0.99
	LARGE (10.0)	eutrophic	0	0	0	105	275	169	1	637	0.94	209	0.89
		mesotrophic	0	0	0	105	276	159	12	605	0.95	203	0.92
		oligotrophic	0	0	0	105	276	148	23	589	0.99	202	0.98
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	111	277	166	0	517	0.24	458	0.54
		mesotrophic	0	0	0	112	279	167	0	787	0.36	582	0.69
		oligotrophic	0	0	0	114	280	166	0	1270	0.58	677	0.80
	MEDIUM (1.7)	eutrophic	0	0	0	115	280	165	0	1160	0.54	630	0.80
		mesotrophic	0	0	0	114	280	166	0	1450	0.67	681	0.86
		oligotrophic	0	0	0	114	280	166	0	1760	0.81	694	0.87
	LARGE (10.0)	eutrophic	0	0	0	114	279	165	0	1900	0.88	680	0.94
		mesotrophic	0	0	0	113	279	166	0	1940	0.89	675	0.93
		oligotrophic	0	0	0	113	279	166	0	1970	0.91	648	0.89
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	115	276	161	0	455	0.12	512	0.33
		mesotrophic	0	0	0	115	278	163	0	670	0.17	694	0.44
		oligotrophic	0	0	0	116	281	165	0	1010	0.25	922	0.58
	MEDIUM (1.7)	eutrophic	0	0	0	116	279	163	0	736	0.19	719	0.49
		mesotrophic	0	0	0	117	280	163	0	914	0.23	833	0.57
		oligotrophic	0	0	0	118	282	164	0	1260	0.32	1000	0.68
	LARGE (10.0)	eutrophic	0	0	0	118	282	164	0	1940	0.49	1060	0.79
		mesotrophic	0	0	0	118	282	164	0	2110	0.53	1100	0.82
		oligotrophic	0	0	0	119	283	164	0	2510	0.63	1180	0.87

PROJECTED COOL-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
DIFFERENCIES (GISS - PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd (%)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	-30	10	40	0	99	19	32	16
		mesotrophic	0	-30	9	35	4	83	16	23	11
		oligotrophic	0	-30	9	18	21	68	13	27	13
	MEDIUM (1.7)	eutrophic	0	-30	10	40	0	109	21	30	15
		mesotrophic	0	-30	10	24	16	73	14	23	12
		oligotrophic	0	-29	9	13	25	51	10	19	10
	LARGE (10.0)	eutrophic	0	-30	9	38	1	114	22	29	16
		mesotrophic	0	-30	10	28	12	81	15	23	13
		oligotrophic	0	-30	10	17	23	65	12	22	12
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-26	5	31	0	-78	-13	-7	-2
		mesotrophic	0	-26	5	31	0	-16	-2	39	7
		oligotrophic	0	-24	4	28	0	-40	-3	38	6
	MEDIUM (1.7)	eutrophic	0	-24	7	31	0	-130	-10	50	9
		mesotrophic	0	-24	7	31	0	50	4	80	13
		oligotrophic	0	-24	6	30	0	170	11	66	11
	LARGE (10.0)	eutrophic	0	-24	7	31	0	290	18	111	20
		mesotrophic	0	-25	7	32	0	300	18	101	18
		oligotrophic	0	-25	7	32	0	290	17	68	12
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-24	4	28	0	-71	-13	-42	-8
		mesotrophic	0	-25	4	29	0	-23	-3	17	3
		oligotrophic	0	-25	3	28	0	10	1	64	7
	MEDIUM (1.7)	eutrophic	0	-25	3	28	0	-126	-15	-32	-4
		mesotrophic	0	-25	3	28	0	-77	-8	16	2
		oligotrophic	0	-24	3	27	0	-30	-2	65	7
	LARGE (10.0)	eutrophic	0	-24	4	28	0	-220	-10	65	7
		mesotrophic	0	-24	3	27	0	-120	-5	90	9
		oligotrophic	0	-23	4	27	0	50	2	130	12

WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day)	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	149	256	107	0	392	0.91	162	0.96
		mesotrophic	0	0	0	149	256	107	0	416	0.96	165	0.98
		oligotrophic	0	0	0	149	256	107	0	424	0.98	166	0.98
	MEDIUM (1.7)	eutrophic	0	0	0	149	256	107	0	408	0.94	157	0.97
		mesotrophic	0	0	0	149	256	107	0	423	0.98	159	0.98
		oligotrophic	0	0	0	149	256	107	0	424	0.98	159	0.98
	LARGE (10.0)	eutrophic	0	0	0	149	255	106	0	409	0.96	145	0.98
		mesotrophic	0	0	0	149	255	106	0	421	0.98	146	0.99
		oligotrophic	0	0	0	149	256	107	0	424	0.98	146	0.98
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	154	258	104	0	366	0.27	317	0.60
		mesotrophic	0	0	0	154	259	105	0	524	0.38	388	0.73
		oligotrophic	0	0	0	154	262	108	0	822	0.58	475	0.86
	MEDIUM (1.7)	eutrophic	0	0	0	154	259	105	0	638	0.46	405	0.80
		mesotrophic	0	0	0	154	261	107	0	834	0.59	444	0.87
		oligotrophic	0	0	0	154	261	107	0	1150	0.82	485	0.94
	LARGE (10.0)	eutrophic	0	0	0	154	258	104	0	1180	0.87	437	0.96
		mesotrophic	0	0	0	154	258	104	0	1220	0.89	442	0.97
		oligotrophic	0	0	0	154	258	104	0	1280	0.94	449	0.98
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	154	257	103	0	326	0.13	361	0.36
		mesotrophic	0	0	0	154	259	105	0	455	0.18	468	0.46
		oligotrophic	0	0	0	155	262	107	0	652	0.25	601	0.58
	MEDIUM (1.7)	eutrophic	0	0	0	155	259	104	0	503	0.20	489	0.52
		mesotrophic	0	0	0	155	261	106	0	611	0.24	558	0.58
		oligotrophic	0	0	0	156	263	107	0	812	0.31	660	0.68
	LARGE (10.0)	eutrophic	0	0	0	156	262	106	0	968	0.38	682	0.78
		mesotrophic	0	0	0	156	263	107	0	1050	0.41	708	0.80
		oligotrophic	0	0	0	156	264	108	0	1320	0.50	767	0.86

PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
2XCO2 CLIMATE SCENARIO GISS - model

LAKE CHARACTERISTICS			SURVIVAL			GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCB (day)	SCE (day)	SCL (day)	GSB (day	GSE (day)	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd / Zm*GSL	Vol*jd / A (m day)	Vol*jd / Vtot*GSL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	0	0	126	272	146	0	519	0.88	218	0.95
		mesotrophic	0	0	0	124	273	149	0	572	0.95	230	0.98
		oligotrophic	0	0	0	125	273	148	0	585	0.98	230	0.99
	MEDIUM (1.7)	eutrophic	0	0	0	124	272	148	0	550	0.92	215	0.96
		mesotrophic	0	0	0	124	273	149	0	585	0.98	222	0.99
		oligotrophic	0	0	0	124	273	149	0	596	0.99	223	0.99
	LARGE (10.0)	eutrophic	0	0	0	124	272	148	0	558	0.94	199	0.97
		mesotrophic	0	0	0	124	272	148	0	580	0.97	202	0.99
		oligotrophic	0	0	0	124	272	148	0	588	0.99	202	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	0	0	133	274	141	0	395	0.21	367	0.51
		mesotrophic	0	0	0	134	274	140	0	614	0.34	482	0.68
		oligotrophic	0	0	0	134	275	141	0	992	0.54	601	0.84
	MEDIUM (1.7)	eutrophic	0	0	0	134	274	140	0	684	0.37	484	0.72
		mesotrophic	0	0	0	134	275	141	0	997	0.54	560	0.83
		oligotrophic	0	0	0	135	275	140	0	1480	0.81	629	0.94
	LARGE (10.0)	eutrophic	0	0	0	134	274	140	0	1530	0.83	574	0.93
		mesotrophic	0	0	0	134	274	140	0	1610	0.88	588	0.96
		oligotrophic	0	0	0	133	274	141	0	1720	0.93	603	0.97
DEEP (24.0)	SMALL (0.2)	eutrophic	0	0	0	135	274	139	0	347	0.10	402	0.30
		mesotrophic	0	0	0	135	274	139	0	523	0.16	556	0.41
		oligotrophic	0	0	0	137	275	138	0	768	0.23	729	0.55
	MEDIUM (1.7)	eutrophic	0	0	0	136	274	138	0	508	0.15	530	0.43
		mesotrophic	0	0	0	136	275	139	0	669	0.20	646	0.52
		oligotrophic	0	0	0	137	276	139	0	929	0.28	793	0.63
	LARGE (10.0)	eutrophic	0	0	0	137	276	139	0	1060	0.32	802	0.70
		mesotrophic	0	0	0	137	276	139	0	1190	0.36	851	0.74
		oligotrophic	0	0	0	137	276	139	0	1610	0.48	940	0.82

PROJECTED WARM-WATER FISH SURVIVAL AND GROWTH PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
DIFFERENCIES (GISS - PAST)

LAKE CHARACTERISTICS			SURVIVAL	GROWTH							
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	SCL (day)	GSB (day	GSE (day	GSL (day)	Gzer (day)	Z*jd (m day)	Z*jd (%)	Vol*jd / A (m day)	Vol*jd / A (%)
SHALLOW (4.0)	SMALL (0.2)	eutrophic	0	-23	16	39	0	127	32	56	35
		mesotrophic	0	-25	17	42	0	156	38	65	39
		oligotrophic	0	-24	17	41	0	161	38	64	39
	MEDIUM (1.7)	eutrophic	0	-25	16	41	0	142	35	58	37
		mesotrophic	0	-25	17	42	0	162	38	63	40
		oligotrophic	0	-25	17	42	0	172	41	64	40
	LARGE (10.0)	eutrophic	0	-25	17	42	0	149	36	54	37
		mesotrophic	0	-25	17	42	0	159	38	56	38
		oligotrophic	0	-25	16	41	0	164	39	56	38
MEDIUM (13.0)	SMALL (0.2)	eutrophic	0	-21	16	37	0	29	8	50	16
		mesotrophic	0	-20	15	35	0	90	17	94	24
		oligotrophic	0	-20	13	33	0	170	21	126	27
	MEDIUM (1.7)	eutrophic	0	-20	15	35	0	46	7	79	20
		mesotrophic	0	-20	14	34	0	163	20	116	26
		oligotrophic	0	-19	14	33	0	330	29	144	30
	LARGE (10.0)	eutrophic	0	-20	16	36	0	350	30	137	31
		mesotrophic	0	-20	16	36	0	390	32	146	33
		oligotrophic	0	-21	16	37	0	440	34	154	34
DEEP (24.0)	SMALL (0.2)	eutrophic	0	-19	17	36	0	21	6	41	11
		mesotrophic	0	-19	15	34	0	68	15	88	19
		oligotrophic	0	-18	13	31	0	116	18	128	21
	MEDIUM (1.7)	eutrophic	0	-19	15	34	0	5	1	41	8
		mesotrophic	0	-19	14	33	0	58	9	88	16
		oligotrophic	0	-19	13	32	0	117	14	133	20
	LARGE (10.0)	eutrophic	0	-19	14	33	0	92	10	120	18
		mesotrophic	0	-19	13	32	0	140	13	143	20
		oligotrophic	0	-19	12	31	0	290	22	173	23

APPENDIX E

Fish Survival and Growth Parameters Based on Dissolved Oxygen (only) in 27 Southern Minnesota Lake Classes for Two Climate Scenarios (1955–79 and 2xCO_2 GISS)

DOB - Earliest Julian date when DO at some depth in vertical lake DO profile is lower than the DO survival limit.

DOE - Latest Julian date when DO at some depth in vertical lake DO profile is lower than the DO survival limit.

DOL - Total days between earliest and latest date of DO limitation, i.e. DO at some depth in vertical lake DO profile is lower than the survival limit.

z - Depth where DO is equal to the DO survival limit, or maximum lake depth, if there is no DO limitation on any given day.

zm - Maximum lake depth.

As - Surface area.

Vtot - Total lake volume.

VDO - Volume without DO limitation.

jd - Time step for integration (dt = 1 day).

TL - Total length of simulated season (Mar. 1 - Nov. 30) = 275 days.

z*jd - Integration of depths over time for those depths (m) and time (days) where and when DO at some depth in vertical lake DO profile is larger than the DO survival limit. Integration begins on the first date of the season (March 1) and ends Nov. 30. This is the summation of depths without DO limitation over a season.

$\frac{z*jd}{zm*TL}$ - Previous interpretation normalized by maximum lake depth and length of the entire season TL. Indicates what fraction of the maximum depth is above the DO limitation during the entire season. Range of values from 0 to 1.

$\frac{VDO*jd}{As}$ - Integration of volumes over time for those volumes (m^3) and time (days) where and when DO above some depth in vertical lake DO profile is larger than the DO survival limit. Integration begins on the first date of the season (March 1) and ends Nov. 30. This is the summation of volumes without DO limitation over a season divided by surface area.

$\frac{VDO*jd}{Vtot*TL}$ - Previous interpretation normalized by average depth (Vtot/As) and length of the entire season TL. Indicates what fraction of the total lake volume is available without DO limitation during the entire season. Range of values from 0 to 1.

PROJECTED COLD AND COOL-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			DO limit = 3.0 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	152	245	79	992	0.90	424	0.99
		mesotrophic			0	1100	1.00	429	1.00
		oligotrophic			0	1100	1.00	429	1.00
	MEDIUM (1.7)	eutrophic	186	232	30	1072	0.97	411	1.00
		mesotrophic			0	1100	1.00	412	1.00
		oligotrophic			0	1100	1.00	412	1.00
	LARGE (10.0)	eutrophic			0	1100	1.00	378	1.00
		mesotrophic			0	1100	1.00	378	1.00
		oligotrophic			0	1100	1.00	378	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	124	284	161	2263	0.63	1160	0.84
		mesotrophic	135	281	147	2540	0.71	1247	0.90
		oligotrophic	153	266	114	3023	0.85	1337	0.96
	MEDIUM (1.7)	eutrophic	139	263	125	2705	0.76	1210	0.93
		mesotrophic	151	253	103	2964	0.83	1252	0.96
		oligotrophic	171	233	63	3353	0.94	1295	0.99
	LARGE (10.0)	eutrophic	154	257	100	3115	0.87	1178	0.98
		mesotrophic	185	214	30	3490	0.98	1196	1.00
		oligotrophic			0	3575	1.00	1199	1.00
DEEP (24.0)	SMALL (0.2)	eutrophic	125	308	184	3390	0.51	1864	0.72
		mesotrophic	149	310	162	4016	0.61	2085	0.80
		oligotrophic	200	310	111	5210	0.79	2407	0.93
	MEDIUM (1.7)	eutrophic	135	294	160	4056	0.61	2017	0.82
		mesotrophic	160	294	135	4614	0.70	2153	0.88
		oligotrophic	208	291	84	5667	0.86	2365	0.96
	LARGE (10.0)	eutrophic	147	269	123	4952	0.75	2094	0.93
		mesotrophic	172	264	93	5451	0.83	2159	0.96
		oligotrophic	219	258	40	6348	0.96	2247	1.00

PROJECTED COLD AND COOL-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
2XCO2 CLIMATE SCENARIO GISS-model

LAKE CHARACTERISTICS			DO limit = 3.0 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	71	261	166	822	0.75	412	0.96
		mesotrophic	139	182	10	1092	0.99	429	1.00
		oligotrophic			0	1100	1.00	429	1.00
	MEDIUM (1.7)	eutrophic	124	242	103	950	0.86	406	0.99
		mesotrophic			0	1100	1.00	412	1.00
		oligotrophic			0	1100	1.00	412	1.00
	LARGE (10.0)	eutrophic	147	232	54	1042	0.95	377	1.00
		mesotrophic			0	1100	1.00	378	1.00
		oligotrophic			0	1100	1.00	378	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	73	276	204	1572	0.44	973	0.70
		mesotrophic	86	277	192	1983	0.55	1132	0.82
		oligotrophic	112	275	164	2596	0.73	1280	0.92
	MEDIUM (1.7)	eutrophic	79	274	196	1963	0.55	1079	0.83
		mesotrophic	103	271	169	2393	0.67	1177	0.90
		oligotrophic	131	243	113	3043	0.85	1271	0.97
	LARGE (10.0)	eutrophic	110	266	150	2671	0.75	1139	0.95
		mesotrophic	142	234	85	3202	0.90	1182	0.99
		oligotrophic			0	3575	1.00	1199	1.00
DEEP (24.0)	SMALL (0.2)	eutrophic	83	281	199	2725	0.41	1563	0.60
		mesotrophic	110	283	174	3521	0.53	1886	0.72
		oligotrophic	166	287	122	4872	0.74	2309	0.89
	MEDIUM (1.7)	eutrophic	86	279	194	3082	0.47	1713	0.70
		mesotrophic	120	280	161	3864	0.59	1950	0.79
		oligotrophic	179	280	102	5176	0.78	2269	0.92
	LARGE (10.0)	eutrophic	100	275	176	3788	0.57	1889	0.84
		mesotrophic	135	275	141	4503	0.68	2025	0.90
		oligotrophic	189	274	86	5705	0.86	2201	0.98

PROJECTED COLD AND COOL-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
DIFFERENCES (GISS - PAST)

LAKE CHARACTERISTICS			DO limit = 3.0 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	-81	16	87	-170	-0.15	-12	-0.03
		mesotrophic			10	-8	-0.01	0	0.00
		oligotrophic			0	0	0.00	0	0.00
	MEDIUM (1.7)	eutrophic	-62	10	73	-122	-0.11	-5	-0.01
		mesotrophic			0	0	0.00	0	0.00
		oligotrophic			0	0	0.00	0	0.00
	LARGE (10.0)	eutrophic	147	232	54	-58	-0.05	-1	0.00
		mesotrophic			0	0	0.00	0	0.00
		oligotrophic			0	0	0.00	0	0.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	-51	-8	43	-691	-0.19	-187	-0.14
		mesotrophic	-49	-4	45	-557	-0.16	-115	-0.08
		oligotrophic	-41	9	50	-427	-0.12	-57	-0.04
	MEDIUM (1.7)	eutrophic	-60	11	71	-742	-0.21	-131	-0.10
		mesotrophic	-48	18	66	-571	-0.16	-75	-0.06
		oligotrophic	-40	10	50	-310	-0.09	-24	-0.02
	LARGE (10.0)	eutrophic	-44	9	50	-444	-0.12	-39	-0.03
		mesotrophic	-43	20	55	-288	-0.08	-14	-0.01
		oligotrophic			0	0	0.00	0	0.00
DEEP (24.0)	SMALL (0.2)	eutrophic	-42	-27	15	-665	-0.10	-301	-0.12
		mesotrophic	-39	-27	12	-495	-0.08	-199	-0.08
		oligotrophic	-34	-23	11	-338	-0.05	-98	-0.04
	MEDIUM (1.7)	eutrophic	-49	-15	34	-974	-0.14	-304	-0.12
		mesotrophic	-40	-14	26	-750	-0.11	-203	-0.09
		oligotrophic	-29	-11	18	-491	-0.08	-96	-0.04
	LARGE (10.0)	eutrophic	-47	6	53	-1164	-0.18	-205	-0.09
		mesotrophic	-37	11	48	-948	-0.15	-134	-0.06
		oligotrophic	-30	16	46	-643	-0.10	-46	-0.02

PROJECTED WARM-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
PAST PERIOD 1955 - 1979

LAKE CHARACTERISTICS			DO limit = 2.5 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	153	245	61	1032	0.94	426	0.99
		mesotrophic			0	1100	1.00	429	1.00
		oligotrophic			0	1100	1.00	429	1.00
	MEDIUM (1.7)	eutrophic	190	224	9	1093	0.99	412	1.00
		mesotrophic			0	1100	1.00	412	1.00
		oligotrophic			0	1100	1.00	412	1.00
	LARGE (10.0)	eutrophic			0	1100	1.00	378	1.00
		mesotrophic			0	1100	1.00	378	1.00
		oligotrophic			0	1100	1.00	378	1.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	126	283	158	2300	0.64	1172	0.84
		mesotrophic	136	280	145	2572	0.72	1254	0.90
		oligotrophic	156	263	108	3063	0.86	1341	0.97
	MEDIUM (1.7)	eutrophic	141	261	121	2759	0.77	1219	0.93
		mesotrophic	153	252	100	3003	0.84	1257	0.96
		oligotrophic	175	230	56	3394	0.95	1298	0.99
	LARGE (10.0)	eutrophic	155	249	94	3205	0.90	1183	0.99
		mesotrophic	190	210	19	3535	0.99	1198	1.00
		oligotrophic			0	3575	1.00	1199	1.00
DEEP (24.0)	SMALL (0.2)	eutrophic	127	308	182	3460	0.52	1890	0.73
		mesotrophic	152	309	158	4103	0.62	2108	0.81
		oligotrophic	206	310	105	5320	0.81	2427	0.93
	MEDIUM (1.7)	eutrophic	137	293	157	4141	0.63	2041	0.83
		mesotrophic	163	293	131	4705	0.71	2173	0.88
		oligotrophic	214	290	77	5780	0.88	2379	0.97
	LARGE (10.0)	eutrophic	149	268	120	5037	0.76	2108	0.93
		mesotrophic	175	262	88	5548	0.84	2171	0.96
		oligotrophic	226	255	30	6442	0.98	2251	1.00

PROJECTED WARM-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
2XCO2 CLIMATE SCENARIO GISS-model

LAKE CHARACTERISTICS			DO limit = 2.5 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW	SMALL	eutrophic	73	251	145	873	0.79	416	0.97
(4.0)	(0.2)	mesotrophic	149	151	3	1099	1.00	429	1.00
		oligotrophic			0	1100	1.00	429	1.00
	MEDIUM	eutrophic	134	241	88	1001	0.91	408	0.99
	(1.7)	mesotrophic			0	1100	1.00	412	1.00
		oligotrophic			0	1100	1.00	412	1.00
	LARGE	eutrophic	148	224	13	1089	0.99	378	1.00
	(10.0)	mesotrophic			0	1100	1.00	378	1.00
		oligotrophic			0	1100	1.00	378	1.00
MEDIUM	SMALL	eutrophic	74	276	203	1605	0.45	991	0.71
(13.0)	(0.2)	mesotrophic	87	276	190	2033	0.57	1141	0.82
		oligotrophic	115	275	161	2627	0.73	1285	0.93
	MEDIUM	eutrophic	80	274	195	2028	0.57	1095	0.84
	(1.7)	mesotrophic	106	269	164	2453	0.69	1186	0.91
		oligotrophic	134	242	109	3083	0.86	1275	0.97
	LARGE	eutrophic	112	252	141	2768	0.77	1148	0.96
	(10.0)	mesotrophic	147	213	67	3281	0.92	1186	0.99
		oligotrophic			0	3575	1.00	1199	1.00
DEEP	SMALL	eutrophic	84	280	197	2787	0.42	1591	0.61
(24.0)	(0.2)	mesotrophic	113	282	170	3596	0.54	1913	0.74
		oligotrophic	172	285	114	5008	0.76	2336	0.90
	MEDIUM	eutrophic	87	278	192	3141	0.48	1739	0.71
	(1.7)	mesotrophic	123	278	156	3961	0.60	1975	0.80
		oligotrophic	184	280	97	5285	0.80	2290	0.93
	LARGE	eutrophic	103	275	173	3867	0.59	1913	0.85
	(10.0)	mesotrophic	139	274	136	4613	0.70	2044	0.91
		oligotrophic	196	274	79	5830	0.88	2212	0.98

PROJECTED WARM-WATER FISH DO LIMITATION PARAMETERS IN SOUTHEREN MINNESOTA LAKES (REGIONAL ANALYSIS)
DIFFERENCES (GISS - PAST)

LAKE CHARACTERISTICS			DO limit = 2.5 (mg/l)						
MAXIMUM DEPTH (m)	SURFACE AREA (km2)	TROPHIC STATUS	DOB (day)	DOE (day)	DOL (days)	Z*jd (m day)	Z*jd / Zm*TL	VDO*jd / As (m day)	VDO*jd / Vtot*TL
SHALLOW (4.0)	SMALL (0.2)	eutrophic	-80	6	84	-159	-0.15	-10	-0.02
		mesotrophic			3	-1	0.00	0	0.00
		oligotrophic			0	0	0.00	0	0.00
	MEDIUM (1.7)	eutrophic	-56	17	79	-92	-0.08	-4	-0.01
		mesotrophic			0	0	0.00	0	0.00
		oligotrophic			0	0	0.00	0	0.00
	LARGE (10.0)	eutrophic	148	224	13	-11	-0.01	0	0.00
		mesotrophic			0	0	0.00	0	0.00
		oligotrophic			0	0	0.00	0	0.00
MEDIUM (13.0)	SMALL (0.2)	eutrophic	-52	-7	45	-695	-0.19	-181	-0.13
		mesotrophic	-49	-4	45	-539	-0.15	-113	-0.08
		oligotrophic	-41	12	53	-436	-0.13	-56	-0.04
	MEDIUM (1.7)	eutrophic	-61	13	74	-731	-0.20	-124	-0.09
		mesotrophic	-47	17	64	-550	-0.15	-71	-0.05
		oligotrophic	-41	12	53	-311	-0.09	-23	-0.02
	LARGE (10.0)	eutrophic	-43	3	47	-437	-0.13	-35	-0.03
		mesotrophic	-43	3	48	-254	-0.07	-12	-0.01
		oligotrophic			0	0	0.00	0	0.00
DEEP (24.0)	SMALL (0.2)	eutrophic	-43	3	47	-437	-0.13	-35	-0.03
		mesotrophic	-43	3	48	-254	-0.07	-12	-0.01
		oligotrophic	0	0	0	0	0.00	0	0.00
	MEDIUM (1.7)	eutrophic	-50	-15	35	-1000	-0.15	-302	-0.12
		mesotrophic	-40	-15	25	-744	-0.11	-198	-0.08
		oligotrophic	-30	-10	20	-495	-0.08	-89	-0.04
	LARGE (10.0)	eutrophic	-46	7	53	-1170	-0.17	-195	-0.08
		mesotrophic	-36	12	48	-935	-0.14	-127	-0.05
		oligotrophic	-30	19	49	-612	-0.10	-39	-0.02