Projected responses of selected limnological variables for the freshwater lakes of the Nelson and Great Lakes-St Lawrence drainages to forecast changes in climate conditions during the 21st century

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Projected responses of selected limnological variables for the freshwater lakes of the Nelson and Great Lakes-St Lawrence drainages to forecast changes in climate conditions during the 21st century

by

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ABSTRACT

To better understand the impact of climate change on Canadian lakes and fish species, the Canadian Lake Assessment Model (CLAM) was used to forecast changes in lake ice phenology and the timing and hatching success of seven fish species at the secondary watershed level in the St. Lawrence and the Nelson River drainage. Our projections were based on four global climate models (GCMs) under two alternate greenhouse gas emission scenarios. Three future time periods (2011-2040, 2041-2070, 2071-2100) were considered and compared with the averaged baseline climate conditions from 1971-2000. This report mainly focused on the 2041-2070 period under the A2 emission scenario. For the St. Lawrence River drainage, the mean average air temperature is projected to increase by 1.9 to 3.9 °C, the duration of ice cover will be reduced by 5 to 23 days and the maximum ice thickness will decrease by 2.1 to 10.7 cm. For the Nelson River drainage, the mean average air temperature is projected to increase by 1.4 to 4.0 °C, the duration of ice cover will be reduced by 0 to 19 days and the maximum ice thickness will decrease by 0 to 9 cm. The biotic response of fish species in both the St. Lawrence and the Nelson River drainages are similar. For fall spawning fish species, if we assume spawning is temperature dependent, the spawning and subsequent hatching dates will be delayed by up to 3 weeks. If we assume spawning is time dependent, the hatching date may be earlier by a month. For spring spawning species, under the assumption that spawning is temperature dependent, the spawning and hatching date is 1 to 6 days earlier. Under the assumption that spawning is time dependent, spawning and hatching date is slightly earlier by 1 to 4 days, but there may be large reductions (10-50%) in hatching success. The projections made in this report should provide a useful tool in the management and risk-assessment of two important Canadian watersheds.

RÉSUMÉ

Afin de mieux comprendre l'impact des changements climatiques sur les lacs et les espèces de poissons du Canada, on a utilisé le modèle canadien d’évaluation des lacs pour prévoir les changements dans la phénologie des glaces de lac, le moment et le succès de l’éclosion pour sept espèces de poissons à l’échelle des bassins secondaires dans les bassins versants du Saint-Laurent et du fleuve Nelson. Nos projections reposaient sur quatre modèles climatiques mondiaux selon deux scénarios différents d’émissions de gaz à effet de serre. Trois périodes à venir ont été prises en compte (2011-2040, 2041-2070, 2071-2100) et comparées à la valeur de référence moyennée des conditions climatiques de 1971-2000. Le rapport est principalement axé sur la période 2041-2070 selon le scénario d’émissions A2. Pour le bassin hydrographique du Saint-Laurent, la moyenne de la température moyenne de l’air devrait augmenter de 1,9 °C à 3,9 °C, la durée de la couverture de glace sera réduite de 5 à 23 jours et l’épaisseur maximale de la glace diminuera de 2,1 cm à 10,7 cm. Pour le bassin versant du fleuve Nelson, la moyenne de la température moyenne de l’air devrait augmenter de 1,4 °C à 4,0 °C, la durée de la couverture de glace sera réduite de 0 à 19 jours et l’épaisseur maximale de la glace diminuera de 0 cm à 9 cm. La réaction biotique des espèces de poissons dans les deux bassins hydrographiques est similaire. En ce qui concerne les espèces de poissons frayant à l’automne, si nous supposons que le frai est dépendant de la température, les dates de frai et ensuite de l’éclosion des œufs pourraient être retardées de trois semaines. Si nous supposons que le frai se fait en fonction du temps, le moment de l’éclosion pourrait être devancé d’un mois. Pour les espèces qui fraient au printemps, en posant comme hypothèse que le frai dépend de la température, le frai et l’éclosion interviendraient de 1 à 6 jours plus tôt. En partant de l'hypothèse que le frai dépend du temps, le frai et l’éclosion seraient légèrement avancés de 1 à 4 jours, mais il pourrait y avoir d’importantes diminutions du succès de l’éclosion (de 10 à 50 %). Les projections faites dans ce rapport devraient constituer un outil utile pour la gestion et l'évaluation axée sur les risques de deux importants bassins versants du Canada.

INTRODUCTION

Under a renewed five-year (2011-2016) Canadian Climate Adaptation Program involving five federal departments (Natural Resources Canada – NRCAN, Environment Canada – EC, Aboriginal Affairs and Northern Development Canada – AANDC, Parks Canada – PC, and Fisheries and Oceans Canada – DFO) DFO has the “Aquatic Climate Change Adaptation Services Program” (ACCASP) which has three primary components:

- Development of eco-region risk assessments to identify key vulnerabilities to climate change.
- Scientific research projects to increase understanding of impacts.
- Development of pilot projects and tools for adaptation.

There is also a secondary component concerned with outreach and evaluation.

Four eco-regions are being examined in the risk assessments: three oceanic regions bordering Canada (Atlantic, Arctic, and Pacific), and the interior freshwater resources, including all lakes and rivers. Following preparatory and background reviews in 2011-2012 preliminary eco-region risk assessments were conducted in 2012-2013 to focus and direct ACCASP efforts on all three primary components with fuller assessments to be conducted in 2015-2016. These risk assessments are a follow-up to the 2005 National Climate Change Risk Assessment (Interis Consulting Inc. 2006). Much of the ecological framework for the aquatic eco-region risk assessments was developed earlier (Minns and Wilson 2005).

This report presents the lacustrine part of the preliminary (2012-2013) freshwater eco-region risk assessment which focuses on the lake resources in the Nelson River drainage (primary watershed, PWS, 05) and the Great Lakes-St. Lawrence drainage (PWS 02) (Figure 1).

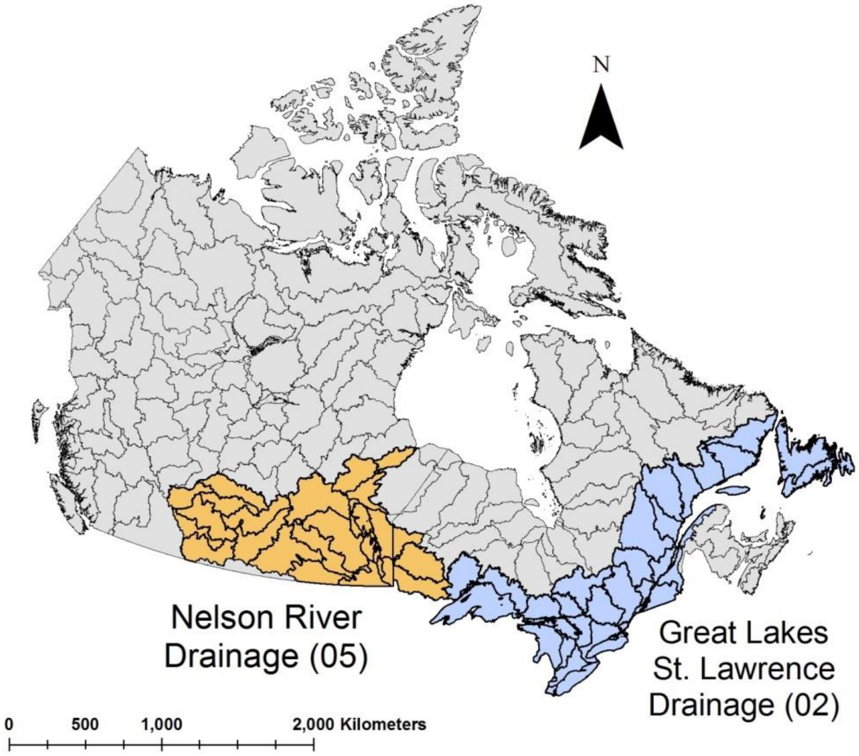


Figure 1. A map of the secondary watershed basins of Canada with those in the primary Nelson River (05) and Great Lakes-St. Lawrence River (02) drainages highlighted.

These two primary watersheds were chosen as representative samples for all of the lake resources across Canada.

Lakes are important integrators, regulators and sentinels of the cumulative impacts of climatic and landscape changes (Williamson et al. 2009). Lakes integrate the combined effects of cumulative landscape and climate changes. Lakes are a major pathway in the global carbon cycle, retaining more carbon than all the oceans, and hence have a key role in regulating CO2 levels in the atmosphere. Lakes also have a feedback role with respect to local climate, especially in regions with large lakes such as are found across the Canadian Boreal-Taiga ecozones. Lakes are valuable sentinels as they provide a wide array of physical, chemical and biological indicators reflecting both accumulated changes in their landscape and climate context and in the lakes themselves.

Canada has extensive lake resources (Minns et al. 2008) which represent a large share of the global supply (Minns and Moore 1995). Minns (2009) estimated that Canada has ≈900,000 lakes (with an area ≥ 0.1 km^2) with a combined area of ≈570,000 km^2. Of those lakes, 562 have an area ≥ 100 km^2 accounting for about half of the total lake area. Beyond the lakes here are extensive wetlands. A large majority of these freshwater resources are located on the Boreal-Taiga regions of the country, including much of the two primary watersheds (02 and 05) which are the focus of this report.

The potential impacts of climate change, especially warming, on freshwater ecosystems have received considerable attention in the literature. There are global reviews by Hickling et al. (2006), Schindler (2009), and Ficke (2007). For North America, there are reviews by Magnuson et al. (1997) and Schindler (1997). More locally there are reviews by Poff et al. 2002 for U.S.A.; Mooij et al. 2005 for the Netherlands; Schindler 2001 for Canada; Kling et al. 2003 for the St. Lawrence Great Lakes) and impacts are expected to be among the most significant among all ecosystem types. Given that climate change effects occur, the mechanisms of impact on fish and other biota are relatively well understood, e.g., Portner (2002), Mehner et al. (2011) and Shuter et al. (2012) and climate change is impacting many aspects of aquatic research already (Pettoreli et al. 2012). However, the expected net outcomes of climate change impinging on many causal pathways have not often been integrated cumulatively across large spatial and temporal scales. Minns and Moore (1992) presented a preliminary assessment of the impact of warming of fisheries production in lakes with extensions by Chu et al (2003) for freshwater fish diversity considering other human stressors and by Minns (2009) for fisheries production considering both increased human development impacts and species distribution changes.

Shuter and Meisner (1992) developed a framework for assessing the impacts of climate change on freshwater fish. Their framework was centred on two ideas drawn from F.E.J. Fry’s work on thermal ecology: a) The “metabolic scope for activity” of a fish is shaped by its past and present environmental history, and b) That some environmental factors are directive, in that fish recognize spatial variation in those factors and selected preferred levels of those factors. That framework is implicitly addressed in the projections developed in this study, albeit incompletely at present.

The assessment took as a starting point recent, observed climate norms and a range of projected climate conditions derived from a series of global climate models (GCMs) using alternate future emission scenarios. A selection of available models was used to project some key abiotic features of lakes and, in turn, to project some key indicators of the performance of biotic responses in lakes, in particular for fishes and fishery resources. Both primary (spawning success, egg development rate and mortality, adult growth and mortality rates) and secondary (population persistence/success, species distributions and potential lake fisheries yield) biotic responses of fishes have been considered. Here, primary effects are considered to be those where climate or abiotic conditions directly affect life history processes while secondary effects are considered to be those that arise as a consequence of the outcomes for individual species or the interactions among species. For this preliminary assessment, two additional components have not been examined explicitly: the responses of non-fish biota (i.e., plankton, benthos, and vegetation) and the social and economic responses of the users of the fishery resources.

Following a description of the methodology used to make projections for abiotic and fish biotic responses in lakes, results are presented by primary watershed area (PWS 02 and then PWS 05). As the results are only preliminary discussion is focused on: the identifiable gaps and limitations; the potential for expansion and improvements; and research needed to reduce the uncertainty and risk in future projections for Canadian lacustrine fishery resources.

MATERIALS AND METHODS

The methodology will be provided in detail for the climate and lake databases used and the models deployed in this work. Canadian Lakes Assessment Model (CLAM) provides the basic lake framework for this study (Minns et al 2008). Climate norms and scenarios were drawn from the NRCAN-CFS website. Models were drawn from ongoing work by Minns, Shuter and associates as well as from published literature and reports.

1. LAKE RESOURCES

The database assembled for the CLAM (Minns et al 2008; Minns 2011) have been drawn on in this study. CLAM contains estimates by secondary watershed unit of the numbers of lakes in a series of lake classes with area intervals at 0.1, 0.2, 0.5, 1, 2, 5, 10, 20, 50 and 100 km^2 (Minns et al 2008). For large lakes with areas ≥ 100 km^2 a complete inventory has been assembled and the lakes assigned to a watershed unit (Minns 2011). Typical characteristics of the lakes (maximum depth, mean depth, Secchi depth) have been determined for the average lake in each watershed by size interval group or individually for large lakes. In addition, characteristic watershed values for variables such as total dissolved solids (mg/l), and pH, have been estimated. The CLAM database is used to provide estimates of the size of lake resources for all secondary watersheds in the two target areas.

Chu et al (2003) developed a stress index assessment for fishes in all Canadian tertiary watershed units. The data used in that study has been used to assemble a first order assessment of fish species presence-absence patterns by secondary watershed in the two target areas.

2. CLIMATE

The Canadian Forest Service (CFS; Natural Resources Canada) applied spatial extrapolation methods to estimate climate values by geographic location with allowance for elevation above sea level. These methods have been applied to both observations of climate and the output from climate simulations for a range of GCMs (McKenney et al. 2011). We extracted the 1971-2000 and 1961-1990 climate norms data from the CFS website (http://cfs.nrcan.gc.ca/projects/3) for the centroids of each secondary watershed for all of Canada. For future climates, we extracted the 30-year averages for three future time periods (2011-2040, 2041-2070, and 2071-2100) for each of two greenhouse gas emission scenarios (A2 and B1) from each of four GCMs described by McKenney et al. (2011):

1) Canadian General Circulation Model (CGCM3.1)
2) Commonwealth Scientific and Industrial and research Organization (CSIRO3.5)
3) National Centre for Atmospheric Research (NCARCCSM3.0)
4) Japanese Center for Climate System Research (MIROC3.2)

The A2 scenario anticipates global atmospheric CO2 equivalents reaching 1,320 ppm by 2100 while the B1 scenario is more conservative and anticipates a level of 915 ppm. The monthly mean minimum and maximum temperatures at 2 m aboveground were averaged to estimate the monthly daily mean temperatures.

The data, separately for each GCM-scenario combination by time period, were then used to estimate the spring and fall 31-day running mean 0 °C dates based on linear interpolation between the mean monthly mid-points. This method leads to small underestimates of the values obtained using daily temperatures; comparison with the observations assembled by Bonsal and Prowse (2003; original data provided by Barrie Bonsal, NWRI, Environment Canada, Saskatchewan) showed the correlations for both spring and fall 0 °C isotherm dates were 0.973, with the spring dates underestimated by about 0.4 days on day 100 (April 10) and the fall dates underestimated by about 1.7 days on day 300 (October 27). The solar elevations were computed using a standard algorithm (Michalsky 1988) recoded in R (R Development Core Team 2008) and checked against a NASA website tool (www.esrl.noaa.gov/gmd/grad/solcalc).

3. ABIOTIC LAKE MODELS

Ice Regime

On and off dates and the durations of ice cover and open water

Shuter et al*.* (2013) have developed empirical models to predict the timing of ice on and ice off in Canadian lakes. Similar models have been used to project future ice dates for Ontario's fishery management zones (Minns et al. 2012. These models generate projected changes similar to those obtained by Dibike et al. (2011) using a detailed physics-based model for the northern hemisphere. The models were developed using both historical records of ice dates from 44 lake sites across Canada and validated ice dates obtained via remote sensing from 150 of Canada's large lakes (≥100 km2) in 2001 to 2003 using methods described by Latifovic and Pouliot (2007).

The models are as follows:

Ice on (freeze up, Julian date):

$= 58.09 + 7.29 * Z_{Mean}^{0.5} + 0.83 * Zero_{Fall} + 0.94 * T_{ZeroFQ}$ ($R^2 = 0.69$, N=162) (Eqtn. 1),
where: Z_{Mean} is lake mean depth (m), $Zero_{Fall}$ is the Julian date when the 31-day running average air temperature last drops below 0°C in the fall, and T_{ZeroFQ} is the mean air temperature °C for the three months centred on the month when $Zero_{Fall}$ occurs.

Ice off (break up, Julian date):

$= 175.83 - 2.95 * SOEL_{Spr} + 1.26 * Zero_{Spr} + 0.00094 * Area + 0.49 * Long + 0.017 * Elev$ ($R^2 = 0.94$, N= 139),

where $SOEL_{Spr}$ is the solar elevation at local noon on the $Zero_{Spr}$ date, $Zero_{Spr}$ is the Julian date when the 31-day running average air temperature last rises above 0°C in the spring, Area is lake area (km^2), Long is negative decimal degrees of longitude at the site, and Elev is the elevation above sea level at the site (m).

The duration of ice cover is computed from the differences between ice-on (freeze-up) and ice-off (break-up) dates and the duration of open water is computed as 365 minus the duration of ice cover.

These models were used to generate projections for two sizes of lakes, one with area and mean depth set to 0 and another with an area of 100 km2 and a mean depth of 20 m. The assessment of projected change is based mainly on computing the difference between two climate periods, therefore the 1971-2000 normals by secondary watershed and by each combination of GCM and emission scenario and future time period, the effect of lake size drops out of the analyses in most instances.

For a few selected lakes that were among the historical database for ice dates and were located within the target primary watershed areas, lake specific models were used to project future ice dates.

Ice thickness

In many of the lakes where ice on and off dates were monitored historically, ice thickness was also measured frequently during the period of ice cover. With these data Minns et al (2012) developed a preliminary model to predict maximum ice thickness (cm):

Ln(maximum ice thickness, cm):

= -3.97 + 0.80*Ln(Duratn) + 1.10*Ln(Lat) (R^2 = 0.66, N= 374, rmse = 0.224), where Ln() indicates natural logarithms, Duratn is the duration of ice cover (days) and Lat is latitude in degrees. This equation was used with a bias correction (Sprugel 1983) for the log-transformation to project changes in ice thickness.

Surface Water Temperature

Peak summer surface water temperature and its timing

Minns et al. (unpublished results) used remotely sensed surface temperatures from many of the over 550 of Canada's large lakes (area ≥ 100 km^2) during open water seasons in the years 2001 and 2002 to develop an empirical model of peak summer temperatures and their timing:

Peak surface temperature (°C):

= 22.62 - 1.39*Ln(Area) + 1.01*Ln(Peri) - 0.63*Lat + 0.0034*Lat^2 - 0.45*Lon - 0.0022*Lon^2 + 0.10* Tjul + 0.36*Tann - 0.60* Pann (R^2= 0.69, N= 824),

Timing of peak temperature (Julian days):

= 429.32 + 5.68*Ln(Area) – 5.52*Ln(Peri) – 7.79*Lat + 0.069*Lat^2 - 0.00021*Lon^2 + 0.65* Tjul – 1.17*Tjja + 0.60* Pjul (R^2= 0.39, N= 824),

where Ln() indicates natural logarithms, Area is lake area (km^2), Peri is lake perimeter (km), Lat and Long are latitude and longitude (decimal degrees), Tjul, Tjja and Tann are mean July, summer (June-August) and annual air temperatures (°C), and Pjul and Pann are mean July and annual precipitation rates (mm/d). The peak temperature model predicts values that lie between the estimates obtained in two models reported by Sharma et al. (2007) based primarily on observations from small lakes. The timing of the peak lags behind the peaks seen in the solar cycle and the surface air temperature (Stine et al 2009). The lake size variables and the geographic coordinates are fixed effects. Peak surface temperatures generally rise about 0.5 °C for every 1 °C in air temperature (Sharma et al. 2007). When the mean summer temperature rises more than the July temperature the peak occurs earlier. Higher precipitation can reduce the peak temperature and delay its arrival.

4. BIOTIC LAKE MODELS

Spawning, Egg Development and Adult Growth

Using the peak summer temperature and its timing, along with the projected dates of ice freeze up and break up, we projected an annual profile of mean daily temperatures for each watershed and each climate dataset. This profile is then used to project the spawning date, hatching date, hatching success and the length of the growth period for seven fish species. Figures 2 and 3 show schematics for fish species that spawns in the fall and spring respectively.

The growth period was defined to be the number of days where the daily mean temperature is within two degrees of the species' Final Temperature Preferendum (FTP). The growth period must be greater than zero for a species to be classified as viable in a particular secondary watershed.

The spawning date under the 1971-2000 climate norms was the Julian day where the mean daily temperature is equal to the optimal spawning temperature (OST) of the fish species. Data for the OST was obtained from Casselman 2002. We defined two scenarios for spawning in future periods. The first is the temperature dependent scenario where spawning occurs on a new date determined by the timing of the OST in the future. The second is time dependent where the fish spawns on the same date as they did under historical conditions. We calculated spawning date, hatching date and hatching success for both scenarios.

The hatching date is determined by using an extension of the egg development model presented in Shuter and Post (1990):

Development Time (DT) = $CDEV*e^{-EPDEV*T}$

where DT is time in days, CDEV and EPDEV are species-specific constants in the larval development curve and T is temperature. We assumed the amount of development on any particular day is equal to 1/DT where the DT on the given day is calculated using that day's mean temperature. The amount of egg development is accumulated until $\sum 1/DT = 1$ where development is complete and hatching occurs. With the exception of Smallmouth Bass and Yellow Perch whose species specific constants were given in Shuter and Post (1990), data for estimating the constants CDEV and EPDEV for the other five fish species were obtained from Allen et al. (2005), Baird et al. (2002), Brooke (1975), Casselman (1995), Dwyer (1987), Ivan et al. (2010), Price (1940), Swift (1965) and Teletchea et al. (2009). For fall spawning species whose eggs develop over the winter period under the ice cover, we assumed there will be refuges where the water temperature will not drop below 2°C. The species-specific larval development constants are tabulated in table 1 along with FTP and OST obtained from Hasnain et al. (2010).

Hatching success is similarly calculated by accumulating daily egg survival. The daily egg survival is equal to the daily development (1/DT) multiplied by the daily egg survival rate. This daily egg survival amount is summed up over the entire development period. Daily egg survival rate is determined by the daily mean temperature via a trapezoid shaped model. Below 1 °C, the survival rate is 0. Survival rate increases linearly from 1 °C until it reaches 1 at 2.5 °C where it stays until the temperature increases to OST+2 °C. After OST+2 °C, the survival rate decreases linearly until it reaches 0 at OST+4 °C and remains at 0 at higher temperature. Figure 4 is a graphical representation of this trapezoid model.

Distribution

Chu et al (2003) presented a Canada-wide assessment of freshwater fish species diversity, climatic conditions, and the accumulated stress of human development by tertiary watershed unit. The species occurrences by tertiary watershed were summarized by secondary watershed and the species*secondary watershed table ordered by the frequency of occurrence in watersheds. Then the columns of the table (watersheds) were sorted from low to high by the 1961-1990 norms mean annual air temperature; the earlier norms period was used as that was the period when most of these species occurrences were recorded. The resultant table was used to identify candidate species distribution changes,

Production

Potential sustainable yield (total)

Minns (2009) used Schlesinger and Regier's (1982) model of sustainable fish yield in lakes to project future potential yield for all Canadian lakes. The Schlesinger and Regier model has inputs of mean lake depth (m), total dissolved solids (mg/l) and mean annual air temperature (°C). Here, again using the CLAM database, potential sustainable fish yields were estimated for all size ranges of lakes by secondary watershed for the 1971-2000 climate norms period and for all combinations of future time period, GCMs, and emission scenarios. The potential effects, of worsening watershed conditions due to human development and of a lack of species adaptation in the fish communities supporting yield, examined in Minns (2009) were not considered here.

The potential sustainable yields were summed by watershed and changes from the 1971-2000 norms values in future time periods expressed as percentage changes. By future time period and emission scenario, the minimum and maximum percentage changes were estimated by secondary watershed.

Potential sustainable yield (selected species)

Schlesinger and Regier (1983) described dome-shaped potential yield curves in relation to mean annual air temperature (MAAT) for three important fishery species: Lake Whitefish (*Coregonus clupeaformis*), Northern Pike (*Esox lucius*), and Walleye (*Sander vitreus*) with optima occurring at roughly -1.0, 1.5, and 2.0 °C respectively. These results were roughly adapted here to provide indications as to whether yields might be expected to increase, decrease, or remain unchanged with regard to project future climate conditions relative to the 1971-2000 norms.

Using Magnuson et al.'s (1979) observation that fish have optimal performance metrics with respect to temperature within a window of ± 2 °C, a simple three-part model of species-level change in response to warming can be specified with boundaries at optimum – 2 °C and optimum +2 °C to give three categories: Up, Nil and Down respectively. Below the plateau (Nil) there is a rising level of yield versus 1971-2000 MAAT (Up) and above the plateau there is a declining level of yield versus 1971-2000 MAAT (Down). Then the projected MAAT for any given future time period can be applied in the same way. The nine combinations of Up, Nil or Down ratings show the projected direction of change in fishery yield (Table 2).

Scope of the Results

Projections were computed for all Canadian secondary watersheds but only the results for the Great Lakes-St. Lawrence R. drainage (02) and the Nelson R. drainage (05) are covered in this report. Using the 1971-2000 climate norms as a reference point climate projections were used from the simulations of four GCMs in three future time periods (2011-2040, 2041-2070, and 2071-2100) under two emission scenarios, A2 and B1. In most instances the results that follow focus on the minima and maxima for the four GCMs under the A2 scenario in the 2041-2070 period which are taken to represent a mid-century view given the current trajectory of emissions.

The results are presented in two sections: A) The Great Lakes-St. Lawrence River drainage (02) watersheds; and B) The Nelson River drainage (05) watersheds.

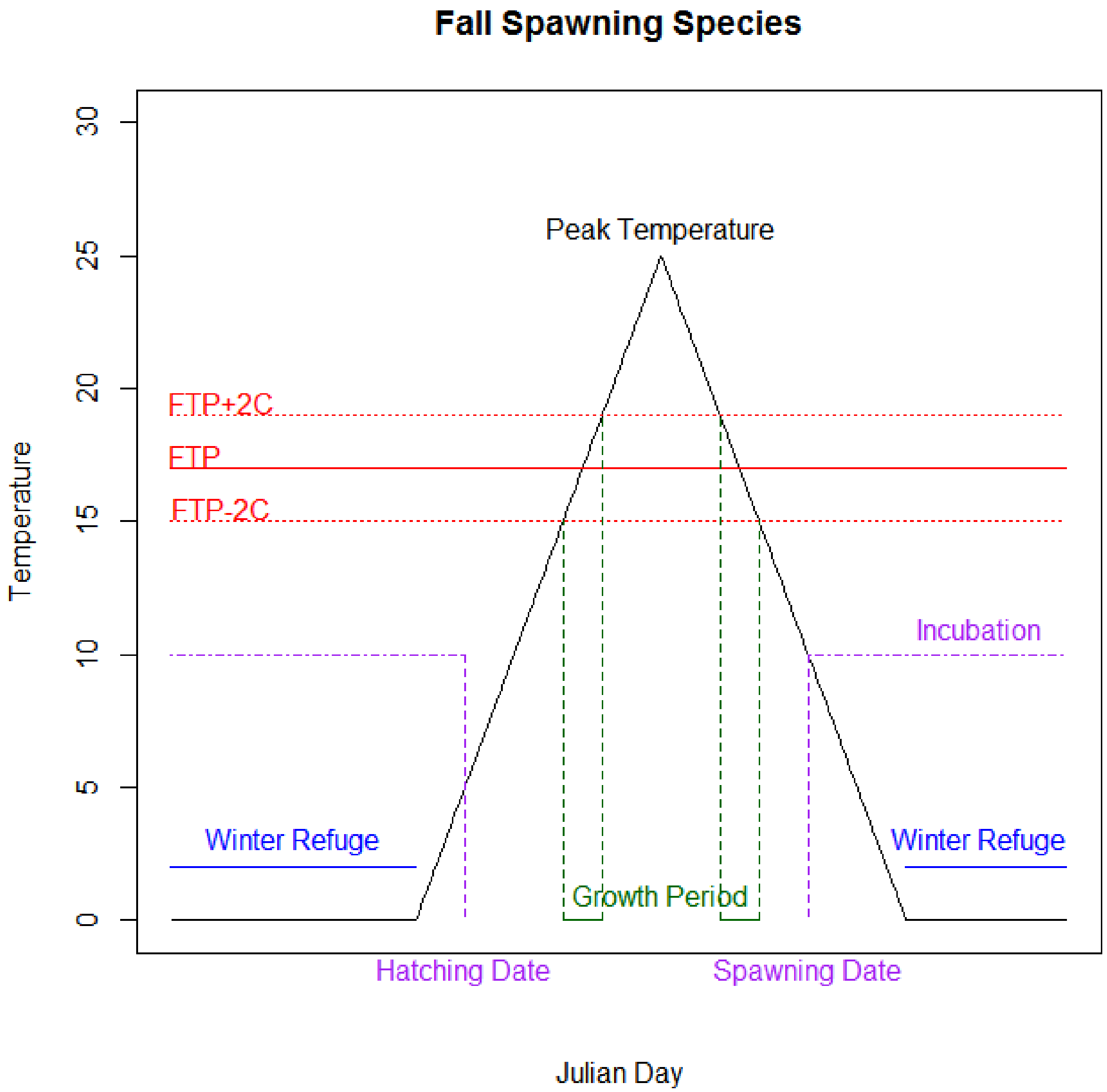


Figure 2. Graphical representation of a fall spawning species. The summer growth period is the number of days where the temperature is within 2 °C of the Final Temperature Preferendum (FTP). The fish spawns in the fall and the eggs incubate over the winter and hatches in the spring. We assume the existence of winter refuges which provide a minimum of 2 °C water temperature under the ice cover during the winter.

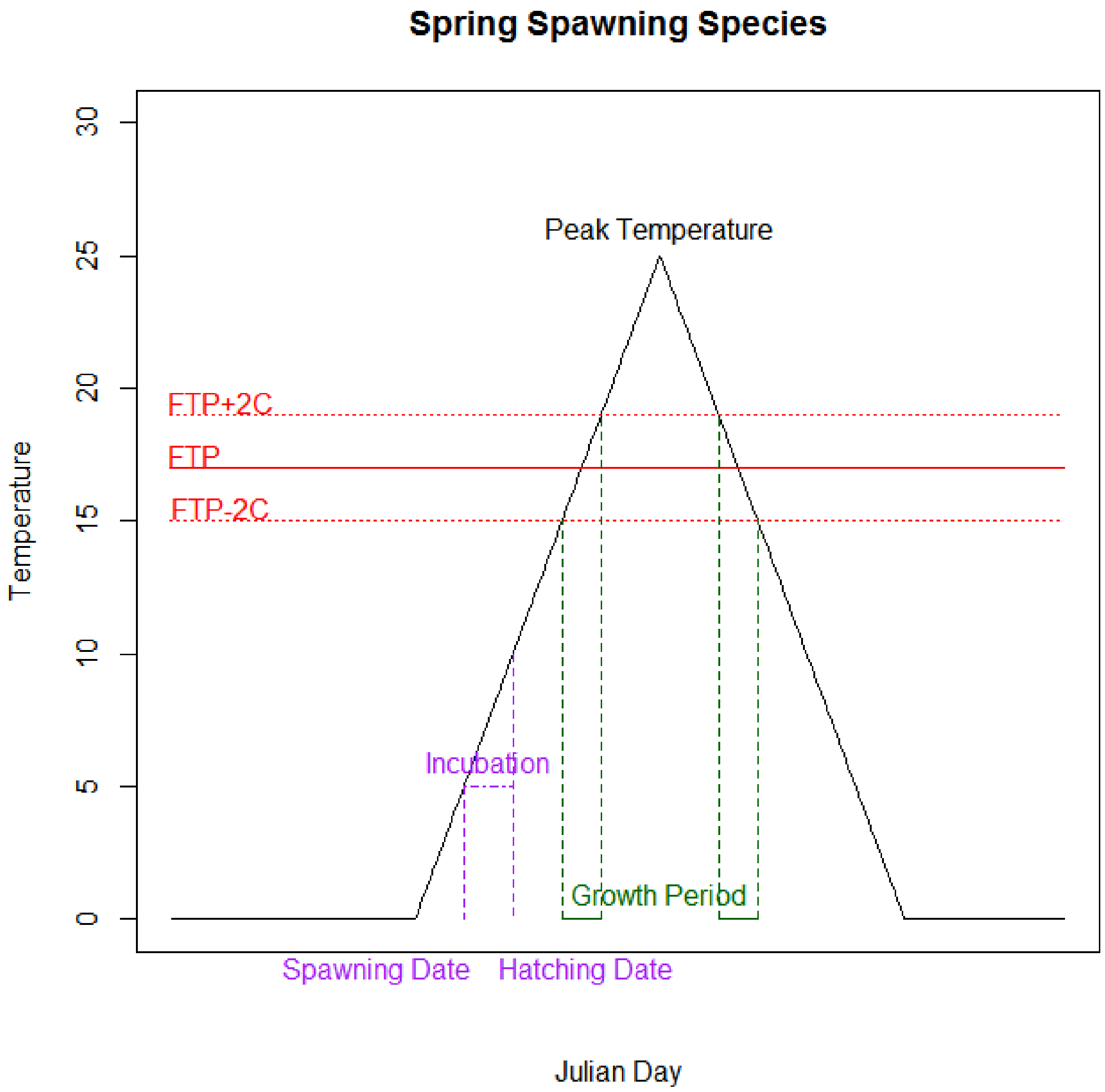


Figure 3. Graphical representation of a spring spawning species. The summer growth period is the number of days where the temperature is within 2 °C of the Final Temperature Preferendum (FTP). The fish spawns in the spring and the eggs incubate quickly and hatch a short while after.

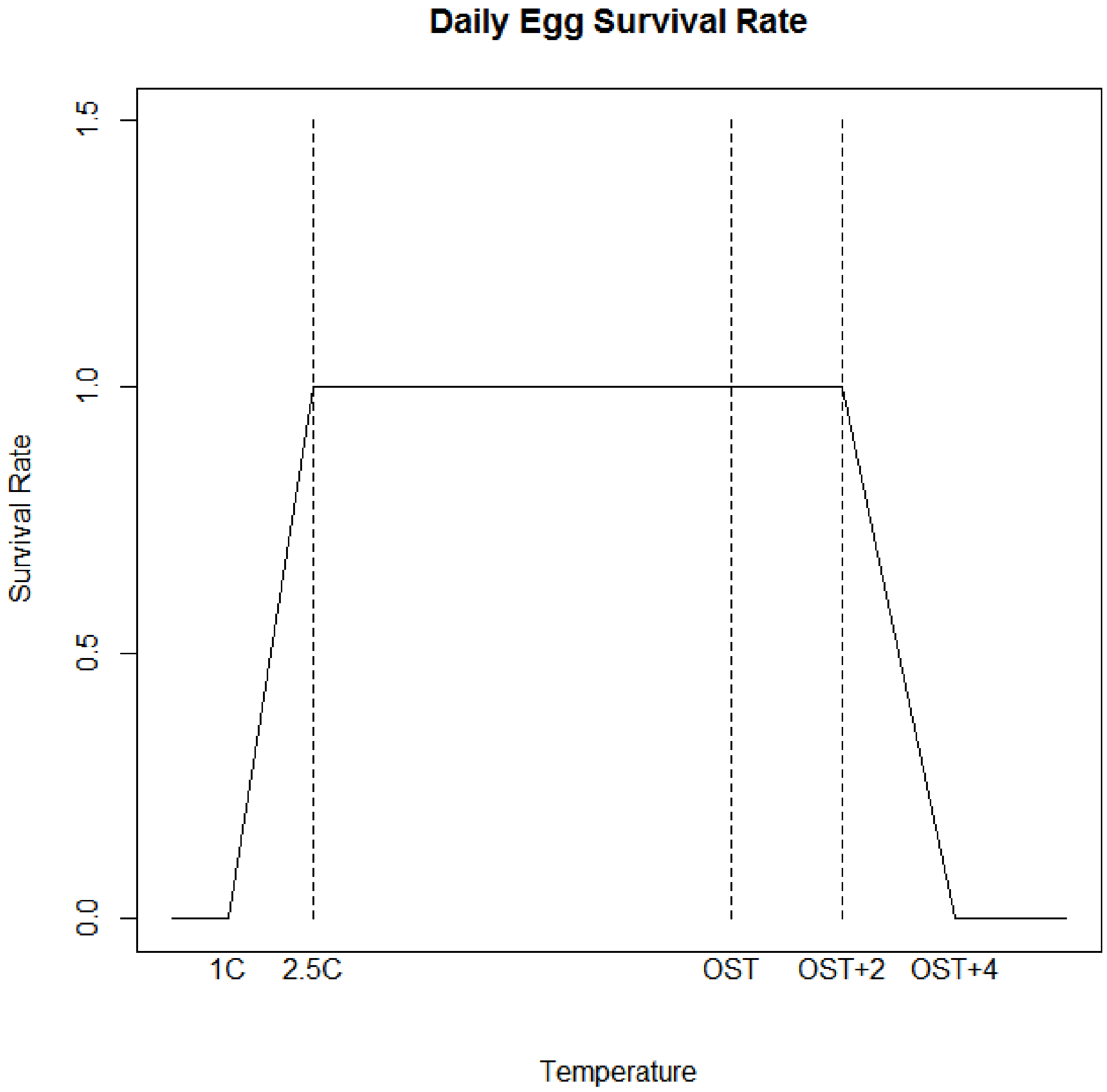


Figure 4. Graphical representation of the trapezoid model for daily egg survival rate as a function of the daily mean temperature. OST is the Optimal Spawning Temperature of the fish species.

Table 1. Parameter values used for the fish species used in the projection of first order biotic responses (spawning time, egg hatching date and success, adult growth). FTP and OST were obtained from Hasnain et al. (2010). CDEV and EPDEV are the species-specific constants describing their larval development growth curve.

Fish Species Spawning Parameters				
Species	Final Temperature Preferendum (FTP) °C	Optimal Spawning Temperature (OST) °C	CDEV	EPDEV
Fall Spawner				
Brook Trout	14.8	10.7	102.52	-0.0133
Lake Trout	11.8	10.6	252.78	-0.1539
Lake Whitefish	12.7	5.7	179	-0.1561
Spring Spawner				
Northern Pike	20.7	6.9	67.133	-0.1638
Smallmouth Bass	25	18	217	-0.161
Walleye	22.5	8	52.861	-0.1148
Yellow Perch	17.6	9.3	140	-0.174

Table 2. The nine potential outcomes for the simple three-part model for projecting qualitative changes in potential sustainable yield in selected fish species in response to a changing climate.

1971-2000 Norms	Future Time Period	Projected Change
Up	Up	Increase
Up	Plateau	Increase
Up	Down	Increase then Decrease
Plateau	Up	Decrease
Plateau	Plateau	No Change
Plateau	Down	Decrease
Down	Up	Increase then Decrease
Down	Plateau	Increase
Down	Down	Decrease

RESULTS

Results will be presented both in map-figure and table formats by secondary watershed unit as well as for selected case studies.

SECTION A - GREAT LAKES- ST-LAWRENCE RIVER (PRIMARY WATERSHED 02)

A.1 Lake Resources

The secondary watersheds of the Great Lakes- St. Lawrence R. drainage gather first into the Great Lakes and then the St Lawrence R. gathers further watershed as it proceeds northeastward to the open Atlantic Ocean (Figure A.1.1). There are three main groupings of secondary watersheds: a) those that drain into the Great Lakes (02A-02M); b) those that drain into the St. Lawrence primarily from Quebec (02N-02X); and c) those that drain the island of Newfoundland (02Y-02Z)

There are an estimated 58,214 lakes ($A_O \geq 0.1$ km^2, Table A.1.1) in the Great Lakes-St. Lawrence R. drainage with 42 large lakes ($A_O \geq 100$ km^2) accounting for 85.0% of the total lake area, 246,945 km^2 (Table A.1.2). There are 9 lakes with $A_O \geq 1000$ km^2 (Figure A.1.2) including the Great Lakes [Superior (86,511 km^2), Huron (59,600), St Clair (1305), Erie (27,351) and Ontario (19,736)] along with Lake Nipigon (14,809), the Réservoirs Manicouagan (4,135) and Gouin (1,765), and Lac Saint-Jean (1,055) in the St. Lawrence R.

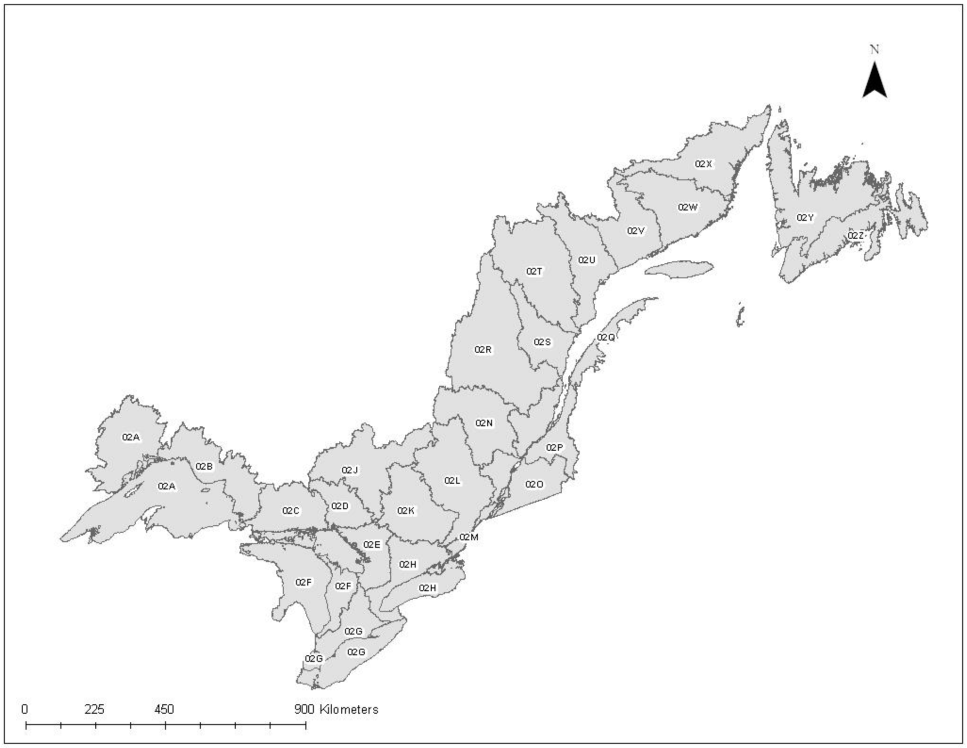


Figure A.1.1. Map of the Great Lakes-St. Lawrence drainage showing the secondary watersheds and their identifiers.

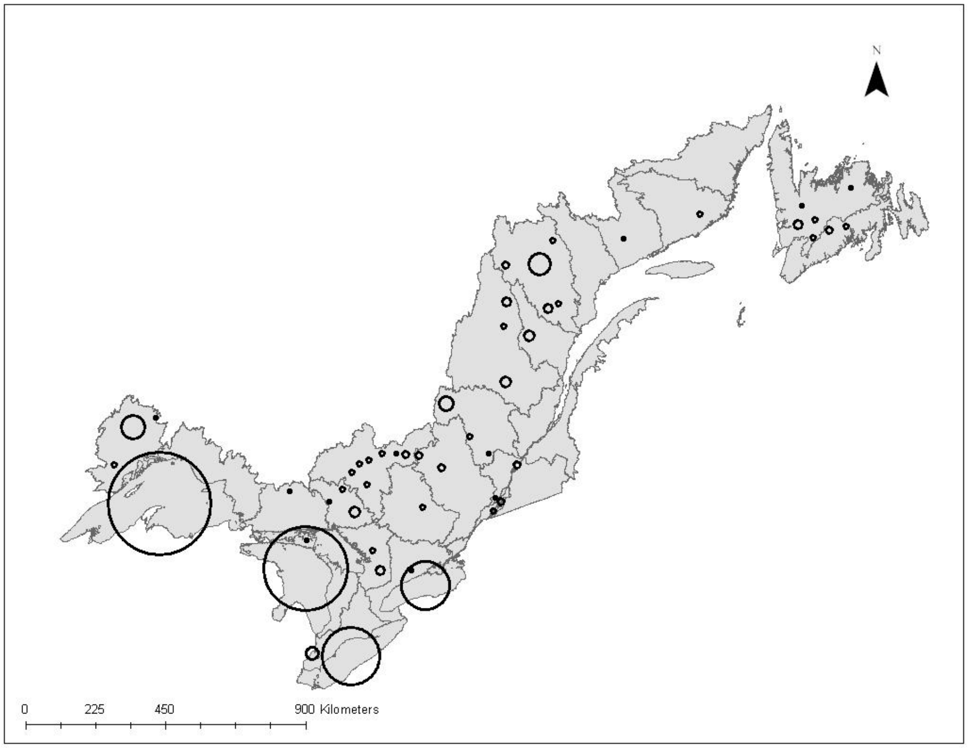


Figure A.1.2. Map showing the location and size of all large (area ≥ 100 km^2) lakes in the Great Lakes-St. Lawrence drainage. The circles indicate the relative size of the large lakes.

Table A.1.1. Estimated numbers of lakes by area size class interval in the secondary watersheds of the Great Lakes- St. Lawrence R. drainage.

SWS	**Lake area intervals, km^2**										
	0.1	**0.2**	**0.5**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**Sum**
02A	2029	1187	385	124	114	44	21	8		4	3916
02B	1105	647	210	50	61	27	10	7	2		2119
02C	1975	1156	375	23	66	40	19	13	1	2	3670
02D	1041	609	198	3	14	11	14	5		3	1898
02E	1043	611	198	3	22	20	9	5	1	2	1914
02F	167	98	32	9	9	2				1	318
02G	270	158	51	3	4		3			3	492
02H	1096	641	208	9	20	16	16	4	3	1	2014
02J	2978	1742	565	40	55	51	30	21	2	7	5491
02K	1567	917	297	18	39	31	18	22	2	1	2912
02L	2755	1612	523	223	151	51	25	15	4	2	5361
02M	355	208	67	8	7	6	2	3		2	658
02N	2125	1243	403	188	131	39	12	10	1	3	4155
02O	637	373	121	40						2	1173
02U		878	285	159	131	39	16	6	2		1516
02V	1476	863	280	149	100	35	8	8	1	1	2921
02W	2627	1537	499	176	229	84	33	22	3	1	5211
02X	1603	938	304	164	173	57	17	9	1		3266
02Y	3144	1840	597	208	193	59	39	13	3	5	6101
02Z	1557	911	296	158	121	42	11	10		2	3108
Sum	29550	18169	5894	1755	1640	654	303	181	26	42	58214

Table A.1.2. Estimated total area of lakes (km^2) by area size class interval in the secondary watersheds of the Great Lakes- St. Lawrence R. drainage.

SWS	**Lake area intervals, km^2**										
	0.1	**0.2**	**0.5**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**Sum**
02A	280.9	361.7	266.5	173.2	346.1	291.7	267.3	248.0		91602.1	93837.6
02B	153.0	197.2	145.4	75.7	186.5	193.3	134.9	285.0	121.4		1492.3
02C	273.4	352.3	259.6	34.6	207.7	278.1	251.8	386.9	51.7	228.2	2324.4
02D	144.1	185.6	137.1	5.4	52.8	71.6	210.3	134.8		1359.0	2300.6
02E	144.4	186.2	137.1	4.0	74.1	147.5	122.1	133.5	70.0	920.1	1939.0
02F	23.1	29.9	22.2	12.7	28.9	12.8				59600.0	59729.5
02G	37.4	48.2	35.3	4.1	15.5		38.2			48392.1	48570.7
02H	151.7	195.3	144.0	13.0	79.2	110.8	224.1	122.3	231.8	105.8	1378.1
02J	412.3	530.9	391.1	54.2	182.4	379.8	401.5	618.0	150.2	1702.5	4822.9
02K	217.0	279.5	205.6	25.9	134.3	220.7	252.0	643.4	151.0	177.5	2306.8
02L	381.4	491.3	362.1	292.2	483.5	347.0	356.4	383.6	332.6	770.7	4200.8
02M	49.2	63.4	46.4	9.9	21.1	49.9	30.1	92.0		624.2	986.1
02N	294.2	378.8	279.0	254.6	395.2	257.6	160.0	286.8	60.9	2053.8	4420.9
02O	88.2	113.7	83.8	54.8						457.4	797.8
02U		267.6	197.3	220.3	405.0	250.5	213.8	210.7	156.5		1921.7
02V	204.4	263.0	193.8	207.3	307.3	232.5	121.8	215.1	56.9	106.4	1908.5
02W	363.7	468.4	345.4	264.1	697.2	559.5	424.3	661.3	169.6	200.7	4154.3
02X	221.9	285.9	210.4	223.7	530.6	370.9	235.7	251.1	62.6		2392.8
02Y	435.3	560.7	413.3	302.6	576.7	401.8	529.3	395.3	175.1	1127.4	4917.5
02Z	215.6	277.6	204.9	233.0	355.1	282.0	140.4	327.5		506.6	2542.7
Sum	4091.2	5537.0	4080.2	2465.3	5079.2	4458.0	4114.0	5395.3	1790.3	209934	246945.1

A.2 Climate

In the 02 drainage, the 1971-2000 norms for mean annual air temperature (MAAT, °C) ranged from -3.7 along the Quebec N. Shore of the St. Lawrence to +7.9 in the lower Great Lakes basin (Figure A.2.1 Upper-left). The projected increases in MAAT are higher for the A2 scenario in all three future time periods compared to the B1 scenario (Table A.2.1). The lowest increases were for the B1*2011-2040 combination with minima ranging from +0.2 to +1.5 and maxima from +1.3 to +2.2. The highest increases were for the A2*2071-2100 combination with minima ranging from +3.0 to +4.9 and maxima ranging from +4.6 to +6.4. As the current emission trajectory is closer to the A2 scenario, or possibly higher, the A2*2041-2070 combination was used as a mid-century reference point relative to the 1971-2000 norms when examining the projected abiotic and biotic responses. The A2*2041-2070 MAAT increases had a minima range of +1.9 to +3.0 and a maxima range of +3.2 to +3.9, roughly overall a projected MAAT increase of 2-4 °C.

For the 1971-2000 norms period, the annual, summer (June-July-August), and July values with respect to temperature and precipitation rates vary across the watersheds of the 02 drainage (Figure A.2.1 Upper-right; Table A.2.2). Mean summer air temperatures ranged from 10.3 to 19.6 °C and July mean air temperatures from 11.8 to 20.7 °C with lower values more common in the eastern and northern watersheds. Precipitation rates were more even across the drainage compared to temperatures though somewhat higher in eastern watersheds (Figure A.2.1 Lower panels; Table A.2.2).

The ranges of projected temperature changes under A2 for the 2041-2070 period for the summer and July values were similar to the annual values (Table A.2.2). The ranges of projected percentage changes in precipitation rates were more variable with both increases and decreases possible. For annual precipitation the minima ranged from -3.6 to +16.1 % and the maxima ranged from +6.8 to 28.6% with no distinct spatial pattern, For summer and July precipitation rates the ranges of the minima and maxima percentages were greater and decreases were more common in the Great Lakes basin for the summer period.

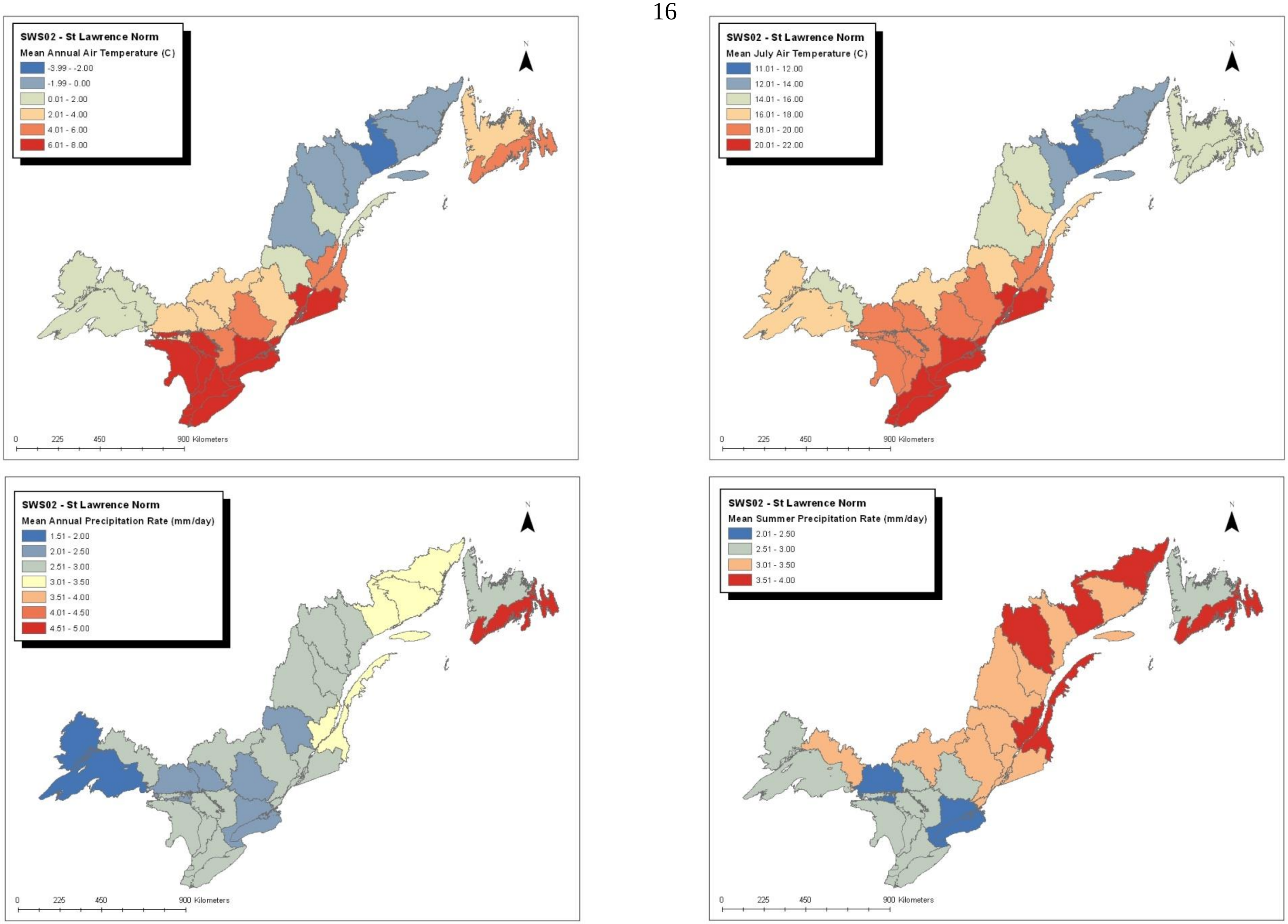


Figure A.2.1. A map of the Great Lakes-St. Lawrence R. drainage (02) secondary watersheds showing the 1971-2000 norms for mean annual and July air temperatures (°C) (Upper panels left and right) and for mean annual and summer precipitation rates (mm/d)(Lower panels left and right).

Table A.2.1. Summary by secondary watershed in the Great Lakes-St. Lawrence R. drainage (02) of the 1971-2000 norms mean annual air temperature (°C) and the ranges of projected changes for the 2011-2041, 2041-2070, and 2071-2100 periods from four GCMs given the B1and A2 emissions scenarios.

SWS	MAAT (°C)	Δ MAAT (°C) for B1 Scenario						Δ MAAT (°C) for A2 Scenario					
	1971-2000	2011-2040		2041-2070		2071-2100		2011-2040		2041-2070		2071-2100	
		min	max	min	max	min	max	min	max	min	max	min	max
02A	0.9	1.1	2.0	2.0	2.8	2.6	3.7	1.3	1.7	2.8	3.5	4.6	6.0
02B	0.9	1.5	2.2	2.4	3.3	2.8	4.2	1.7	2.2	3.2	3.9	4.9	6.4
02C	3.5	1.0	1.6	1.9	2.9	2.2	3.9	1.2	1.7	2.7	3.3	4.2	6.0
02D	3.9	1.3	1.9	2.1	3.2	2.4	4.2	1.5	2.0	2.9	3.6	4.4	6.2
02E	5.7	1.1	1.7	1.9	3.0	2.0	4.0	1.2	1.8	2.6	3.3	4.0	5.9
02F	6.5	0.9	1.5	1.8	2.9	1.9	3.9	1.1	1.7	2.4	3.2	3.8	5.8
02G	7.9	0.9	1.5	1.8	2.9	1.9	3.8	1.1	1.7	2.4	3.2	3.7	5.7
02H	6.5	1.2	1.8	2.1	3.2	2.1	4.1	1.4	2.0	2.7	3.5	4.1	5.9
02J	2.1	1.3	2.0	2.2	3.4	2.5	4.3	1.6	2.1	3.1	3.7	4.7	6.3
02K	4.7	1.1	1.7	1.9	3.1	2.1	4.0	1.2	1.8	2.7	3.4	4.1	5.9
02L	3.4	1.2	1.8	2.1	3.3	2.2	4.2	1.4	1.9	2.9	3.5	4.3	6.0
02M	6.1	1.3	1.7	2.1	3.1	2.2	4.0	1.5	2.1	2.9	3.4	4.2	5.7
02N	1.1	1.2	1.8	2.1	3.3	2.3	4.2	1.3	1.9	2.9	3.6	4.5	6.2
02O	6.1	1.3	1.7	2.1	3.1	2.2	4.0	1.4	2.0	2.9	3.4	4.3	5.7
02P	4.5	1.2	1.7	2.0	3.1	2.2	4.0	1.3	1.9	2.8	3.4	4.3	5.8
02Q	1.4	1.0	1.7	2.0	3.1	2.4	3.9	1.4	1.7	2.7	3.4	4.2	5.8
02R	-0.4	0.6	1.4	1.6	2.9	2.0	3.8	0.9	1.5	2.5	3.2	4.1	6.0
02S	0.6	0.8	1.6	1.8	3.0	2.2	4.0	1.2	1.7	2.6	3.4	4.3	6.1
02T	-1.6	0.2	1.3	1.3	2.7	1.9	3.6	0.7	1.3	2.1	3.1	3.7	5.8
02U	-1.9	0.4	1.5	1.5	2.9	2.1	3.7	0.9	1.5	2.2	3.2	3.8	5.8
02V	-3.7	0.8	2.0	2.0	3.3	2.5	4.1	1.3	2.0	2.6	3.7	4.2	6.2
02W	-0.9	0.9	2.1	2.1	3.3	2.6	4.1	1.4	2.0	2.6	3.6	4.1	6.0
02X	-1.4	1.0	2.2	2.1	3.5	2.5	4.2	1.3	2.2	2.6	3.8	4.1	6.2
02Y	3.2	0.7	1.7	1.6	2.6	2.1	3.2	1.0	1.6	2.1	3.3	3.3	5.0
02Z	4.3	0.6	1.5	1.4	2.3	1.8	2.9	0.8	1.4	1.9	3.0	3.0	4.6
Min	-3.7	0.2	1.3	1.3	2.3	1.8	2.9	0.7	1.3	1.9	3.0	3.0	4.6
Max	7.9	1.5	2.2	2.4	3.5	2.8	4.3	1.7	2.2	3.2	3.9	4.9	6.4

Table A.2.2. Summary by secondary watershed in the Great Lakes-St. Lawrence R. drainage (02) of the 1971-2000 climate norms and the range of projected changes for the 2041-2070 period from four GCMs given the A2 emissions scenario.

SWS	1971-2000 Climate Normals						Projected changes under scenario A2 in the period 2041-2070											
	Temperature °C			Precipitation mm.d^{-1}			ΔTemperature °C						Δ Precipitation %					
	Ann	Sum	Jul	Ann	Sum	Jul	Ann		Sum		Jul		Ann		Sum		Jul	
							Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
02A	0.9	15.6	16.9	1.9	2.6	2.6	2.8	3.5	2.8	3.3	3.2	3.9	12.4	24.2	3.1	34.0	13.4	38.5
02B	0.9	13.9	14.9	2.6	3.0	3.2	3.2	3.9	3.1	3.7	3.4	4.0	3.1	12.8	-9.2	9.6	-12.8	2.5
02C	3.5	16.8	18.1	2.3	2.5	2.3	2.7	3.3	2.6	3.0	3.0	3.5	15.2	28.6	-1.6	30.0	-8.2	31.3
02D	3.9	17.6	19.0	2.4	2.6	2.5	2.9	3.6	2.9	3.3	3.0	3.5	3.0	13.5	-6.2	16.2	-9.9	17.5
02E	5.7	18.1	19.3	3.0	2.8	2.8	2.6	3.3	2.6	3.1	3.1	3.4	-1.0	9.8	-11.9	19.1	-18.2	6.5
02F	6.5	18.0	19.1	2.9	2.8	2.4	2.4	3.2	2.6	3.1	2.8	3.3	0.0	16.3	-10.2	32.0	-13.6	23.1
02G	7.9	19.6	20.7	2.8	2.8	2.8	2.4	3.2	2.6	3.2	3.0	3.5	-3.6	11.6	-15.5	23.7	-23.5	7.2
02H	6.5	18.8	20.1	2.4	2.5	2.1	2.7	3.5	2.7	3.1	3.0	3.3	-2.5	10.5	-12.1	27.1	-4.7	29.0
02J	2.1	16.3	17.5	2.5	3.0	3.1	3.1	3.7	2.8	3.3	2.8	3.6	4.3	12.6	1.0	14.5	-5.6	14.4
02K	4.7	18.1	19.4	2.3	2.7	2.7	2.7	3.4	2.6	2.9	2.8	3.2	1.7	8.6	-6.7	13.7	-11.3	11.3
02L	3.4	17.0	18.3	2.7	3.2	3.1	2.9	3.5	2.7	3.1	2.7	3.3	5.1	12.5	-3.1	18.4	2.3	28.2
02M	6.1	18.8	20.0	2.8	3.2	3.1	2.9	3.4	2.7	3.1	3.1	3.3	-2.5	6.8	-11.1	21.5	-14.4	18.6
02N	1.1	15.3	16.4	2.5	3.2	3.5	2.9	3.6	2.2	2.9	2.0	3.1	16.1	23.8	9.3	29.5	11.6	36.4
02O	6.1	19.3	20.5	2.9	3.3	3.4	2.9	3.4	2.7	3.1	3.0	3.4	4.1	8.8	-6.9	21.4	-9.9	26.5
02P	4.5	18.0	19.3	3.3	3.9	4.2	2.8	3.4	2.5	3.2	2.7	3.6	6.4	11.2	-4.7	16.1	-8.6	26.1
02Q	1.4	14.9	16.2	3.1	3.5	3.8	2.7	3.4	2.2	3.4	2.5	3.8	4.5	14.3	3.4	13.6	1.3	19.7
02R	-0.4	14.1	15.3	2.6	3.4	3.9	2.5	3.2	2.2	3.4	2.0	3.8	14.4	22.1	12.1	30.2	-1.8	24.9
02S	0.6	15.0	16.1	2.7	3.3	3.7	2.6	3.4	2.4	3.6	2.5	4.2	5.2	13.4	1.2	17.3	-5.9	15.8
02T	-1.6	13.2	14.4	2.8	3.5	3.9	2.1	3.1	1.7	3.4	1.8	4.0	6.4	12.7	1.7	19.9	-1.6	27.8
02U	-1.9	12.6	13.9	2.9	3.5	3.7	2.2	3.2	1.7	3.5	1.9	4.0	4.2	12.2	1.4	19.1	-0.5	23.3
02V	-3.7	10.3	11.8	3.1	3.7	3.9	2.6	3.7	2.2	4.1	2.4	4.6	-0.3	8.1	-0.3	13.9	-1.3	13.0
02W	-0.9	11.7	13.2	3.0	3.3	3.5	2.6	3.6	2.1	4.1	2.2	4.4	-0.7	10.6	-0.6	10.5	-4.9	9.2
02X	-1.4	10.9	12.4	3.1	3.6	3.7	2.6	3.8	1.9	4.3	2.0	4.8	6.8	13.6	7.7	11.0	5.9	23.0
02Y	3.2	14.2	15.8	2.7	2.8	2.6	2.1	3.3	2.0	3.5	2.0	3.8	7.9	12.1	2.8	13.7	-6.2	12.8
02Z	4.3	13.8	14.9	4.6	4.0	4.1	1.9	3.0	1.9	3.0	1.9	3.2	0.9	7.1	-0.8	11.1	-12.0	5.1
Min	-3.7	10.3	11.8	1.9	2.5	2.1	1.9	3.0	1.7	2.9	1.8	3.1	-3.6	6.8	-15.5	9.6	-23.5	2.5
Max	7.9	19.6	20.7	4.6	4.0	4.2	3.2	3.9	3.1	4.3	3.4	4.8	16.1	28.6	12.1	34.0	13.4	38.5

A.3 Abiotic Lake Responses

Ice break-up and freeze-up dates, duration of ice cover and open water

In the 02 drainage, the 1971-2000 norms for ice freeze-up date ranged from Julian day 325 to day 368 (Figure A.3.1 upper-left; Table A.3.1). By 2041-2070 under the A2 climate scenario, the freeze up date will on average be 7 to 16 days later (Figure A.3.1 lower-left; Table A.3.1). The minimum delay in freeze up date is 3 days and the maximum is 21 days (Figure A.3.2). The ice break up date during the 1971-2000 norms ranged from 102 to 155 Julian days (Figure A.3.1 upper-right; Table A.3.1). The change in ice break up date is much smaller in comparison to freeze up. The projected change by 2041-2070 is -1 to -3 days on average (Figure A.3.1 lower-right; Table A.3.1) and ranges from 0 to -4 days (Figure A.3.2).

Given that maximum ice thickness is largely determined by the duration of ice cover, the ice duration and thickness results for the 02 drainage are similar (Figure A.3.4; Table A.3.2). Ice cover duration during the 1971-2000 norms ranged from 99 to 195 days and is projected to be reduced on average by 8 to 17 days (Table A.3.X) by 2041-2070. The possible range of reduction will be from 5 to 23 days. The 1971-2000 norms for ice thickness are projected to be between 53.3 cm and 111.1 cm (Table A.3.2). The projected change by 2041-2070 is an average reduction of 3.7 cm to 7.7 cm but can be as little as 2.1 cm to as much as 10.7 cm.

The duration of open water (Figure A.3.7; Table A.3.2) is simply 365 minus the duration of ice cover and has a range of 170 to 266 days during the 1971-2000 norms. Increases in open water duration are equal to the reduction in ice cover duration.

Peak summer surface temperature and its timing

The projected summer peak water surface temperature for the 02 drainage during the 1971-2000 norms ranged from 16.92 °C to 27.13 °C (Figure A.3.9; Table A.3.3). This temperature is projected to increase by an average of 1.02 °C to 1.54 °C by 2041-2070 under the A2 scenario (Table A.3.3). The maximum and minimum increase for this period is 0.73 °C and 1.68 °C. The timing of the peak temperature changes very little in our projections. From a range of 205 to 212 Julian days in the 1971-2000 norms, the date of peak temperature will occur earlier by 0 to 2 days by 2041-2000 (Figure A.3.9; Table A.3.3).

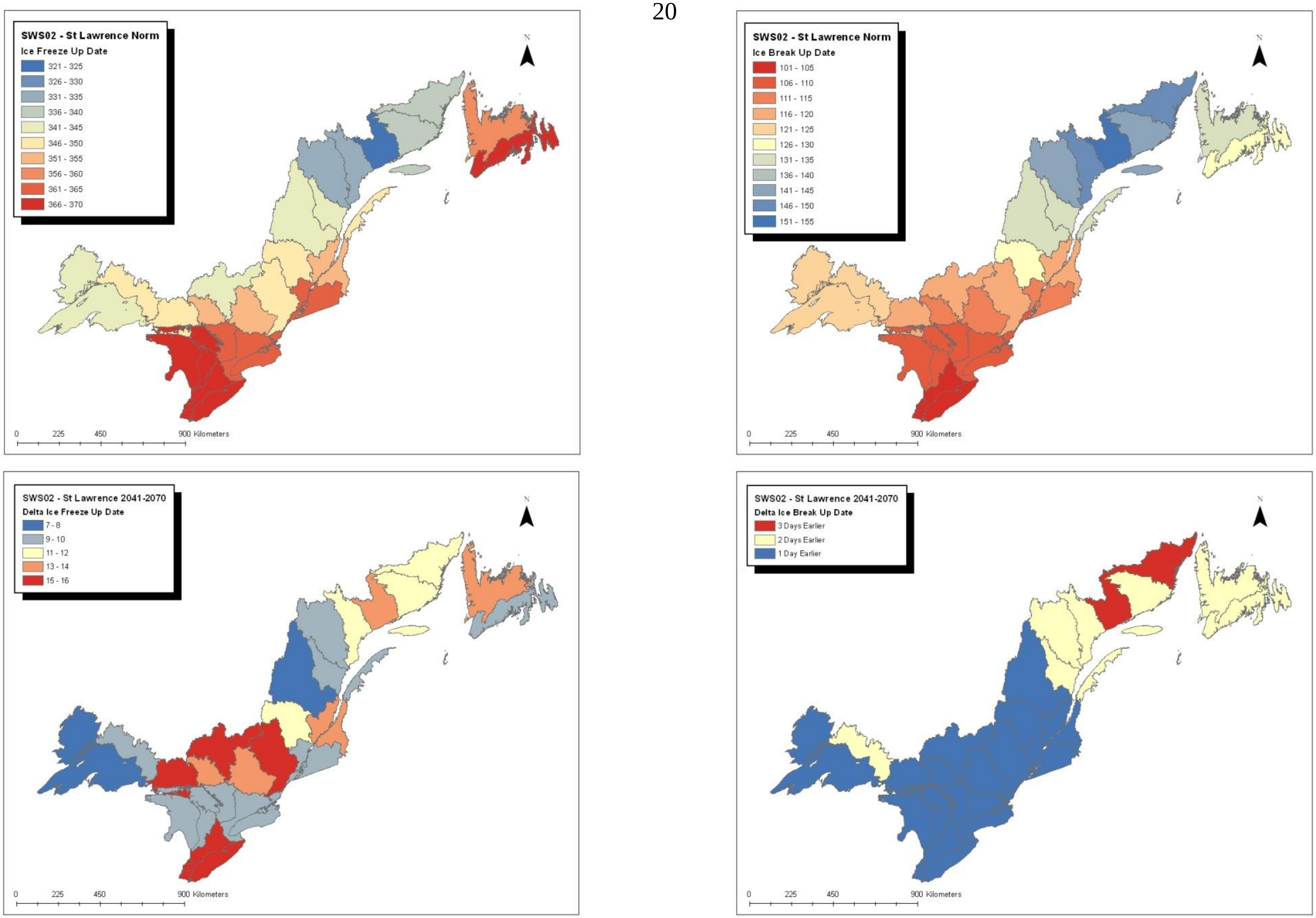


Figure A.3.1. Spatial variation in projected Julian ice-in and ice-out dates (upper panels left and right) for the 1971-2000 period by secondary watershed in the 02 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panels, left and right).

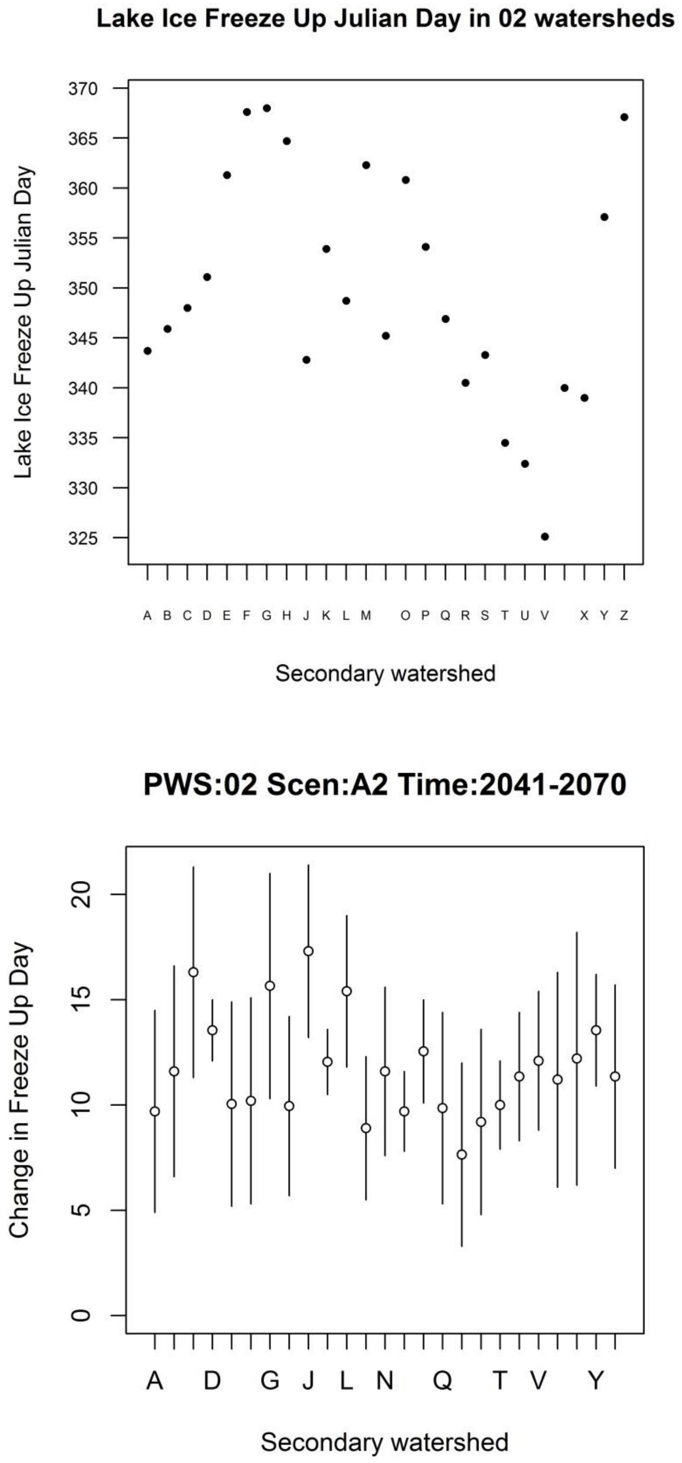
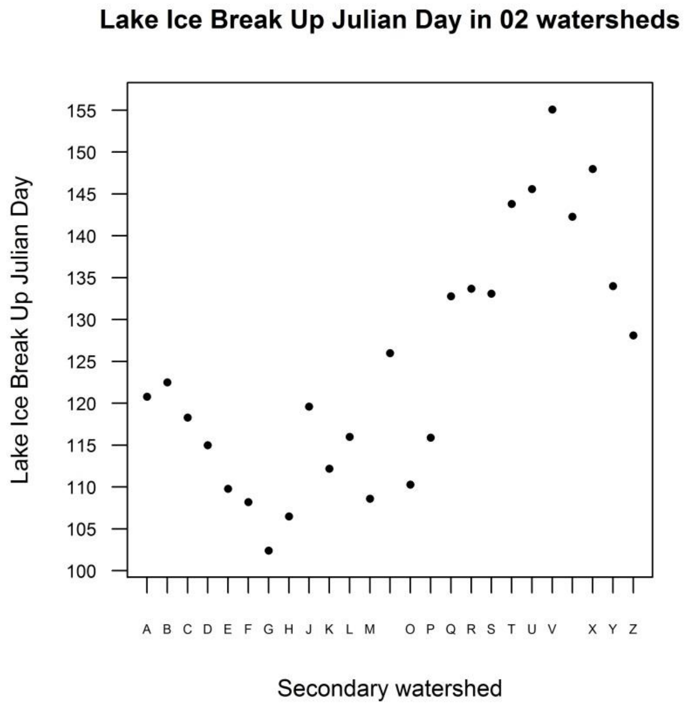


Figure A.3.2. Projected Julian freeze-up dates for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).



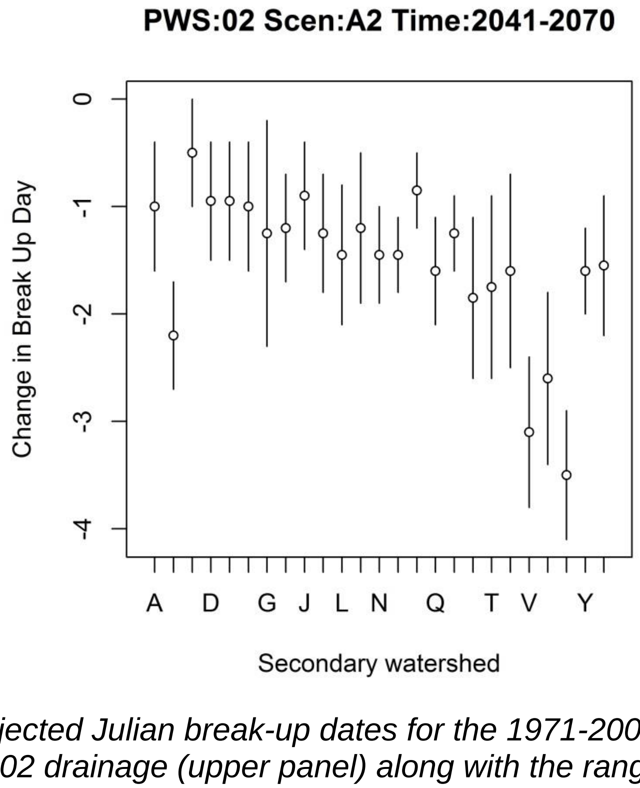


Figure A.3.3. Projected Julian break-up dates for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

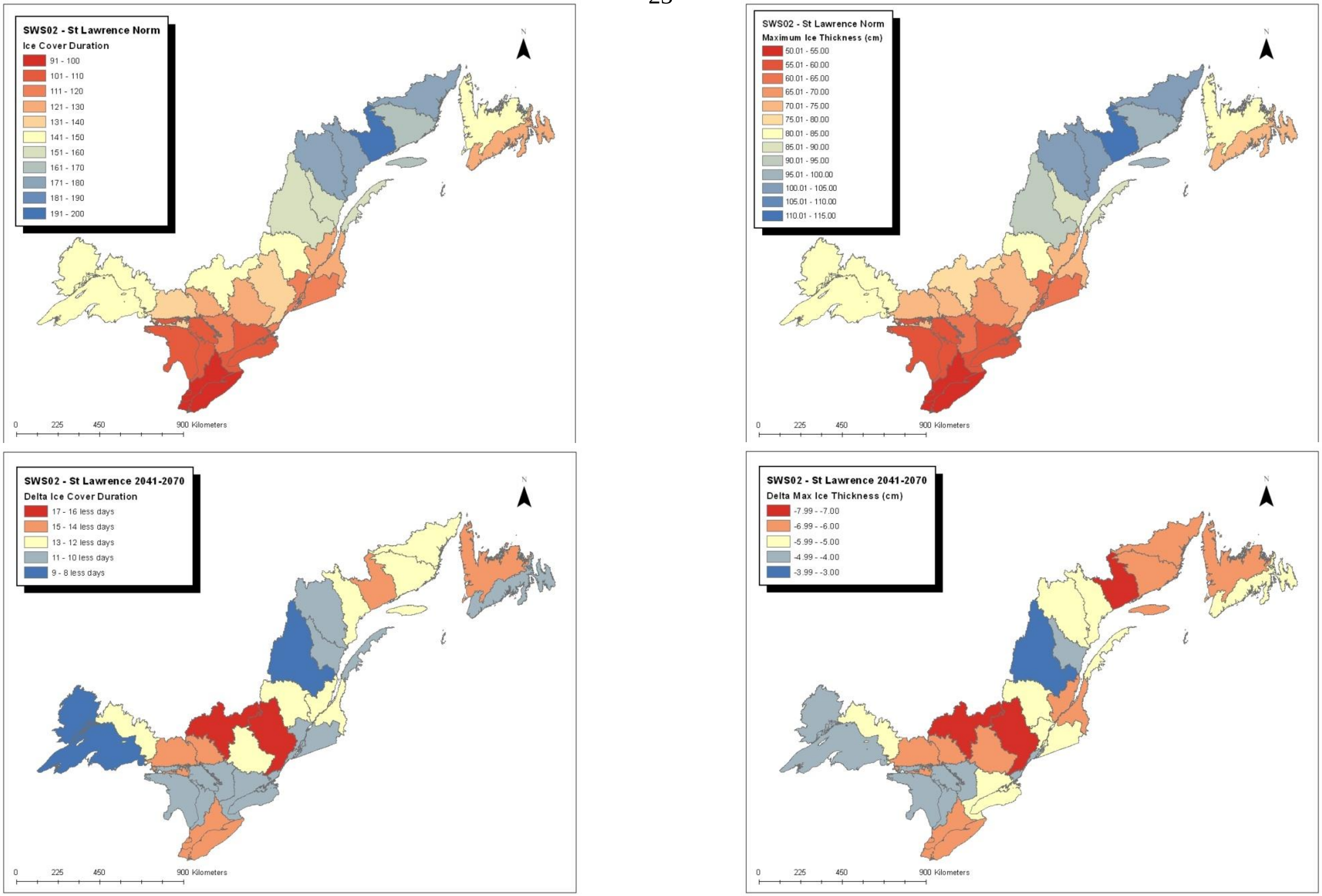


Figure A.3.4. Spatial variation in projected duration of ice cover (days) and maximum ice thickness (cm) (upper panels left and right) for the 1971-2000 period by secondary watershed in the 02 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panels, left and right).

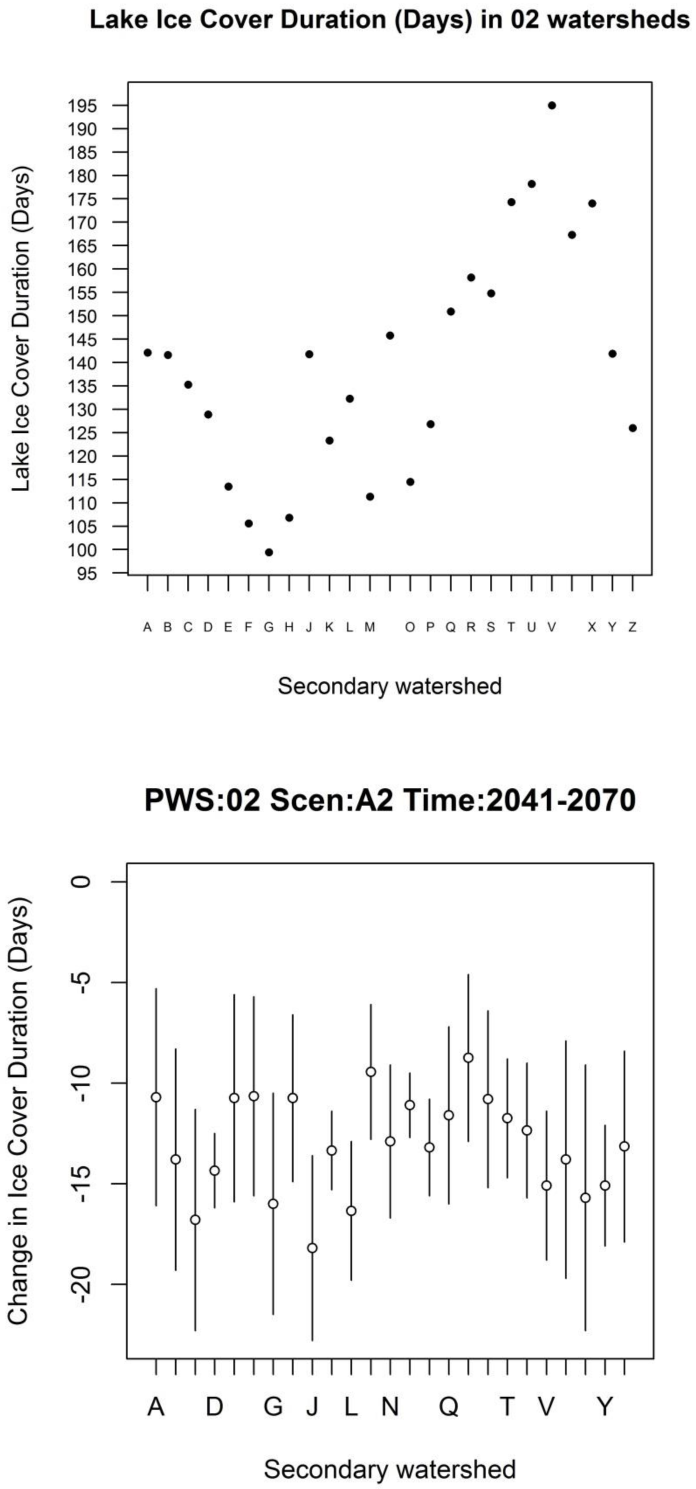


Figure A.3.5. Projected ice cover duration (Julian days) for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

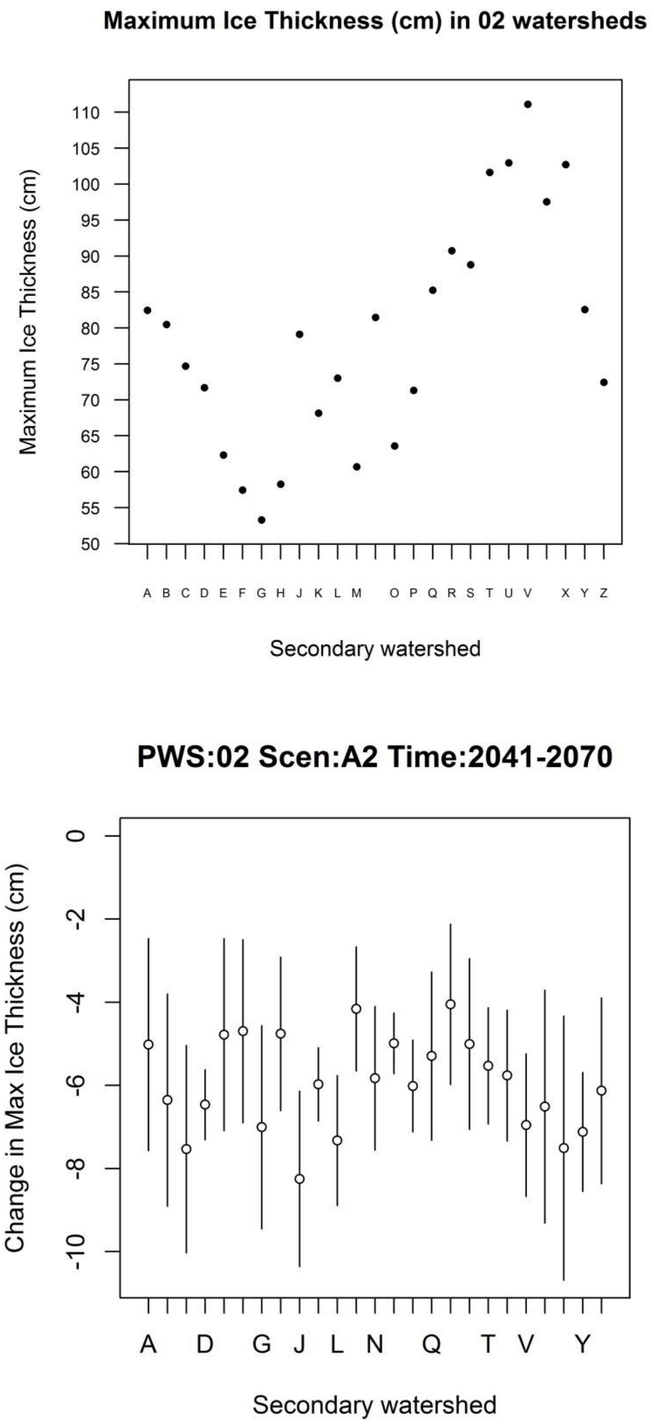


Figure A.3.6. Projected ice thickness (cm) for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

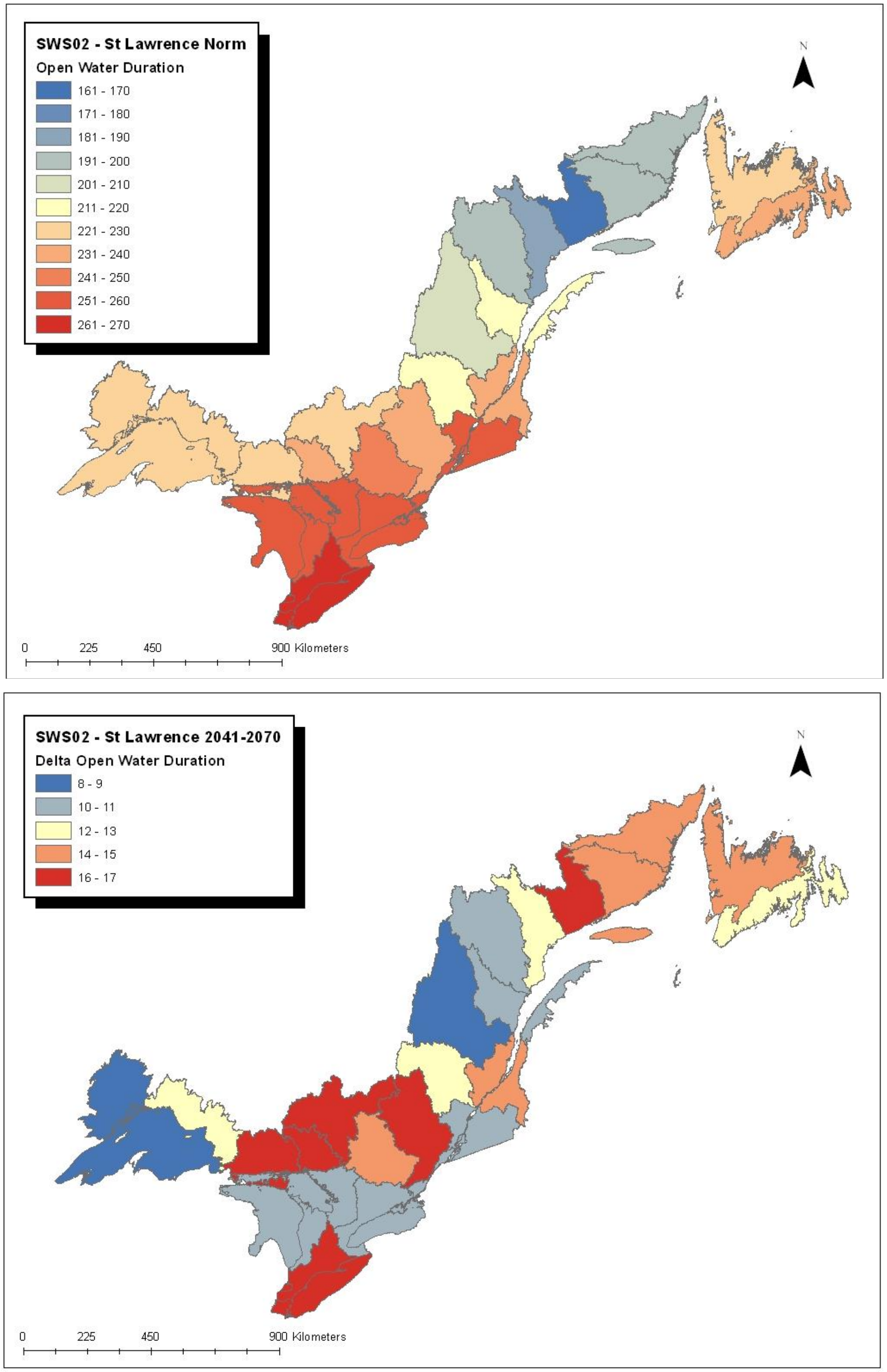


Figure A.3.7. Spatial variation in projected open water duration (Julian days) for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

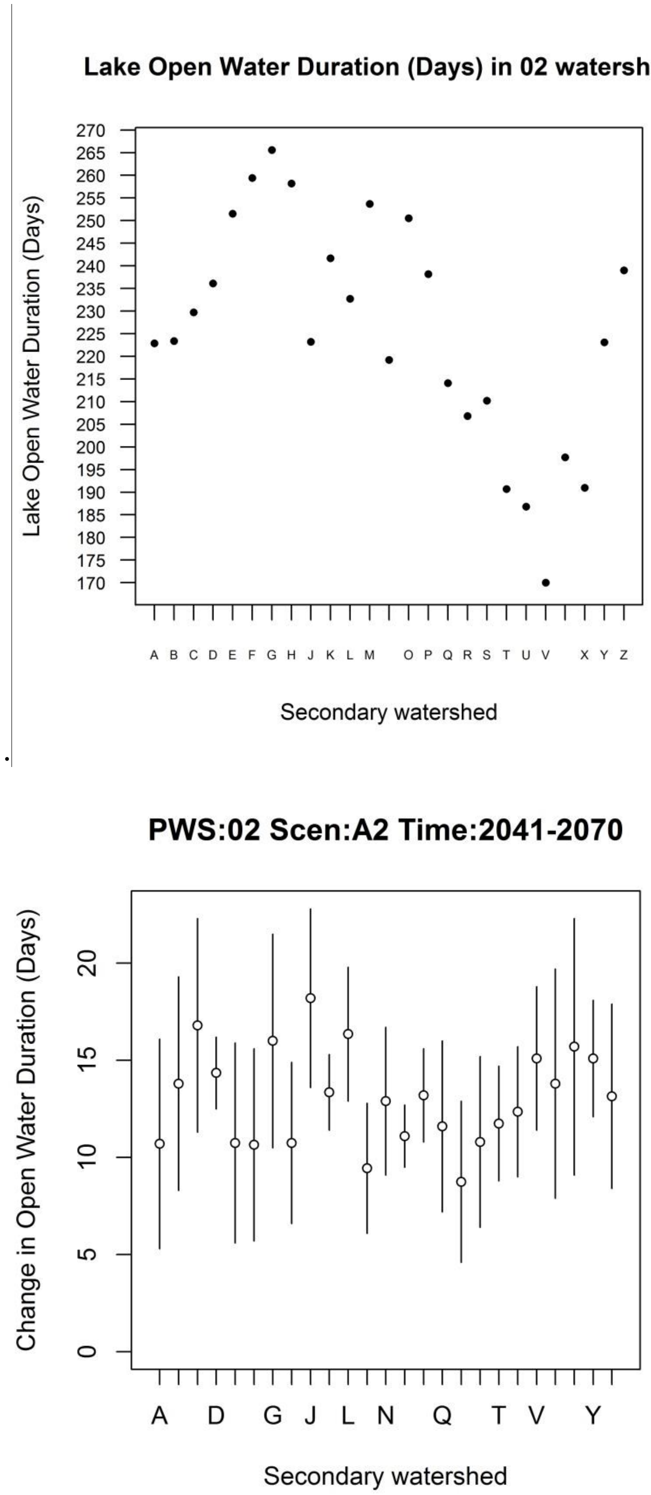


Figure A.3.8. Projected open water duration (Julian days) for the 1971-2000 period by secondary watershed in the 02 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel)

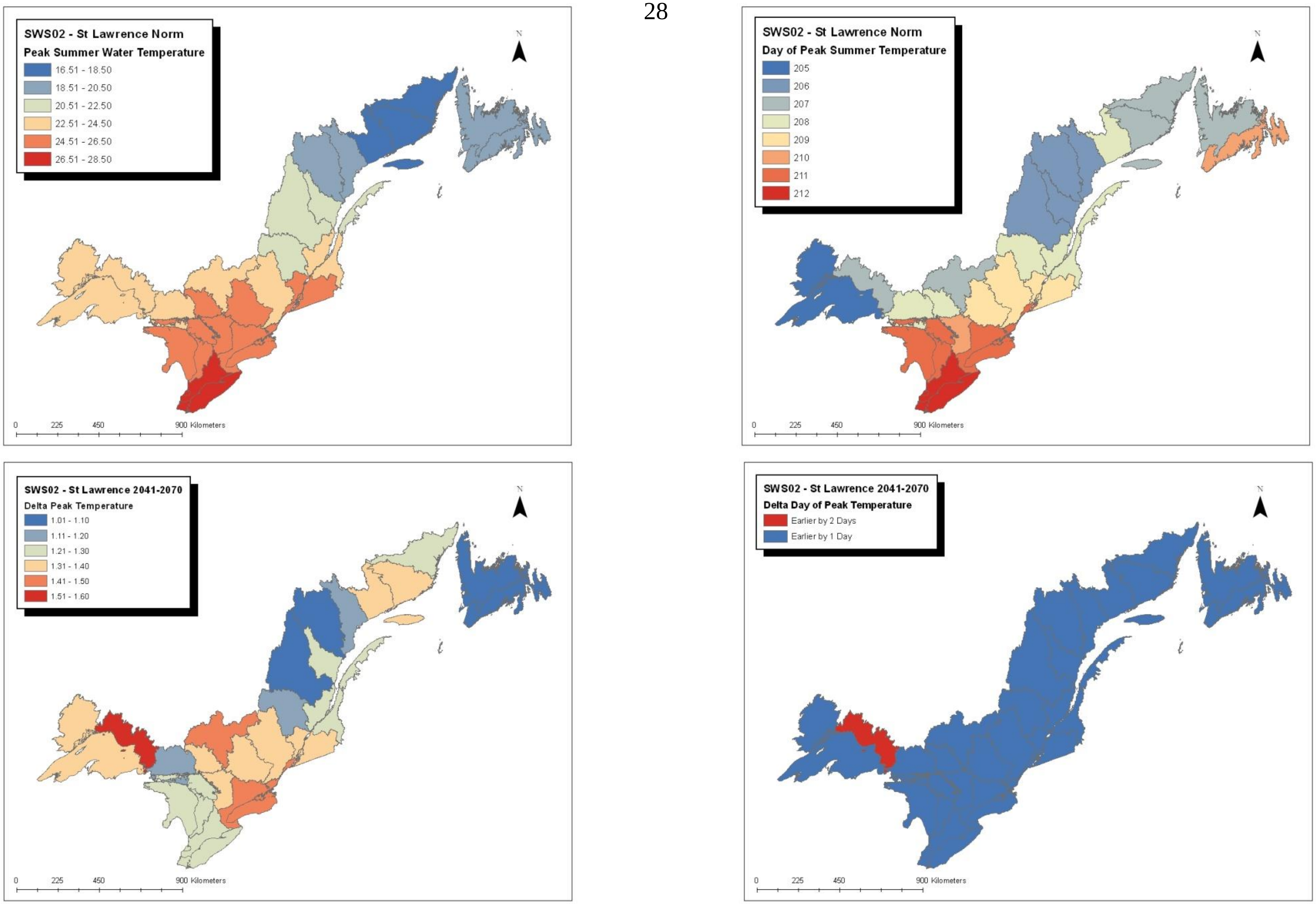


Figure A.3.9. Spatial variation in projected peak surface water temperature (°C) and its timing (Julian date) (upper left and right) for the 1971-2000 period by secondary watershed in the 02 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower left and right).

Table A.3.1. Projected break-up and freeze-up dates in the St. Lawrence R. drainage under the 1971-2000 norms and the projected range and mean of projected changes under A2 emissions in the 2041-2070 period.

SWS	1971-2000 Climate Normals		Projected changes under scenario A2 in the period 2041-2070					
			∆ Break Up Date			∆ Freeze Up Date		
	Break Up	Freeze Up	Min	Max	Mean	Min	Max	Mean
02A	120.8	343.7	-1.6	-0.4	-0.95	4.9	14.5	7.975
02B	122.5	345.9	-2.7	-1.7	-2.3	6.6	16.6	9.85
02C	118.3	348	-1	0	-0.575	11.3	21.3	15
02D	115	351.1	-1.5	-0.4	-1.05	12.1	15	14.075
02E	109.8	361.3	-1.5	-0.4	-1.1	5.2	14.9	9.825
02F	108.2	367.6	-1.6	-0.4	-1.025	5.3	15.1	9.725
02G	102.4	368	-2.3	-0.2	-1.175	10.3	21	14.475
02H	106.5	364.7	-1.7	-0.7	-1.25	5.7	14.2	10.075
02J	119.6	342.8	-1.4	-0.4	-1.025	13.2	21.4	15.9
02K	112.2	353.9	-1.8	-0.7	-1.225	10.5	13.6	12.55
02L	116	348.7	-2.1	-0.8	-1.4	11.8	19	14.9
02M	108.6	362.3	-1.9	-0.5	-0.975	5.5	12.3	9.075
02N	126	345.2	-1.9	-1	-1.375	7.6	15.6	10.625
02O	110.3	360.8	-1.8	-1.1	-1.5	7.8	11.6	9.7
02P	115.9	354.1	-1.2	-0.5	-0.75	10.1	15	12.575
02Q	132.8	346.9	-2.1	-1.1	-1.675	5.3	14.4	9.475
02R	133.7	340.5	-1.6	-0.9	-1.275	3.3	12	6.825
02S	133.1	343.3	-2.6	-1.1	-1.725	4.8	13.6	8.55
02T	143.8	334.5	-2.6	-0.9	-1.7	7.9	12.1	9.7
02U	145.6	332.4	-2.5	-0.7	-1.675	8.3	14.4	10.975
02V	155.1	325.1	-3.8	-2.4	-3.05	8.8	15.4	12.8
02W	142.3	340	-3.4	-1.8	-2.75	6.1	16.3	10.525
02X	148	339	-4.1	-2.9	-3.375	6.2	18.2	10.475
02Y	134	357.1	-2	-1.2	-1.65	10.9	16.2	12.975
02Z	128.1	367.1	-2.2	-0.9	-1.625	7	15.7	9.95
Min	102.4	325.1	-4.1	-2.9	-3.375	3.3	11.6	6.825
Max	155.1	368	-1	0	-0.575	13.2	21.4	15.9

Table A.3.2.Projected open water and ice cover duration (days) and maximum ice thickness (cm) under the 1971-2000 norms and projected the range and mean changes under A2 emissions in the 2041-2070 period.

SWS	1971-2000 Climate Normals			Projected changes under scenario A2 in the period 2041-2070								
	Open Water Duration	Ice Cover Duration	Max Ice Thickness	∆ Open Water Duration			∆ Ice Cover Duration			∆ Max Ice Thickness		
				Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
02A	222.9	142.1	82.47	5.3	16.1	8.925	-16.1	-5.3	-8.925	-7.57	-2.47	-4.18
02B	223.4	141.6	80.47	8.3	19.3	12.15	-19.3	-8.3	-12.15	-8.91	-3.8	-5.585
02C	229.7	135.3	74.7	11.3	22.3	15.575	-22.3	-11.3	-15.575	-10.03	-5.04	-6.975
02D	236.1	128.9	71.69	12.5	16.2	15.125	-16.2	-12.5	-15.125	-7.31	-5.62	-6.8175
02E	251.5	113.5	62.34	5.6	15.9	10.925	-15.9	-5.6	-10.925	-7.09	-2.47	-4.855
02F	259.4	105.6	57.46	5.7	15.6	10.75	-15.6	-5.7	-10.75	-6.9	-2.49	-4.735
02G	265.6	99.4	53.3	10.5	21.5	15.65	-21.5	-10.5	-15.65	-9.45	-4.56	-6.8425
02H	258.2	106.8	58.27	6.6	14.9	11.325	-14.9	-6.6	-11.325	-6.61	-2.91	-5.0125
02J	223.2	141.8	79.11	13.6	22.8	16.925	-22.8	-13.6	-16.925	-10.36	-6.14	-7.66
02K	241.7	123.3	68.15	11.4	15.3	13.775	-15.3	-11.4	-13.775	-6.86	-5.09	-6.1675
02L	232.7	132.3	73.03	12.9	19.8	16.3	-19.8	-12.9	-16.3	-8.89	-5.76	-7.3
02M	253.7	111.3	60.68	6.1	12.8	10.05	-12.8	-6.1	-10.05	-5.65	-2.67	-4.4275
02N	219.2	145.8	81.47	9.1	16.7	12	-16.7	-9.1	-12	-7.56	-4.1	-5.4175
02O	250.5	114.5	63.58	9.5	12.7	11.2	-12.7	-9.5	-11.2	-5.72	-4.26	-5.035
02P	238.2	126.8	71.31	10.8	15.6	13.325	-15.6	-10.8	-13.325	-7.12	-4.91	-6.0725
02Q	214.1	150.9	85.26	7.2	16	11.15	-16	-7.2	-11.15	-7.32	-3.27	-5.085
02R	206.8	158.2	90.72	4.6	12.9	8.1	-12.9	-4.6	-8.1	-5.98	-2.12	-3.745
02S	210.2	154.8	88.78	6.4	15.2	10.275	-15.2	-6.4	-10.275	-7.06	-2.95	-4.7575
02T	190.7	174.3	101.62	8.8	14.7	11.4	-14.7	-8.8	-11.4	-6.93	-4.13	-5.3625
02U	186.8	178.2	102.97	9	15.7	12.65	-15.7	-9	-12.65	-7.34	-4.19	-5.905
02V	170	195	111.1	11.4	18.8	15.85	-18.8	-11.4	-15.85	-8.67	-5.24	-7.3
02W	197.7	167.3	97.54	7.9	19.7	13.275	-19.7	-7.9	-13.275	-9.31	-3.71	-6.2575
02X	191	174	102.74	9.1	22.3	13.85	-22.3	-9.1	-13.85	-10.69	-4.33	-6.6125
02Y	223.1	141.9	82.56	12.1	18.1	14.625	-18.1	-12.1	-14.625	-8.55	-5.69	-6.89
02Z	239	126	72.43	8.4	17.9	11.575	-17.9	-8.4	-11.575	-8.37	-3.89	-5.3875
Min	170	99.4	53.3	4.6	12.7	8.1	-22.8	-13.6	-16.925	-10.69	-6.14	-7.66
Max	265.6	195	111.1	13.6	22.8	16.925	-12.7	-4.6	-8.1	-5.65	-2.12	-3.745

Table A.3.3. Projected peak summer temperatures and their timing for the 1971-2000 norms by secondary watershed in the 02 drainage along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070.

SWS	1971-2000 Climate Normals		Projected changes under scenario A2 in the period 2041-2070					
	Peak Summer Temperature °C	Day of Peak Temperature	∆ Peak Temperature °C			∆ Day of Peak Temperature		
			Min	Max	Mean	Min	Max	Mean
02A	23.34	205.23	1.12	1.42	1.31	-1.30	-0.65	-1.00
02B	22.76	207.32	1.35	1.68	1.54	-1.92	-1.22	-1.58
02C	24.45	207.76	0.99	1.31	1.14	-1.36	-0.51	-1.00
02D	24.51	207.67	1.25	1.58	1.40	-1.66	-0.92	-1.33
02E	25.25	209.71	1.15	1.56	1.34	-1.56	-0.83	-1.27
02F	26.02	211.08	1.03	1.49	1.22	-1.59	-0.80	-1.28
02G	27.13	212.28	1.05	1.57	1.28	-1.70	-0.88	-1.34
02H	26.10	210.47	1.22	1.61	1.40	-1.51	-0.81	-1.27
02J	23.14	207.34	1.30	1.63	1.44	-1.58	-0.99	-1.24
02K	24.72	208.38	1.16	1.52	1.34	-1.48	-0.91	-1.21
02L	23.55	208.39	1.17	1.52	1.33	-1.42	-0.82	-1.13
02M	25.22	210.43	1.33	1.61	1.44	-1.60	-0.85	-1.29
02N	22.03	207.72	0.99	1.36	1.15	-1.24	-0.48	-0.87
02O	24.58	208.81	1.26	1.49	1.35	-1.53	-0.68	-1.10
02P	23.00	207.97	1.14	1.45	1.29	-1.52	-0.61	-1.08
02Q	20.60	207.44	1.11	1.44	1.27	-1.44	-0.68	-1.03
02R	20.51	206.60	0.81	1.28	1.06	-1.29	-0.60	-0.93
02S	20.68	206.31	1.07	1.49	1.30	-1.43	-0.71	-1.06
02T	18.96	205.84	0.82	1.32	1.07	-0.98	-0.34	-0.62
02U	18.53	206.30	0.90	1.37	1.12	-1.08	-0.34	-0.64
02V	17.08	207.67	1.15	1.64	1.37	-1.66	-0.79	-1.08
02W	17.98	207.07	1.07	1.58	1.33	-1.85	-0.87	-1.20
02X	16.92	207.06	0.97	1.60	1.28	-1.84	-0.56	-1.05
02Y	19.31	207.04	0.79	1.35	1.09	-1.66	-0.87	-1.1325
02Z	18.79	209.27	0.73	1.34	1.02	-1.62	-0.91	-1.2475
Min	16.92	205.23	0.73	1.28	1.02	-1.92	-1.22	-1.58
Max	27.13	212.28	1.35	1.68	1.54	-0.98	-0.34	-0.62

A.4 Biotic Responses

Spawning, egg development and adult growth

Projections for a fall spawning species (Lake Trout) and a spring spawning species (Northern Pike) are shown in full in figures A.4.1 and A.4.2 and tables A.4.1 to A.4.6 (Lake Trout) and in figures A.4.3 and A.4.4 and table A.4.7 to A.4.12 (Northern Pike). The minimum and maximum values of 1970-2000 period norms and changes under future periods are then aggregated over the entire St Lawrence drainage and summarized along with all other species in tables A.4.13 to A.4.17 (time-dependent spawning date, temperature-dependent spawning date, hatching date, hatching success, and adult growth).

For all variables, trends in changes over future time periods tend to be similar, with greater magnitude of change as one proceeds later in time. The only exceptions are the 02G and 02Z secondary watersheds which may lose all winter ice cover by 2071-2100. This qualitative change in the system is reflected in the projections for those time periods.

Three of the spring spawning species (Northern Pike, Smallmouth Bass and Walleye) are missing from certain secondary watersheds in the St Lawrence region under 1970-2000 climate conditions due to having a projected growth period of less than zero in those watersheds. Future warming may allow these species to become viable in those areas. The areas where those species are missing and the time period when they may first become viable are summarized in table A.4.17.

For fall spawning species, temperature dependent spawning results in later spawning dates and later hatching dates, although the delay in hatching is mostly due to the delayed spawning. The delay can be one to two weeks by 2041-2070 or up to a month by 2071-2100. The hatching success for temperature dependent spawning does not change much from the 1970-2000 norms. If spawning is time dependent, the hatching date is earlier than the norms. The eggs develop much more quickly and, depending on species, can hatch up to two weeks to one month earlier by 2041-2070. By 2071-2100, hatching can be one to three months early. The hatching success for time dependent spawning will increase under warmer conditions. However, due to the much shorter incubation period, fries may hatch much earlier than the arrival of the spring conditions to which they are adapted to under the 1970-2000 climate regime. Overall recruitment may be drastically lowered as a result. The length of the growth period does not change much but there is a maximum increase of about three weeks in 2071-2100.

For spring spawning species, temperature dependent spawning will result in an earlier spawning dates and hatching dates. Again, the change in hatching date is mostly due to the change in spawning date and not changes to the length of the incubation period. In SWS 02G, the lack of ice cover in 2071-2100 can cause spawning and hatching to occur up to two to three months earlier, but in most cases the spawning and hatching dates are only a week earlier. The change in hatching success can be varied, with increases or decreases under different conditions but the magnitude of the change is usually under 10%. Cases where the magnitude of the change is greater than 10%, the change is positive. Under the time dependent spawning scenario, the hatching date is either unchanged or is a few days earlier but the hatching success will undergo large reductions, possibly leading to zero egg survival. Changes to the length of growth period will be either small or an increase of up to two to three week by 2041-2070 and up to one month by 2071-2100.

Species distributions

The patterns of species occurrences show how the direct influence of the Great Lakes and the indirect influence of glacial history and refugia (Table A.4.18). Species richness varied from 7 to 138 among the watersheds. Watersheds draining into the St. Lawrence R. have far fewer species than those draining into Great Lakes. The eastern watersheds are cooler and may be able to accommodate more species with warming although the saltwater in the lower St.

Lawrence will create a barrier whereby only euryhaline species will be able to spread. Within the Great Lakes, pathways for spread already exist although the cooler watersheds in the upper lakes can likely accommodate more species from the main lake ensembles once those watershed are warmer. The greater concern is how warming further north may facilitate expansion of more Great Lake species into the Hudson's-James Bay drainages (PWS 04).

Potential sustainable yield (total)

The total potential sustainable fish yield of lakes in the 02 drainage for the 1971-2000 climate norms was 149,833 MT/y with much of it accounted for in the yields of the Great Lakes (Table A.4.19). Projected percentage changes for future time periods have a wide range. The lowest ranges of percentage change were for the B1*2011-2040 combination with a minima range of +3.9 to +16.0% and a maxima range of +15.9 to +25.6%. The highest ranges were for the A2*2071-2100 combination with a minima range of +35.6 to +64.9% and a maxima range of +59.8 to +92.4%. The ranges of the reference A2*2041-2070 combination were in between with a minima range of +20.9 to +38.7% and a maxima range of +35.5 to +48.0%.The spatial locations of minima and maxima varied across emission scenarios and time periods though the Newfoundland watersheds (02Y and 02Z) had many of the minima.

Potential sustainable yield (selected species)

For the three fish species considered (Lake Whitefish, Northern Pike and Walleye) projected decreases are the most common outcome across the watersheds of the 02 drainage (Table A.4.20). The projected increases are concentrated in the eastern watershed along the St. Lawrence for Northern Pike and Walleye. At present Walleye is absent in most of the watersheds with projected increases.

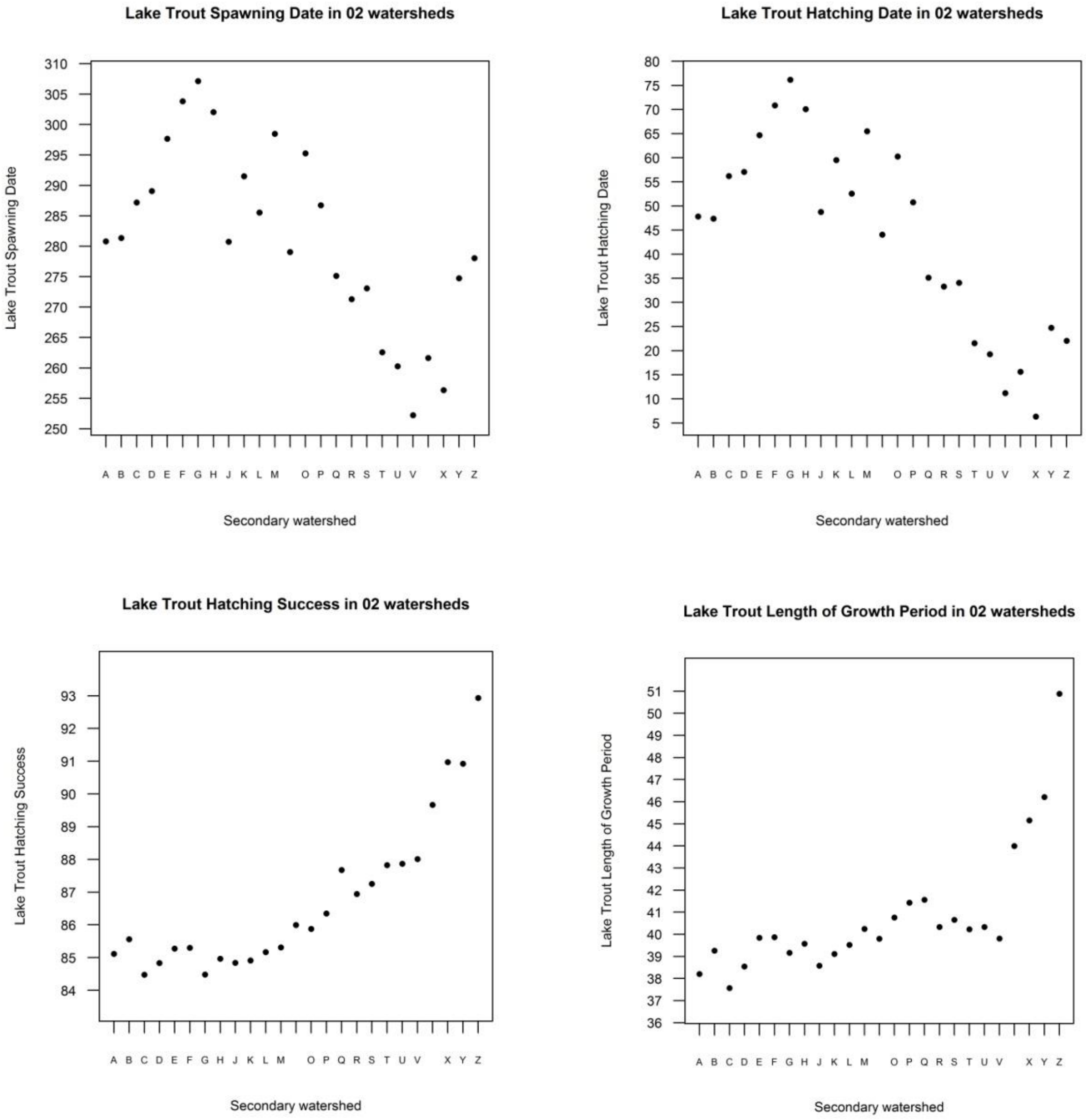
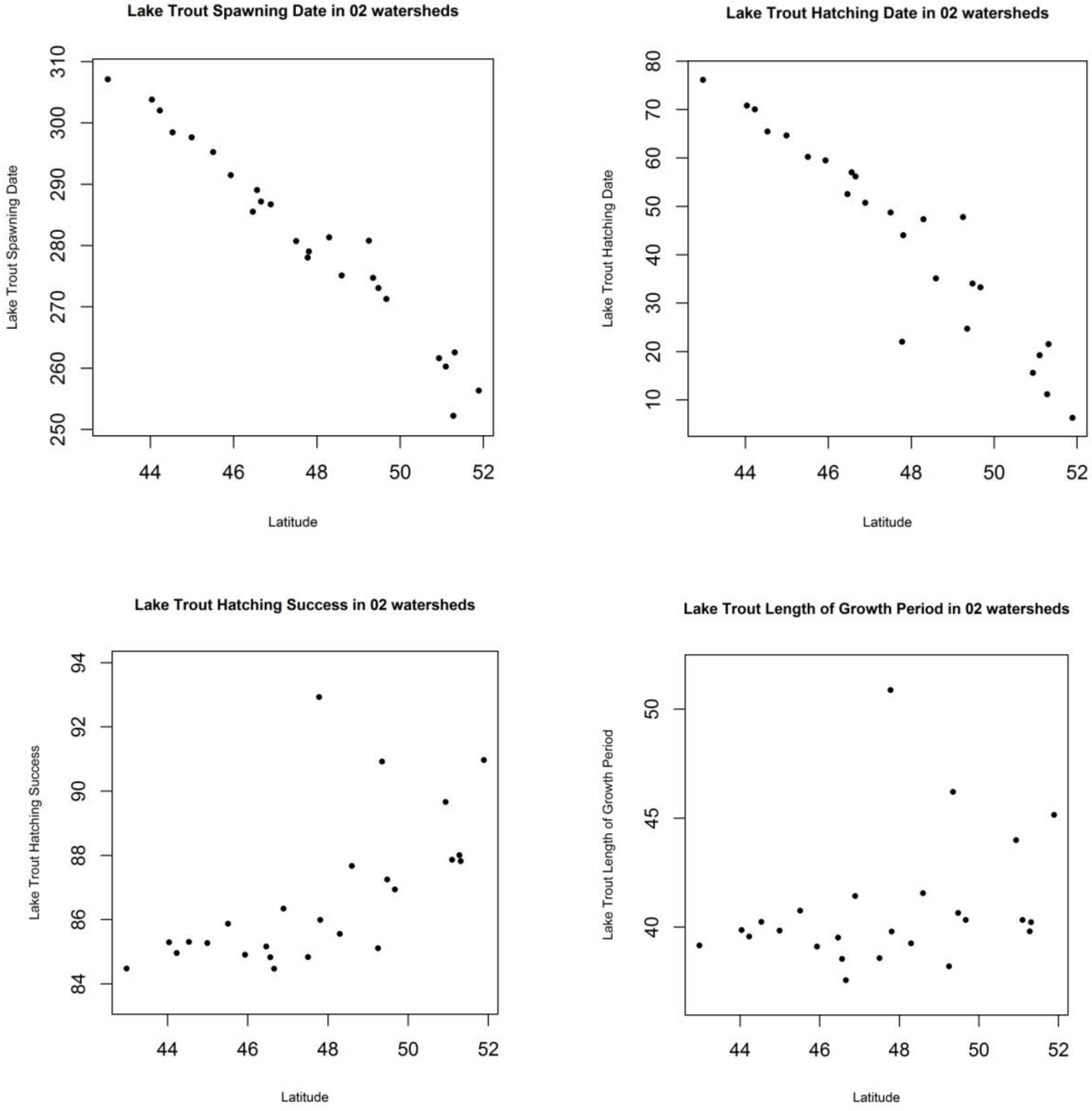


Figure A.4.1. Summary of projected Lake Trout spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by secondary watershed in the 02 drainage.


Lake Trout Spawning Date in 02 watersheds

Lake Trout Hatching Date in 02 watersheds

Lake Trout Hatching Success in 02 watersheds

Lake Trout Length of Growth Period in 02 watersheds

Figure A.4.2. Summary of projected Lake Trout spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by latitude in the 02 drainage.

Table A.4.1. Summary of projected temperature dependent spawning dates for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Temperature Dependent Spawning Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	281	1	6	5	11	9	17
02B	281	2	8	7	13	11	19
02C	287	4	10	9	15	13	19
02D	289	6	10	10	12	14	19
02E	298	5	8	5	12	10	21
02F	304	1	4	5	11	10	22
02G	307	4	7	8	15	-7	26
02H	302	3	5	6	11	10	23
02J	281	6	11	10	15	15	19
02K	292	5	9	9	11	13	17
02L	286	6	9	9	14	14	18
02M	298	5	8	6	10	10	18
02N	279	3	7	7	12	11	18
02O	295	5	8	8	10	10	17
02P	287	5	8	9	11	14	17
02Q	275	3	6	6	12	11	18
02R	271	2	4	4	10	10	15
02S	273	2	5	6	11	11	17
02T	263	4	6	6	10	9	16
02U	260	4	5	7	10	10	16
02V	252	5	6	8	12	13	17
02W	262	3	6	7	13	13	19
02X	256	3	7	7	14	13	21
02Y	275	3	8	8	13	12	25
02Z	278	2	6	6	13	11	28
Min	252	1	4	4	10	-7	15
Max	307	6	11	10	15	15	28

Table A.4.2. Summary of projected temperature dependent hatching dates for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Temperature Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	48	3	4	6	9	9	13
02B	47	3	5	7	10	10	15
02C	56	3	5	7	10	10	14
02D	57	5	6	8	10	11	16
02E	65	4	6	5	9	9	14
02F	71	1	3	5	8	9	14
02G	76	3	5	6	10	-29	18
02H	70	3	5	6	8	9	16
02J	49	4	6	8	10	12	16
02K	60	4	6	7	9	10	14
02L	53	4	6	7	10	11	16
02M	65	4	6	6	8	9	14
02N	44	2	4	6	8	9	13
02O	60	4	6	7	9	10	14
02P	51	3	4	7	9	11	13
02Q	35	3	4	6	9	10	15
02R	33	2	4	5	8	8	14
02S	34	3	5	7	9	10	16
02T	22	2	6	5	9	9	16
02U	19	2	5	6	9	9	16
02V	11	3	6	6	9	10	16
02W	16	3	6	7	10	11	18
02X	6	3	7	7	11	10	18
02Y	25	2	5	6	10	10	16
02Z	22	3	6	6	11	9	16
Min	6	1	3	5	8	-29	13
Max	76	5	7	8	11	12	18

Table A.4.3. Summary of projected time dependent hatching dates for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Time Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	48	-21	0	-40	-15	-66	-30
02B	47	-28	-5	-47	-20	-72	-37
02C	56	-35	-13	-57	-29	-74	-47
02D	57	-36	-18	-42	-33	-72	-51
02E	65	-25	-16	-42	-16	-78	-33
02F	71	-15	-3	-41	-16	-80	-33
02G	76	-22	-14	-59	-27	-89	-21
02H	70	-18	-10	-40	-18	-83	-35
02J	49	-39	-20	-59	-36	-72	-54
02K	60	-30	-15	-39	-29	-66	-44
02L	53	-32	-19	-52	-32	-66	-49
02M	65	-26	-15	-35	-18	-68	-35
02N	44	-24	-8	-42	-22	-67	-39
02O	60	-26	-17	-33	-24	-63	-33
02P	51	-29	-17	-40	-29	-64	-48
02Q	35	-21	-6	-41	-18	-64	-37
02R	33	-14	-4	-32	-12	-57	-31
02S	34	-17	-4	-38	-16	-61	-36
02T	22	-19	-11	-33	-20	-57	-29
02U	19	-18	-11	-34	-22	-56	-29
02V	11	-20	-15	-42	-25	-59	-47
02W	16	-18	-7	-45	-19	-61	-43
02X	6	-21	-6	-46	-19	-61	-43
02Y	25	-25	-10	-43	-26	-67	-38
02Z	22	-17	-5	-39	-18	-64	-34
Min	6	-39	-20	-59	-36	-89	-54
Max	76	-14	0	-32	-12	-56	-21

Table A.4.4. Summary of projected temperature dependent hatching success for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Temperature Dependent Hatching Success							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	85.12%	-0.50%	0.75%	-0.24%	0.83%	-0.26%	1.36%
02B	85.56%	-0.39%	0.97%	-0.04%	1.06%	-0.04%	1.73%
02C	84.48%	0.45%	1.68%	0.78%	1.85%	0.98%	2.09%
02D	84.83%	0.48%	1.39%	0.72%	0.98%	0.76%	1.68%
02E	85.27%	0.38%	0.68%	-0.04%	0.98%	0.21%	2.22%
02F	85.30%	-0.17%	0.53%	0.03%	1.18%	0.21%	2.55%
02G	84.48%	0.29%	0.75%	0.64%	1.69%	1.10%	10.64%
02H	84.97%	-0.15%	0.36%	-0.02%	0.88%	0.19%	2.30%
02J	84.84%	0.49%	1.67%	0.80%	1.74%	0.79%	1.66%
02K	84.91%	0.38%	1.06%	0.61%	0.92%	0.02%	1.37%
02L	85.17%	0.49%	1.31%	0.71%	1.45%	0.76%	1.38%
02M	85.31%	0.28%	0.60%	-0.11%	0.63%	0.13%	1.36%
02N	86.00%	-0.01%	1.02%	0.28%	1.20%	0.48%	1.70%
02O	85.88%	0.31%	0.81%	0.00%	0.46%	0.01%	1.11%
02P	86.35%	0.48%	1.16%	0.52%	1.22%	0.17%	1.29%
02Q	87.68%	-0.39%	0.60%	-0.15%	0.87%	0.18%	1.54%
02R	86.94%	-0.66%	0.63%	-0.32%	0.70%	-0.05%	1.32%
02S	87.25%	-0.60%	0.36%	-0.31%	0.70%	-0.03%	1.28%
02T	87.83%	0.20%	1.15%	0.34%	0.53%	-0.26%	1.19%
02U	87.87%	0.10%	1.06%	0.13%	1.40%	-0.24%	1.11%
02V	88.01%	-0.03%	1.01%	0.30%	1.31%	0.24%	1.01%
02W	89.67%	-0.67%	0.06%	-0.10%	0.98%	0.41%	1.33%
02X	90.97%	-0.28%	0.67%	-0.31%	1.31%	0.34%	1.74%
02Y	90.92%	0.36%	1.01%	0.71%	1.03%	0.44%	3.11%
02Z	92.93%	-0.22%	0.13%	0.05%	0.80%	0.50%	4.20%
Min	84.48%	-0.67%	0.06%	-0.32%	0.46%	-0.26%	1.01%
Max	92.93%	0.49%	1.68%	0.80%	1.85%	1.10%	10.64%

Table A.4.5. Summary of projected time dependent hatching success for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Time Dependent Hatching Success

SWS	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
02A	85.12%	-0.05%	5.31%	3.59%	9.67%	7.19%	12.86%
02B	85.56%	1.12%	6.87%	4.76%	11.24%	8.73%	11.27%
02C	84.48%	3.34%	8.77%	7.13%	13.48%	11.27%	13.03%
02D	84.83%	4.49%	8.88%	7.98%	10.09%	11.60%	13.33%
02E	85.27%	3.96%	6.14%	3.79%	10.03%	7.78%	11.68%
02F	85.30%	0.65%	3.65%	3.77%	9.87%	7.39%	11.52%
02G	84.48%	3.48%	5.48%	6.63%	13.53%	-1.42%	13.23%
02H	84.97%	2.24%	4.32%	4.19%	9.57%	5.63%	12.02%
02J	84.84%	4.99%	9.68%	8.69%	13.66%	11.72%	13.52%
02K	84.91%	3.75%	7.41%	6.97%	9.27%	10.32%	13.13%
02L	85.17%	4.71%	7.98%	7.75%	12.50%	11.65%	13.61%
02M	85.31%	3.66%	6.30%	4.20%	8.36%	8.17%	12.59%
02N	86.00%	1.97%	5.92%	5.21%	10.14%	9.16%	12.44%
02O	85.88%	4.14%	6.49%	5.70%	7.92%	7.81%	12.96%
02P	86.35%	4.08%	7.10%	6.89%	9.64%	11.32%	12.53%
02Q	87.68%	1.34%	5.09%	4.16%	9.78%	8.66%	12.32%
02R	86.94%	0.71%	3.49%	2.76%	7.78%	7.24%	12.94%
02S	87.25%	0.84%	4.15%	3.78%	9.15%	8.44%	12.21%
02T	87.83%	2.86%	4.94%	4.96%	8.00%	6.81%	12.06%
02U	87.87%	2.78%	4.68%	5.40%	8.49%	6.85%	12.05%
02V	88.01%	3.62%	5.07%	6.00%	10.12%	11.18%	11.84%
02W	89.67%	1.57%	4.30%	4.51%	10.33%	9.50%	10.33%
02X	90.97%	1.43%	5.10%	4.53%	9.03%	7.99%	9.03%
02Y	90.92%	2.59%	6.31%	6.51%	9.08%	5.22%	9.08%
02Z	92.93%	1.23%	4.19%	4.45%	7.07%	1.66%	7.07%
Min	84.48%	-0.05%	3.49%	2.76%	7.07%	-1.42%	7.07%
Max	92.93%	4.99%	9.68%	8.69%	13.66%	11.72%	13.61%

Table A.4.6. Summary of projected length of growth period for Lake Trout in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Lake Trout Length of Growth Period							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	38	-1	1	-1	0	-2	1
02B	39	-1	1	-1	1	-1	1
02C	38	0	2	0	2	0	2
02D	39	0	1	0	0	0	1
02E	40	0	0	-1	0	-1	2
02F	40	-1	0	-1	1	0	2
02G	39	0	1	0	1	0	10
02H	40	-1	0	-1	0	-1	2
02J	39	0	2	0	1	-1	1
02K	39	0	1	0	0	-1	1
02L	40	0	1	0	1	0	1
02M	40	0	0	-1	0	-1	1
02N	40	0	1	0	1	-1	1
02O	41	0	1	-1	0	-1	0
02P	41	0	1	0	1	-1	0
02Q	42	-1	0	-1	0	-1	1
02R	40	-1	1	-1	0	-1	1
02S	41	-1	0	-1	0	-1	1
02T	40	0	1	0	0	-1	1
02U	40	0	1	0	1	-1	1
02V	40	0	1	0	1	-1	1
02W	44	-2	0	-1	1	-1	1
02X	45	-1	1	-1	1	-1	2
02Y	46	0	1	0	1	-1	3
02Z	51	-1	0	-1	0	0	19
Min	38	-2	0	-1	0	-2	0
Max	51	0	2	0	2	0	19

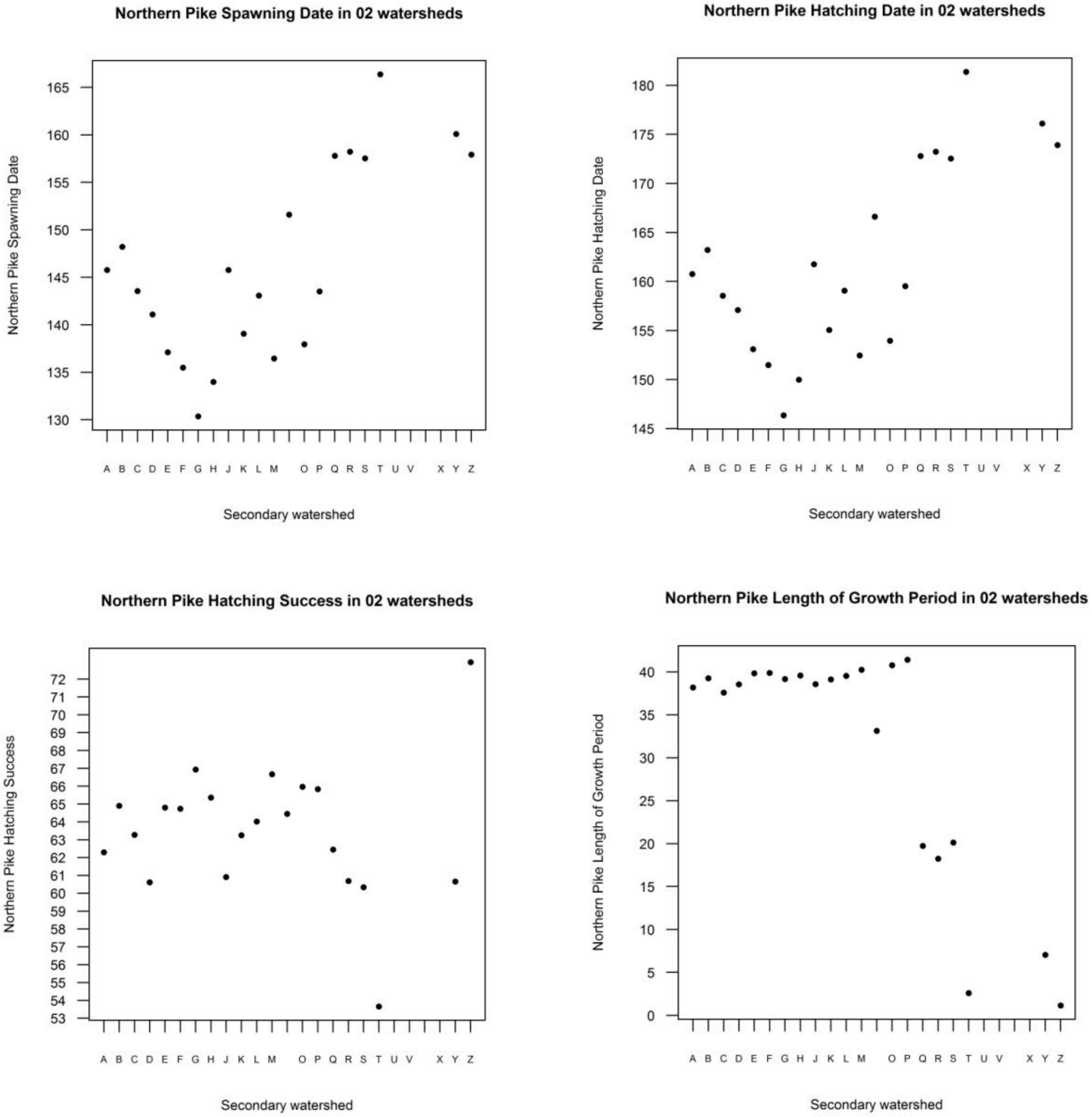
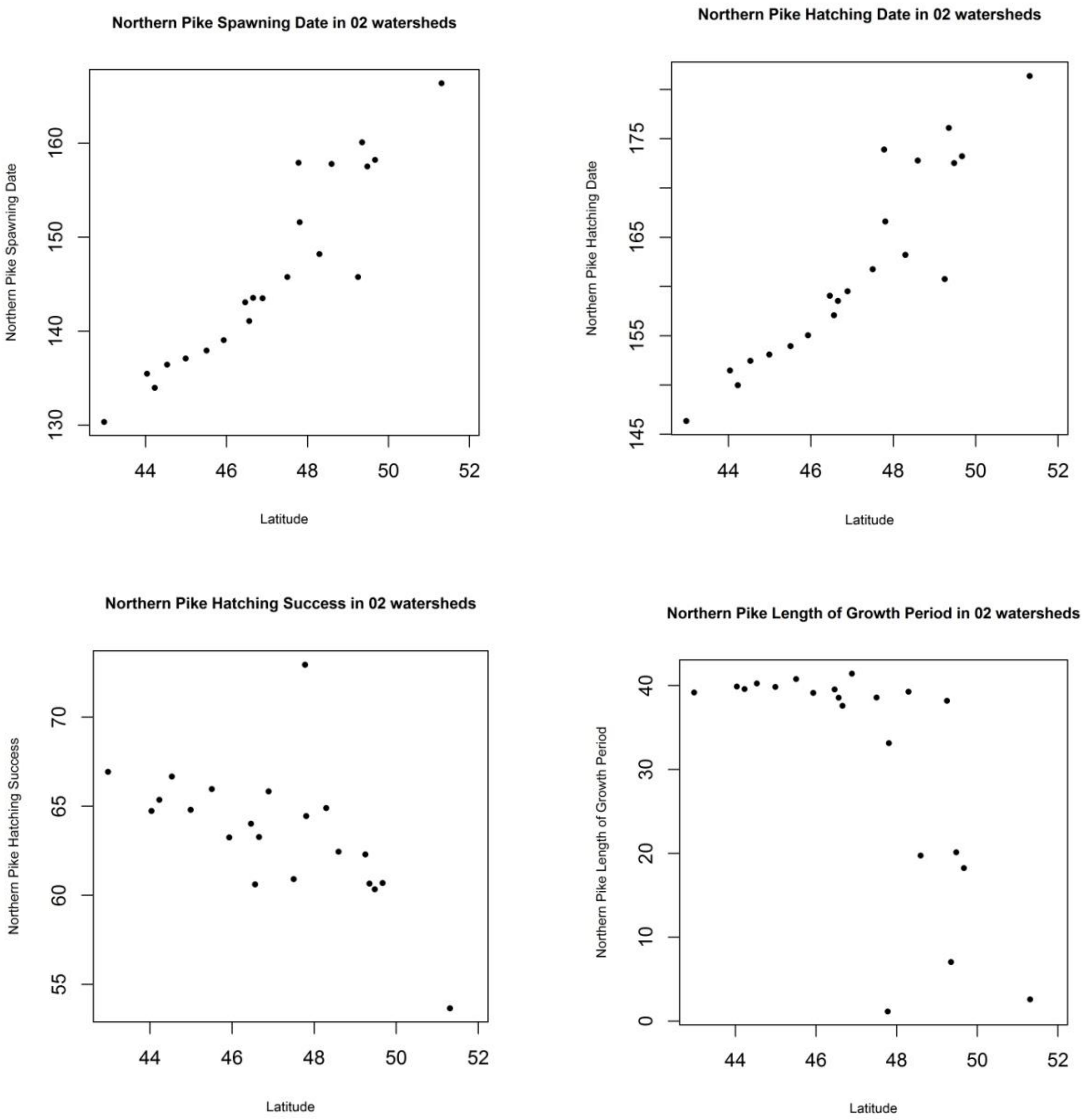


Figure A.4.3. Summary of projected Northern Pike spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by secondary watershed in the 02 drainage.



Northern Pike Spawning Date in 02 watersheds

Northern Pike Hatching Date in 02 watersheds

Northern Pike Hatching Success in 02 watersheds

Northern Pike Length of Growth Period in 02 watersheds

Figure A.4.4. Summary of projected Northern Pike spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by latitude in the 02 drainage.

Table A.4.7. Summary of projected temperature dependent spawning dates for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Temperature Dependent Spawning Date

SWS	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
02A	146	-1	-1	-3	-2	-5	-4
02B	148	-3	-2	-4	-3	-8	-5
02C	144	-1	0	-2	-1	-5	-3
02D	141	-2	-1	-3	-2	-6	-4
02E	137	-2	-1	-3	-2	-7	-4
02F	135	-2	-1	-3	-2	-22	-4
02G	130	-2	-1	-3	-2	-94	-4
02H	134	-2	-1	-3	-2	-8	-4
02J	146	-2	-1	-3	-2	-6	-4
02K	139	-2	-1	-3	-2	-6	-3
02L	143	-2	-1	-4	-2	-6	-4
02M	136	-2	-1	-3	-2	-6	-4
02N	152	-2	0	-3	-2	-6	-4
02O	138	-3	-2	-3	-2	-7	-4
02P	144	-1	-1	-3	-2	-6	-4
02Q	158	-2	-1	-4	-2	-6	-5
02R	158	-1	0	-3	-2	-6	-4
02S	158	-2	-1	-4	-2	-7	-5
02T	166	-1	0	-4	-2	-7	-4
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	160	-2	-1	-3	-2	-7	-5
02Z	158	-2	-1	-4	-2	-59	-4
Min	130	-3	-2	-4	-3	-94	-5
Max	166	-1	0	-2	-1	-5	-3

Table A.4.8. Summary of projected temperature dependent hatching dates for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Temperature Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	161	-1	-1	-3	-2	-5	-4
02B	163	-3	-2	-4	-3	-8	-5
02C	159	-1	0	-2	-1	-5	-3
02D	157	-3	-2	-4	-3	-7	-5
02E	153	-2	-1	-4	-2	-8	-5
02F	151	-2	-1	-3	-2	-22	-4
02G	146	-2	-1	-3	-2	-92	-4
02H	150	-2	-1	-3	-2	-9	-5
02J	162	-3	-1	-4	-3	-7	-5
02K	155	-2	-1	-4	-3	-7	-4
02L	159	-2	-1	-5	-2	-7	-5
02M	152	-2	-1	-3	-2	-7	-4
02N	167	-2	0	-3	-2	-6	-4
02O	154	-3	-2	-3	-2	-8	-4
02P	160	-1	-1	-3	-2	-7	-5
02Q	173	-2	-1	-4	-2	-6	-5
02R	173	-1	0	-3	-2	-6	-4
02S	173	-2	-1	-4	-2	-7	-5
02T	181	-1	0	-4	-2	-7	-4
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	176	-3	-1	-4	-3	-8	-6
02Z	174	-2	-1	-4	-2	-57	-4
Min	146	-3	-2	-5	-3	-92	-6
Max	181	-1	0	-2	-1	-5	-3

Table A.4.9. Summary of projected time dependent hatching dates for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Time Dependent Hatching Date

SWS	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
02A	161	0	0	-1	-1	-3	-2
02B	163	-1	-1	-2	-1	-3	-2
02C	159	0	0	-1	0	-2	-1
02D	157	-1	-1	-2	-2	-4	-2
02E	153	-1	-1	-2	-1	-4	-2
02F	151	-1	-1	-2	-1	-8	-2
02G	146	-1	-1	-2	-1	-13	-2
02H	150	-1	-1	-2	-1	-4	-2
02J	162	-2	-1	-2	-2	-4	-3
02K	155	-1	-1	-2	-2	-3	-2
02L	159	-1	-1	-2	-2	-4	-3
02M	152	-1	-1	-2	-1	-3	-2
02N	167	0	0	-1	-1	-3	-2
02O	154	-1	-1	-2	-2	-3	-2
02P	160	-1	-1	-2	-1	-3	-2
02Q	173	-1	0	-2	-1	-3	-2
02R	173	-1	0	-1	-1	-3	-2
02S	173	-1	0	-2	-1	-3	-2
02T	181	-1	0	-2	-1	-4	-2
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	176	-2	-1	-2	-2	-4	-3
02Z	174	-1	0	-2	-1	-10	-2
Min	146	-2	-1	-2	-2	-13	-3
Max	181	0	0	-1	0	-2	-1

Table A.4.10. Summary of projected temperature dependent hatching success for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Temperature Dependent Hatching Success							
	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	62.30%	-2.63%	-1.05%	-5.16%	-4.01%	-9.29%	-5.50%
02B	64.91%	-2.61%	-1.85%	-6.03%	-4.33%	-8.66%	-6.03%
02C	63.27%	-1.86%	-1.01%	-5.07%	-3.40%	-8.62%	-4.77%
02D	60.61%	2.16%	4.09%	-0.13%	1.00%	-2.81%	-0.77%
02E	64.80%	-2.94%	-1.88%	-4.91%	0.00%	-2.67%	-0.04%
02F	64.74%	-2.74%	-1.32%	-5.12%	-4.02%	-4.63%	8.24%
02G	66.94%	-3.66%	-1.21%	-5.17%	-3.76%	-5.59%	30.37%
02H	65.36%	-3.11%	-1.72%	-5.31%	-4.45%	-5.12%	-0.26%
02J	60.91%	-1.30%	3.57%	-0.67%	0.51%	-4.08%	-1.54%
02K	63.25%	-2.35%	-1.09%	0.46%	1.24%	-3.22%	-0.12%
02L	64.02%	-2.95%	-0.70%	-4.22%	1.00%	-2.77%	0.11%
02M	66.67%	-3.71%	-1.94%	-6.27%	-4.97%	-6.61%	-2.65%
02N	64.45%	-1.80%	-0.65%	-4.54%	-2.72%	-7.49%	-4.81%
02O	65.96%	-1.93%	-1.18%	-5.01%	-3.72%	-5.96%	-1.38%
02P	65.83%	-3.28%	-1.27%	-5.82%	-4.29%	-2.80%	-0.90%
02Q	62.45%	-2.51%	-1.00%	-5.06%	-3.25%	-8.63%	-4.77%
02R	60.69%	-2.17%	-0.68%	-5.03%	-2.78%	-7.86%	-4.80%
02S	60.34%	-2.34%	-0.89%	-5.21%	-3.53%	-8.00%	-4.75%
02T	53.65%	-2.14%	-1.16%	-3.32%	-2.15%	-4.89%	-3.47%
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	60.66%	-0.67%	4.45%	-0.02%	2.46%	-2.23%	2.68%
02Z	72.95%	-2.70%	-0.16%	-5.71%	-2.94%	-8.63%	25.25%
Min	53.65%	-3.71%	-1.94%	-6.27%	-4.97%	-9.29%	-6.03%
Max	72.95%	2.16%	4.45%	0.46%	2.46%	-2.23%	30.37%

Table A.4.11. Summary of projected time dependent hatching success for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Time Dependent Hatching Success							
	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
02A	62.30%	-11.46%	-5.44%	-19.98%	-12.48%	-35.56%	-25.71%
02B	64.91%	-18.39%	-11.13%	-25.09%	-22.64%	-50.27%	-36.24%
02C	63.27%	-10.81%	-2.94%	-16.40%	-12.66%	-36.39%	-22.11%
02D	60.61%	-8.65%	-3.94%	-17.84%	-8.48%	-37.75%	-21.40%
02E	64.80%	-10.57%	-3.39%	-17.65%	-10.33%	-38.47%	-22.14%
02F	64.74%	-10.89%	-0.12%	-17.04%	-10.44%	-64.74%	-20.83%
02G	66.94%	-12.02%	-1.80%	-18.30%	-9.77%	-66.94%	-20.88%
02H	65.36%	-12.51%	-5.31%	-18.46%	-13.92%	-46.45%	-24.44%
02J	60.91%	-8.04%	-4.28%	-18.76%	-9.44%	-34.82%	-21.43%
02K	63.25%	-10.48%	-4.62%	-18.34%	-9.31%	-35.41%	-20.92%
02L	64.02%	-10.14%	-4.77%	-20.32%	-10.32%	-36.48%	-23.92%
02M	66.67%	-11.02%	-5.44%	-19.17%	-13.88%	-38.57%	-23.90%
02N	64.45%	-13.67%	-3.54%	-22.78%	-14.45%	-40.57%	-28.20%
02O	65.96%	-15.35%	-7.11%	-17.80%	-11.17%	-40.18%	-23.81%
02P	65.83%	-7.97%	-2.93%	-16.39%	-11.10%	-36.91%	-25.53%
02Q	62.45%	-13.10%	-9.61%	-21.72%	-17.21%	-37.40%	-32.01%
02R	60.69%	-7.50%	-2.54%	-21.00%	-12.94%	-39.45%	-25.90%
02S	60.34%	-12.42%	-9.29%	-23.51%	-15.85%	-42.67%	-32.51%
02T	53.65%	-6.11%	-0.70%	-19.61%	-9.95%	-40.45%	-23.42%
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	60.66%	-7.31%	-3.16%	-18.83%	-7.95%	-36.57%	-21.93%
02Z	72.95%	-11.68%	-7.54%	-22.90%	-14.18%	-72.95%	-21.76%
Min	53.65%	-18.39%	-11.13%	-25.09%	-22.64%	-72.95%	-36.24%
Max	72.95%	-6.11%	-0.12%	-16.39%	-7.95%	-34.82%	-20.83%

Table A.4.12. Summary of projected length of growth period for Northern Pike in the 02 watershed under 1971-2000 normals and the projected change over three future time periods.

SWS 02 – Northern Pike Length of Growth Period

SWS	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
02A	38	-1	1	-1	0	-2	1
02B	39	-1	1	-1	1	-1	1
02C	38	0	2	0	2	0	2
02D	39	0	1	0	0	0	1
02E	40	0	0	-1	0	-1	2
02F	40	-1	0	-1	1	0	2
02G	39	0	1	0	1	0	10
02H	40	-1	0	-1	0	-1	2
02J	39	0	2	0	1	-1	1
02K	39	0	1	0	0	-1	1
02L	40	0	1	0	1	0	1
02M	40	0	0	-1	0	-1	1
02N	33	3	6	6	7	6	8
02O	41	0	1	-1	0	-1	0
02P	41	0	1	0	1	-1	0
02Q	20	6	8	11	15	18	23
02R	18	3	6	8	12	16	21
02S	20	5	8	11	15	18	21
02T	3	3	7	8	13	15	25
02U	**No Growth**	**Viable**		**Viable**		**Viable**	
02V	**No Growth**	**No Growth**		**No Growth**		**Viable**	
02W	**No Growth**	**No Growth**		**Viable**		**Viable**	
02X	**No Growth**	**No Growth**		**No Growth**		**No Growth**	
02Y	7	4	8	9	16	16	26
02Z	1	4	9	9	17	14	36
Min	1	-1	0	-1	0	-2	0
Max	41	6	9	11	17	18	36

Table A.4.13. Summary of projected time dependent spawning dates in the 02 watershed under 1971-2000 normals.

	SWS 02 - Time Dependent Spawning Date						
	Fall Spawners		Spring Spawners				
SWS	Brook Trout	Lake Trout	Lake Whitefish	Northern Pike	Smallmouth Bass	Walleye	Yellow Perch
02A	280	281	310	146	186	150	154
02B	281	281	311	148	**NG**	152	157
02C	287	287	315	144	184	148	152
02D	288	289	318	141	183	145	150
02E	297	298	327	137	181	141	147
02F	303	304	333	135	179	140	145
02G	307	307	335	130	175	135	140
02H	301	302	331	134	178	138	144
02J	280	281	309	146	188	150	155
02K	291	292	320	139	182	143	148
02L	285	286	315	143	187	147	152
02M	298	298	328	136	181	141	146
02N	278	279	310	152	**NG**	156	161
02O	295	295	326	138	182	142	148
02P	286	287	318	144	**NG**	148	153
02Q	274	275	308	158	**NG**	162	167
02R	271	271	303	158	**NG**	**NG**	167
02S	272	273	306	158	**NG**	161	166
02T	262	263	296	166	**NG**	**NG**	174
02U	260	260	294	**NG**	**NG**	**NG**	176
02V	252	252	286	**NG**	**NG**	**NG**	184
02W	261	262	298	**NG**	**NG**	**NG**	176
02X	256	256	295	**NG**	**NG**	**NG**	180
02Y	274	275	313	160	**NG**	**NG**	169
02Z	277	278	319	158	**NG**	**NG**	168
Min	252	252	286	130	175	135	140
Max	307	307	335	166	188	162	184

*NG = No Growth

Table A.4.14. Summary of projected change in temperature dependent spawning date in the 02 watersheds over three future time periods.

SWS 02 - Temperature Dependent Spawning Date								
		1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
Species			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	252	1	4	4	10	-7	15
	Max	307	6	11	10	15	15	28
Lake Trout	Min	252	1	4	4	10	-7	15
	Max	307	6	11	10	15	15	28
Lake Whitefish	Min	286	0	5	4	11	-12	17
	Max	335	7	13	12	18	16	35
Spring Spawner								
Northern Pike	Min	130	-3	-2	-4	-3	-94	-5
	Max	166	-1	0	-2	-1	-5	-3
Smallmouth Bass	Min	175	-4	-2	-6	-5	-56	-7
	Max	188	-2	-1	-5	-3	-9	-6
Walleye	Min	135	-3	-2	-4	-3	-90	-6
	Max	162	-1	0	-2	-1	-6	-3
Yellow Perch	Min	140	-3	-2	-5	-4	-85	-6
	Max	184	-1	0	-3	-2	-6	-4

Table A.4.15. Summary of projected change in hatching date in the 02 drainage over three future time periods.

SWS 02 - Temperature Dependent Hatching Date

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	3	1	4	4	10	-7	15
	Max	359	6	11	10	15	15	27
Lake Trout	Min	6	1	3	5	8	-29	13
	Max	76	5	7	8	11	12	18
Lake Whitefish	Min	44	0	5	4	11	-46	17
	Max	94	7	13	12	18	16	28
Spring Spawner								
Northern Pike	Min	146	-3	-2	-5	-3	-92	-6
	Max	181	-1	0	-2	-1	-5	-3
Smallmouth Bass	Min	185	-4	-2	-6	-5	-55	-7
	Max	198	-2	-1	-5	-3	-9	-6
Walleye	Min	152	-4	-3	-5	-4	-88	-7
	Max	178	-1	0	-2	-1	-6	-3
Yellow Perch	Min	159	-4	-2	-6	-4	-82	-7
	Max	201	-1	0	-3	-2	-7	-4

SWS 02 - Time Dependent Hatching Date

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	3	-1	-1	-2	-1	-4	-2
	Max	359	0	0	-1	0	-2	0
Lake Trout	Min	6	-39	-20	-59	-36	-89	-54
	Max	76	-14	0	-32	-12	-56	-21
Lake Whitefish	Min	44	-15	-7	-23	-12	-50	-19
	Max	94	-4	0	-11	-3	-20	-9
Spring Spawner								
Northern Pike	Min	146	-2	-1	-2	-2	-13	-3
	Max	181	0	0	-1	0	-2	-1
Smallmouth Bass	Min	185	-1	-1	-2	-2	-6	-2
	Max	198	-1	0	-2	-1	-3	-2
Walleye	Min	152	-2	-1	-2	-2	-11	-3
	Max	178	0	0	-1	0	-2	-1
Yellow Perch	Min	159	-2	-1	-4	-2	-15	-4
	Max	201	-1	0	-2	-1	-4	-2

Table A.4.16. Summary of projected change in hatching success in the 02 drainage over three future time periods.

SWS 02 - Temperature Dependent Hatching Success

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	83.65%	-0.61%	0.10%	-0.29%	0.48%	-0.21%	0.93%
	Max	91.52%	0.51%	1.52%	0.77%	1.76%	1.04%	7.23%
Lake Trout	Min	84.48%	-0.67%	0.06%	-0.32%	0.46%	-0.26%	1.01%
	Max	92.93%	0.49%	1.68%	0.80%	1.85%	1.10%	10.64%
Lake Whitefish	Min	73.36%	-0.29%	0.04%	-0.12%	0.19%	-0.08%	0.42%
	Max	76.55%	0.20%	0.61%	0.32%	1.19%	0.88%	17.19%
Spring Spawner								
Northern Pike	Min	53.65%	-3.71%	-1.94%	-6.27%	-4.97%	-9.29%	-6.03%
	Max	72.95%	2.16%	4.45%	0.46%	2.46%	-2.23%	30.37%
Smallmouth Bass	Min	91.38%	-1.64%	-0.86%	-3.13%	-2.52%	-6.06%	-3.55%
	Max	95.95%	-0.82%	-0.30%	-2.11%	-1.49%	-2.31%	4.05%
Walleye	Min	56.64%	-3.27%	-1.72%	-5.56%	-4.44%	-8.20%	-5.57%
	Max	63.74%	2.29%	3.01%	0.52%	2.19%	-2.05%	32.23%
Yellow Perch	Min	40.13%	-3.69%	-1.72%	-5.55%	-4.44%	-7.48%	-5.68%
	Max	57.46%	0.98%	3.19%	-0.35%	1.51%	-0.67%	37.49%

SWS 02 - Time Dependent Hatching Success

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	83.65%	-0.17%	1.97%	1.45%	4.12%	3.32%	6.87%
	Max	91.52%	2.92%	5.41%	4.58%	7.23%	6.35%	9.07%
Lake Trout	Min	84.48%	-0.05%	3.49%	2.76%	7.07%	-1.42%	7.07%
	Max	92.93%	4.99%	9.68%	8.69%	13.66%	11.72%	13.61%
Lake Whitefish	Min	73.36%	-0.17%	2.56%	1.68%	5.64%	-2.35%	7.82%
	Max	76.55%	3.74%	7.61%	6.33%	9.05%	8.16%	11.60%
Spring Spawner								
Northern Pike	Min	53.65%	-18.39%	-11.13%	-25.09%	-22.64%	-72.95%	-36.24%
	Max	72.95%	-6.11%	-0.12%	-16.39%	-7.95%	-34.82%	-20.83%
Smallmouth Bass	Min	91.38%	-20.38%	-7.43%	-45.68%	-27.50%	-95.95%	-62.00%
	Max	95.95%	-8.93%	-4.92%	-29.06%	-18.70%	-78.24%	-39.80%
Walleye	Min	56.64%	-14.77%	-10.54%	-26.42%	-17.68%	-63.74%	-32.21%
	Max	63.74%	-8.25%	1.18%	-16.90%	-9.83%	-36.13%	-21.30%
Yellow Perch	Min	40.13%	-15.19%	-10.34%	-24.56%	-17.84%	-57.46%	-27.93%
	Max	57.46%	-6.03%	1.16%	-12.97%	-7.13%	-29.36%	-16.14%

Table A.4.17. Summary of projected change in length of growth period in the 02 watershed over three future time periods.

SWS 02 - Length of Growth Period								
		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
Species			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	38	-2	0	-1	0	-2	0
	Max	51	0	2	0	2	0	19
Lake Trout	Min	38	-2	0	-1	0	-2	0
	Max	51	0	2	0	2	0	19
Lake Whitefish	Min	38	-2	0	-1	0	-2	0
	Max	51	0	2	0	2	1	19
Spring Spawner								
Northern Pike	Min	1	-1	0	-1	0	-2	0
	Max	41	6	9	11	17	18	36
Smallmouth Bass	Min	1	0	1	0	1	0	10
	Max	39	7	10	13	16	19	27
Walleye	Min	1	-1	0	-1	0	-1	1
	Max	41	7	9	13	16	19	27
Yellow Perch	Min	15	-1	0	-1	0	-2	0
	Max	43	6	11	12	18	18	30

Table A.4.18. Species occurrences by secondary watershed in the 02 drainage with columns ordered from low to high by the mean annual air temperature in the 1961-1990 norms period when most species occurrences were recorded and with rows ordered by species frequencies from high to low.

		02 SWS	V	U	T	X	R	W	S	A	N	B	Q	J	C	Y	L	D	P	Z	K	E	O	M	F	H	G	#
		MAAT C	-3.8	-2.5	-2.4	-1.2	-1.0	-0.9	0.2	0.6	1.0	1.0	1.3	2.1	3.1	3.2	3.4	4.0	4.3	4.3	4.5	5.5	6.1	6.2	6.2	6.5	7.7	
Code	Common name	Species name																										
S080	Brook trout	Salvelinus fontinalis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	25
S162	Longnose sucker	Catostomus catostomus	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	24
S091	Lake whitefish	Coregonus clupeaformis	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	23
S163	White sucker	Catostomus commersoni	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	23
S121	Rainbow smelt	Osmerus mordax	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	22
S131	Northern pike	Esox lucius	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	22
S185	Lake chub	Couesius plumbeus	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	22
S271	Burbot	Lota lota	0	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	22
S081	Lake trout	Salvelinus namaycush	1	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	21
S282	Threespine stickleback	Gasterosteus aculeatus	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	21
S283	Ninespine stickleback	Pungitius pungitius	1	1	0	0	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	21
S076	Rainbow trout	Oncorhynchus mykiss	0	1	0	0	0	1	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	18
S077	Atlantic salmon(l)	Salmo salar	1	1	1	1	1	1	0	0	1	0	1	1	0	1	1	0	1	1	1	0	1	1	1	1	0	18
S182	Northern redbelly dace	Phoxinus eos	0	0	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	18
S211	Longnose dace	Rhinichthys cataractae	0	1	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	18
S214	Pearl dace	Margariscus margarita	0	0	1	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	18
S251	American eel	Anguilla rostrata	1	1	0	1	0	1	1	1	0	0	1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	18
S331	Yellow perch	Perca flavescens	0	0	0	0	1	0	1	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	18
S381	Mottled sculpin	Cottus bairdi	0	0	1	0	1	0	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	18
S382	Slimy sculpin	Cottus cognatus	0	0	0	0	1	0	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	18
S183	Finescale dace	Phoxinus neogaeus	0	0	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S194	Golden shiner	Notemigonus crysoleucas	0	0	0	0	1	0	1	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S198	Common shiner	Luxilus cornutus	0	0	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S212	Creek chub	Semotilus atromaculatus	0	0	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S281	Brook stickleback	Culaea inconstans	0	0	0	0	1	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S291	Trout-perch	Percopsis omiscomaycus	1	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S342	Logperch	Percina caprodes	0	0	0	0	1	1	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	17
S093	Cisco(lake herring)	Coregonus artedi	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S102	Round whitefish	Prosopium cylindraceum	1	0	1	0	1	1	0	1	0	1	0	0	1	1	0	1	1	0	1	1	1	0	1	1	1	16
S141	Central mudminnow	Umbra limi	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S196	Emerald shiner	Notropis atherinoides	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S201	Spottail shiner	Notropis hudsonius	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S209	Fathead minnow	Pimephales promelas	0	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S233	Brown bullhead	Ameiurus nebulosus	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S334	Walleye(yellow pickerel)	Stizostedion vitreum	0	0	0	0	1	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	16
S031	Lake sturgeon	Acipenser fulvescens	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S079	Arctic char	Salvelinus alpinus	1	1	0	1	1	1	1	0	1	0	0	0	1	1	1	0	1	1	0	1	1	0	0	0	1	15
S200	Blacknose shiner	Notropis heterolepis	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S311	Rock bass	Ambloplites rupestris	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S313	Pumpkinseed	Lepomis gibbosus	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S316	Smallmouth bass	Micropterus dolomieu	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S341	Johnny darter	Etheostoma nigrum	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	15
S168	Silver redhorse	Moxostoma anisurum	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S171	Shorthead redhorse	Moxostoma macrolepidotum	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14

S189	Brassy minnow	Hybognathus hankinsoni	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S206	Mimic shiner	Notropis volucellus	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S208	Bluntnose minnow	Pimephales notatus	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S210	Blacknose dace	Rhinichthys atratulus	0	0	0	0	0	0	0	1	0	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S213	Fallfish	Semotilus corporalis	0	0	0	0	1	0	0	0	1	1	0	1	0	0	1	1	1	0	1	1	1	1	1	1	1	14
S317	Largemouth bass	Micropterus salmoides	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S338	Iowa darter	Etheostoma exile	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	14
S078	Brown trout	Salmo trutta	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	13
S132	Muskellunge	Esox masquinongy	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	13
S199	Blackchin shiner	Notropis heterodon	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	13
S202	Rosyface shiner	Notropis rubellus	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	13
S204	Sand shiner	Notropis ludibundus	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1	0	1	1	1	1	1	1	1	13
S314	Bluegill	Lepomis macrochirus	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	1	0	0	1	1	1	1	1	1	1	13
S332	Sauger	Stizostedion canadense	0	0	0	0	0	0	0	1	1	1	0	1	1	0	1	1	0	0	1	1	1	1	0	1	1	13
S383	Spoonhead sculpin	Cottus ricei	0	0	0	0	1	0	0	1	1	0	0	1	1	0	1	1	0	0	1	1	1	1	1	0	1	13
S013	Silver lamprey	Ichthyomyzon unicuspis	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	12
S061	Alewife	Alosa pseudoharengus	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	12
S063	Gizzard shad	Dorosoma cepedianum	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	12
S186	Carp	Cyprinus carpio	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	12
S234	Channel catfish	Ictalurus punctatus	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	1	1	1	1	1	1	1	12
S261	Banded killifish	Fundulus diaphanus	0	0	0	0	0	1	0	0	0	1	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	12
S319	Black crappie	Pomoxis nigromaculatus	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0	1	1	1	1	1	1	1	12
S011	American brook lamprey	Lampetra appendix	0	0	0	0	0	0	0	1	1	1	0	0	1	0	1	0	1	0	0	1	1	0	1	1	1	11
S014	Sea lamprey	Petromyzon marinus	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	1	0	0	1	1	1	1	1	1	11
S041	Longnose gar	Lepisosteus osseus	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	11
S161	Quillback	Carpiodes cyprinus	0	0	0	0	0	0	0	1	0	0	0	1	1	0	1	0	1	0	0	1	1	1	1	1	1	11
S012	Northern brook lamprey	Ichthyomyzon fossor	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	1	1	0	1	1	1	10
S051	Bowfin	Amia calva	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	10
S075	Chinook salmon	Oncorhynchus tshawytscha	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	1	0	0	0	1	1	1	1	1	1	10
S172	Greater redhorse	Moxostoma valenciennesi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	1	1	10
S231	Black bullhead	Ameiurus melas	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	0	0	0	1	1	1	1	1	1	1	10
S302	White bass	Morone chrysops	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	1	1	1	1	1	10
S073	Coho salmon	Oncorhynchus kisutch	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	1	1	1	1	1	9
S203	Spotfin shiner	Cyprinella spiloptera	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	1	1	1	1	1	9
S232	Yellow bullhead	Ameiurus natalis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	1	1	9
S284	Fourspine stickleback	Apeltes quadracus	1	1	0	0	0	1	1	1	0	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	9
S301	White perch	Morone americana	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	1	1	1	1	1	1	9
S339	Fantail darter	Etheostoma flabellare	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	1	1	1	1	9
S346	Tessellated darter	Etheostoma olmstedi	0	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	0	1	1	0	1	1	9
S371	Freshwater drum	Aplodinotus grunniens	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	1	0	1	1	1	1	1	9
S384	Deepwater sculpin	Myoxocephalus thompsoni	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	1	1	0	0	1	1	0	9
S173	River redhorse	Moxostoma carinatum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	8
S181	goldfish	Carassius auratus	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	8
S192	Hornyhead chub	Nocomis biguttatus	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	1	0	0	1	1	1	8
S235	Stonecat	Noturus flavus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	1	1	1	8
S315	Longear sunfish	Lepomis megalotis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	1	1	1	1	8
S361	Brook silverside	Labidesthes sicculus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	8
S387	Fourhorn sculpin	Myoxocephalus quadricornis	0	0	0	0	0	0	0	1	0	1	0	1	1	0	1	0	0	0	1	0	0	0	1	1	0	8
S071	Pink salmon	Oncorhynchus gorbuscha	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	1	1	7
S133	Grass pickerel	Esox americanus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	7
S152	Mooneye	Hiodon tergisus	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	1	1	0	1	1	7
S190	Eastern silvery minnow	Hybognathus regius	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	1	1	0	1	1	7
S236	Tadpole madtom	Noturus gyrinus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	1	1	1	7
S094	Bloater	Coregonus hoyi	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	1	0	0	1	1	0	6
S165	Northern hog sucker	Hypentelium nigricans	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	1	1	6

S193	River chub	Nocomis micropogon	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	6
S217	Striped shiner	Luxilus chrysocephalus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	1	6
S272	Atlantic tomcod	Microgadus tomcod	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	6
S285	Blackspotted stickleback	Gasterosteus wheatlandi	0	1	0	0	0	1	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	0	0	6
S318	White crappie	Pomoxis annularis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	1	1	1	6
S337	Rainbow darter	Etheostoma caeruleum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	1	1	6
S344	Blackside darter	Percina maculata	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	1	1	6
S062	American shad	Alosa sapidissima	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	0	1	5
S074	Sockeye salmon	Oncorhynchus nerka	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	1	5
S097	Blackfin cisco	Coregonus nigripinnis	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	1	1	0	5
S188	Cutlips minnow	Exoglossum maxillingua	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	0	1	1	0	0	0	5
S197	Bridle shiner	Notropis bifrenatus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	0	5
S216	Stoneroller	Campostoma anomalum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	1	1	1	5
S312	Green sunfish	Lepomis cyanellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	1	5
S340	Least darter	Etheostoma microperca	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	1	5
S343	Channel darter	Percina copelandi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	1	5
S092	Longjaw cisco	Coregonus alpenae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	4
S095	Deepwater cisco(chub)	Coregonus johannae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	4
S096	Kiyi	Coregonus kiyi	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	4
S099	Shortnose cisco	Coregonus reighardi	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	4
S100	Shortjaw cisco	Coregonus zenithicus	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	4
S184	Redside dace	Clinostomus elongatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	4
S205	Redfin shiner	Lythrurus umbratilis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	4
S218	Ghost shiner	Notropis buchanani	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	4
S219	grass carp	Ctenopharyngodon idella	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1	4
S238	Margined madtom	Noturus insignis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	4
S335	Eastern sand darter	Ammocrypta pellucida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	4
S336	Greenside darter	Etheostoma blennioides	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	4
S083	Aurora trout	Salvelinus fontinalis	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	3
S098	Nipigon cisco	Coregonus nipigon	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
S151	Goldeye	Hiodon alosoides	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3
S164	Lake chubsucker	Erimyzon sucetta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S169	Black redhorse	Moxostoma duquesneii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S170	Golden redhorse	Moxostoma erythrurum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S174	Black buffalo	Ictiobus niger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S180c	Mississippi silvery minnow	Hybognathus nuchalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	3
S195	Pugnose shiner	Notropis anogenus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	3
S215	Silver shiner	Notropis photogenis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S333	Blue pike(pickerel)	Stizostedion vitreum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	3
S366	Round goby	Neogobius melanostomus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	3
S042	Spotted gar	Lepisosteus oculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
S111	Arctic grayling	Thymallus arcticus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2
S120c	capelin	Mallotus villosus	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
S135	Chain pickerel	Esox niger	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	2
S166	Bigmouth buffalo	Ictiobus cyprinellus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
S175	Copper redhorse	Moxostoma hubbsi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
S220	Rudd	Scardinius erythrophthalmus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	2
S262	Blackstripe topminnow	Fundulus notatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
S263	Mummichog	Fundulus heteroclitus	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2
S396	European flounder	Platichthys flesus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
S032	Atlantic sturgeon	Acipenser oxyrhynchus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
S044	Florida gar	Lepisosteus platyrhincus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
S070a	Danube salmon	Hucho hucho	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
S070b	cutthroat trout	Oncorhynchus clarki	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
S101	Pygmy whitefish	Prosopium coulteri	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

S130b	Amur pike	Esox reicherti	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
S134	Redfin pickerel	Esox americanus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
S167	Spotted sucker	Minytrema melanops	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S180h	suckermouth minnow	Phenacobius mirabilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S187	Gravel chub	Erimystax x-punctatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S191	Silver chub	Macrhybopsis storeriana	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S207	Pugnose minnow	Opsopoeodus emiliae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S237	Brindled madtom	Noturus miurus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S239	Flathead catfish	Pylodictis olivaris	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S244	Northern madtom	Noturus stigmosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S304	Striped bass	Morone saxatilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
S323	Warmouth	Chaenobryttus gulosus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S324	Orangespotted sunfish	Lepomis humilis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S345	River darter	Percina shumardi	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S355	Ruffe	Gymnocephalus cernuus	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S367	Tubenose goby	Proterorhinus marmoratus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S501	Oscar	Astronotus ocellatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
S502	Jaguar guapote	Cichlasoma managuense	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
#			17	20	17	11	35	20	15	84	46	74	29	62	97	14	99	69	85	7	86	102	105	96	119	129	138	

Table A.4.19. Projected potential sustainable fish yield for the 1971-2000 norms by secondary watershed in the 02 drainage along with the range of projected percentage changes under the B1 and A2 emission scenarios for the future periods 2011-2040, 2014-2070, and 2070-2100.

SWS	Yield MT.y^{-1}		Percentage increases B1 Scenario						Percentage increases A2 Scenario					
	1971-2000		2011-2040		2041-2070		2071-2100		2011-2040		2041-2070		2071-2100	
			min	max	min	max	min	max	min	max	min	max	min	max
02A	19566.1		11.5	22.6	23.1	33.2	30.5	46.4	14.3	19.4	33.6	43.3	59.0	84.1
02B	526.4		16.0	25.6	27.3	39.8	33.0	53.7	19.2	24.6	38.7	48.0	64.9	92.4
02C	847.2		11.1	17.6	20.7	34.5	24.6	48.6	13.0	19.4	31.0	39.7	52.6	83.6
02D	1040.4		13.9	21.1	23.9	39.0	27.1	53.3	15.9	22.2	34.8	43.7	56.9	87.1
02E	958.4		11.3	18.3	21.0	36.0	23.1	49.9	13.0	20.4	29.9	40.5	49.9	81.7
02F	49059.6		10.1	16.9	19.9	34.0	21.6	48.0	11.9	18.9	27.4	39.0	46.7	80.6
02G	61712.2		10.1	17.0	20.1	33.8	21.2	47.3	11.9	18.9	27.1	39.0	45.8	79.3
02H	1192.0		13.0	19.6	23.2	37.8	24.4	51.4	15.1	22.7	31.8	42.3	51.6	82.2
02J	1958.1		14.6	22.7	25.3	41.1	28.9	55.1	17.1	23.5	37.6	46.1	60.9	89.4
02K	1330.4		11.6	18.9	21.0	37.3	23.7	50.6	13.4	20.5	31.4	41.5	51.6	81.5
02L	2578.9		13.0	20.3	23.2	39.3	25.5	52.6	14.9	21.5	34.2	43.4	55.1	83.7
02M	1034.6		13.6	19.2	24.1	37.7	24.7	50.3	16.4	23.2	34.2	41.7	53.9	78.4
02N	918.0		12.5	20.3	23.5	39.5	26.4	53.3	14.4	20.7	34.5	43.9	57.4	87.3
02O	851.6		13.6	18.8	24.4	37.6	25.3	50.0	15.8	22.6	34.4	41.4	54.2	78.0
02U	190.9		3.9	15.9	16.4	33.8	23.2	45.3	9.2	16.3	25.4	38.4	46.8	81.3
02V	123.7		8.9	22.2	22.4	40.4	29.3	52.0	14.2	22.2	30.6	45.2	52.8	88.3
02W	1020.9		10.1	23.2	23.4	40.1	29.8	51.4	14.9	22.7	30.5	44.6	51.9	84.7
02X	836.8		10.6	24.7	23.4	42.1	29.5	53.7	14.2	24.7	30.7	46.8	52.5	87.7
02Y	2461.2		7.6	19.4	17.9	30.9	23.4	38.8	10.3	17.2	23.4	39.7	40.5	65.6
02Z	1626.0		6.1	16.8	14.7	26.8	19.5	34.1	8.4	15.1	20.9	35.5	35.6	59.8
Total	149833.4	Min	3.9	15.9	14.7	26.8	19.5	34.1	8.4	15.1	20.9	35.5	35.6	59.8
		Max	16.0	25.6	27.3	42.1	33.0	55.1	19.2	24.7	38.7	48.0	64.9	92.4

*Table A.4.20. Projected potential qualitative changes in sustainable fish yield of selected species by secondary watershed in the 02 drainage from the 1971-2000 climate norms to the range of projected climate under the A2 emission scenario in the future period 2041-2070.**

		Climate		Projected qualitative change in species sustainable yield								
SWS	1971-2000	Δ MAAT A2 2041-2070		Lake Whitefish (TOPT -1.5°C)			Northern Pike (TOPT 1.0°C)			Walleye (TOPT 2.0°C)		
	Norm °C	Min °C	Max °C	P/A	Min	Max	P/A	Min	Max	P/A	Min	Max
02A	0.9	2.8	3.5	1	Decrease	Decrease	1	Decrease	Decrease	1	No change	Decrease
02B	0.9	3.2	3.9	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02C	3.5	2.7	3.3	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02D	3.9	2.9	3.6	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02E	5.7	2.6	3.3	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02F	6.5	2.4	3.2	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02G	7.9	2.4	3.2	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02H	6.5	2.7	3.5	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02J	2.1	3.1	3.7	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02K	4.7	2.7	3.4	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02L	3.4	2.9	3.5	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02M	6.1	2.9	3.4	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02N	1.1	2.9	3.6	1	Decrease	Decrease	1	Decrease	Decrease	1	No change	Decrease
02O	6.1	2.9	3.4	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02P	4.5	2.8	3.4	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
02Q	1.4	2.7	3.4	1	Decrease	Decrease	0	Decrease	Decrease	0	Decrease	Decrease
02R	-0.4	2.5	3.2	1	Decrease	Decrease	1	No change	No change	1	Increase	Increase
02S	0.6	2.6	3.4	1	Decrease	Decrease	1	No change	Decrease	0	No change	No change
02T	-1.6	2.1	3.1	1	No change	Decrease	1	Increase	Increase	0	Increase	Increase
02U	-1.9	2.2	3.2	1	No change	Decrease	1	Increase	Increase	0	Increase	Increase
02V	-3.7	2.6	3.7	1	Increase	Increase	1	Increase	Increase	0	Increase	Increase
02W	-0.9	2.6	3.6	1	Decrease	Decrease	1	Increase	Increase	0	Increase	Increase
02X	-1.4	2.6	3.8	1	Decrease	Decrease	1	Increase	Increase	0	Increase	Increase
02Y	3.2	2.1	3.3	0	Decrease	Decrease	0	Decrease	Decrease	0	Decrease	Decrease
02Z	4.3	1.9	3.0	0	Decrease	Decrease	0	Decrease	Decrease	0	Decrease	Decrease

**P/A shows Species presence/absence from Chu et al. (2003)*

SECTION B - NELSON RIVER (PRIMARY WATERSHED 05)

B.1 Lake Resources

The secondary watersheds of the Nelson R. drainage run mainly to the north-east gathering from the Red, Winnipeg and Saskatchewan rivers into the Nelson R. which enters Hudson Bay (Figure B.1.1).

There are an estimated 71,041 lakes ($A_O \geq 0.1$ km^2) in the Nelson R. drainage (Table B.1.1) with 78 large lakes ($A_O \geq 100$ km^2, indicated in figure B.1.2) accounting for 59.6% of the total lake area, 102,840 km^2 (Table B.1.2). There are 7 lakes with $A_O \geq 1000$ km^2 : Lake Winnipeg (24024 km^2), Lake Winnipegosis (5295), Lake Manitoba (4633), Lake of the Woods (4408), Cedar Lake (2866), Lac Seul (1735) and Rainy Lake (1015).

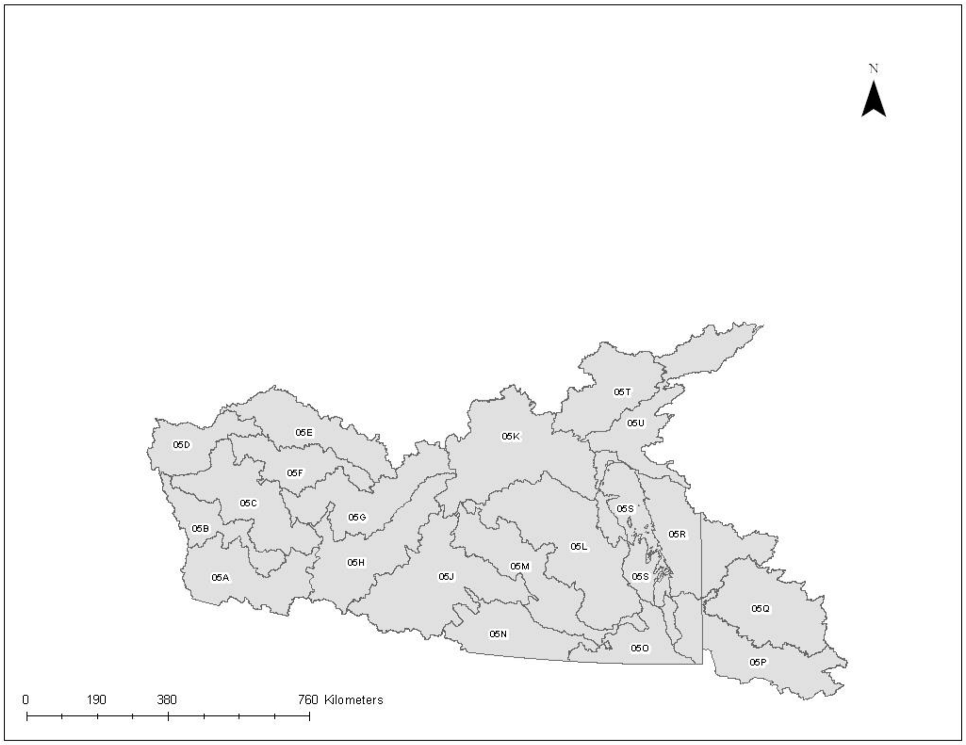


Figure B.1.1. Map of the Nelson R. drainage showing the secondary watersheds and their identifiers.

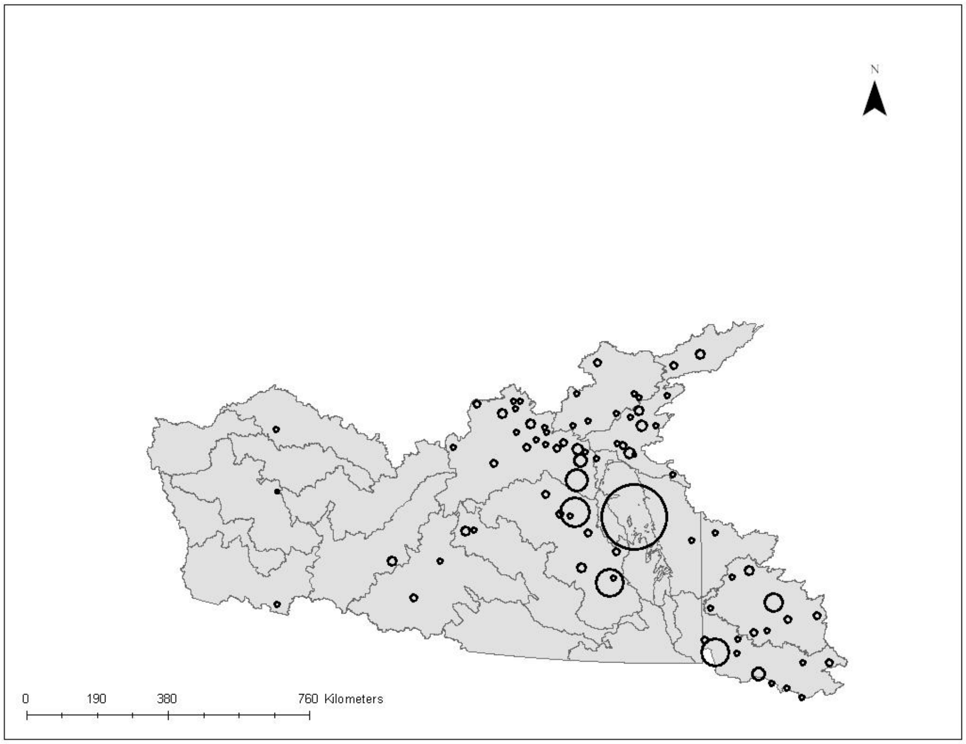


Figure B.1.2. Map showing the location and size of all large (area ≥ 100 km^2) lakes in the Nelson R. drainage. The circles indicate the relative size of the large lakes.

Table B.1.1. Estimated numbers of lakes by area size class interval in the secondary watersheds of the Nelson R. drainage.

SWS	**Lake area intervals, km^2**										
	0.1	**0.2**	**0.5**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**Sum**
05A	396	232	75	18	18	5	3	4		1	752
05B	244	143	46	11	17	7	2		1		471
05C	453	265	86	22	14	5	1	4	2	1	853
05D	267	156	51	11	6	2		2	2		497
05E	1073	628	204	55	45	13	8	6	4	1	2037
05F	303	177	58	22	17	4	3	1	1		586
05G	603	353	114	41	38	14	3	2	2		1170
05H	480	281	91	21	10	6	6	4		1	900
05J	646	378	123	22	18	5	8	3		2	1205
05K	5655	3309	1074	178	153	56	32	23	6	20	10506
05L	2307	1350	438	81	65	21	6	11	4	9	4292
05M	718	420	136	63	39	11	1	2	1	2	1393
05N	170	99	32	31	10	4			1		347
05O	174	102	33	7	11	1	1	2			331
05P	6368	3726	1209	283	323	117	55	21	12	10	12124
05Q	6600	3862	1253	334	303	98	58	33	13	8	12562
05R	3435	2010	652	274	283	88	29	24	5	2	6802
05S	781	457	148	27	29	9	9	4		2	1466
05T	3633	2126	690	148	102	46	23	17	8	7	6800
05U	3131	1832	595	206	106	32	21	6	6	12	5947
Sum	37437	21906	7108	1855	1607	544	269	169	68	78	71041

Table B.1.2. Estimated total area of lakes (km^2) by area size class interval in the secondary watersheds of the Nelson R. drainage.

SWS	**Lake area intervals, km^2**										
	0.1	**0.2**	**0.5**	**1**	**2**	**5**	**10**	**20**	**50**	**100**	**Sum**
05A	54.8	70.7	51.9	23.7	56.4	34.5	38.8	121.8		124.4	577.0
05B	33.8	43.6	31.8	14.5	55.0	51.6	30.0		61.1		321.4
05C	62.7	80.8	59.5	28.0	40.5	39.9	18.4	143.2	166.2	100.4	739.6
05D	37.0	47.5	35.3	14.4	22.5	12.2		68.6	148.7		386.2
05E	148.6	191.4	141.2	76.5	128.5	91.4	95.1	196.0	257.0	148.2	1473.9
05F	42.0	53.9	40.2	28.7	49.1	24.3	39.3	22.5	94.7		394.6
05G	83.5	107.6	78.9	57.9	120.5	104.8	40.9	43.7	144.9		782.7
05H	66.5	85.6	63.0	31.5	30.7	33.8	86.5	118.1		443.4	959.1
05J	89.4	115.2	85.1	30.1	58.3	30.5	112.3	94.7		508.9	1124.6
05K	782.9	1008.4	743.5	249.7	454.4	407.4	428.5	729.1	408.7	7866.4	13079.1
05L	319.4	411.4	303.2	108.8	192.6	148.3	86.4	398.2	312.2	11836.3	14116.8
05M	99.4	128.0	94.1	82.6	103.1	83.4	19.0	76.3	70.8	598.8	1355.6
05N	23.5	30.2	22.2	42.0	27.8	25.0			80.3		251.0
05O	24.1	31.1	22.8	8.9	32.0	6.5	13.1	49.1			187.6
05P	881.7	1135.5	836.9	395.8	985.8	776.1	802.8	622.0	784.4	6740.5	13961.5
05Q	913.8	1176.9	867.4	475.0	915.6	656.7	796.7	1035.7	914.1	3465.3	11217.2
05R	475.6	612.5	451.4	391.7	852.9	616.0	391.0	651.0	333.7	245.0	5020.8
05S	108.1	139.3	102.5	33.0	86.7	75.1	118.2	129.1		24133.6	24925.6
05T	503.0	647.9	477.7	204.9	306.4	300.6	303.3	515.0	495.7	1150.3	4904.8
05U	433.5	558.3	411.9	272.6	306.5	210.3	284.5	167.6	434.7	3980.5	7060.4
Sum	5183.2	6675.9	4920.6	2570.3	4825.3	3728.4	3704.8	5181.7	4707.2	61342.2	102839.6

B.2 Climate

In the 05 drainage, the 1971-2000 norms for mean annual air temperature (MAAT, °C) ranged from -2.3 °C in the northern watersheds to +5.7 °C in the southern watersheds to the east and west (Figure B.2.1 Upper-left). The project increases in MAAT are higher for the A2 scenario in all three future time periods compared to the B1 scenario (Table B.2.1). The lowest increases were for the B1*2011-2040 combination with minima ranging from -0.1°C to +1.3 °C and maxima from +1.2 °C to +2.4 °C. The highest increases were for the A2*2071-2100 combination with minima ranging from +2.6 to +4.8 and maxima ranging from +4.1 to +6.5. As the current emission trajectory is closer to the A2 scenario, or possibly higher, the A2*2041-2070 combination was used as a mid-century reference point relative to the 1971-2000 norms when examining the projected abiotic and biotic responses. The A2*2041-2070 MAAT increases had a minima range of +1.4 to +3.0 and a maxima range of +2.4 to +4.0, roughly overall a projected MAAT increase of 1.5-4 °C.

For the 1971-2000 norms period, the annual, summer (June-July-August), and July values with respect to temperature and precipitation rates vary across the watersheds of the 02 drainage (Figure B.2.1 Upper-right; Table B.2.2). Mean summer air temperatures ranged from 13.4 to 19.7 °C and July mean air temperatures from 14.3 to 20.8 °C with lower values more common in the northwestern and northeastern watersheds. Precipitation rates were more even across the drainage compared to temperatures though somewhat higher in eastern and western ends of the drainage (Figure B.2.1 Lower panel; Table B.2.2).

The ranges of projected temperature changes under A2 for the 2041-2070 period for the summer and July values were similar to the annual values (Table B.2.2). The ranges of projected percentage changes in precipitation rates were more variable with both increases and decreases possible. For annual precipitation the minima ranged from -5.7 to +13.3 % and the maxima ranged from +7.6 to 28.3% with no distinct spatial pattern, For summer and July precipitation rates the ranges of the minima and maxima percentages were greater and decreases were widespread in the drainage.

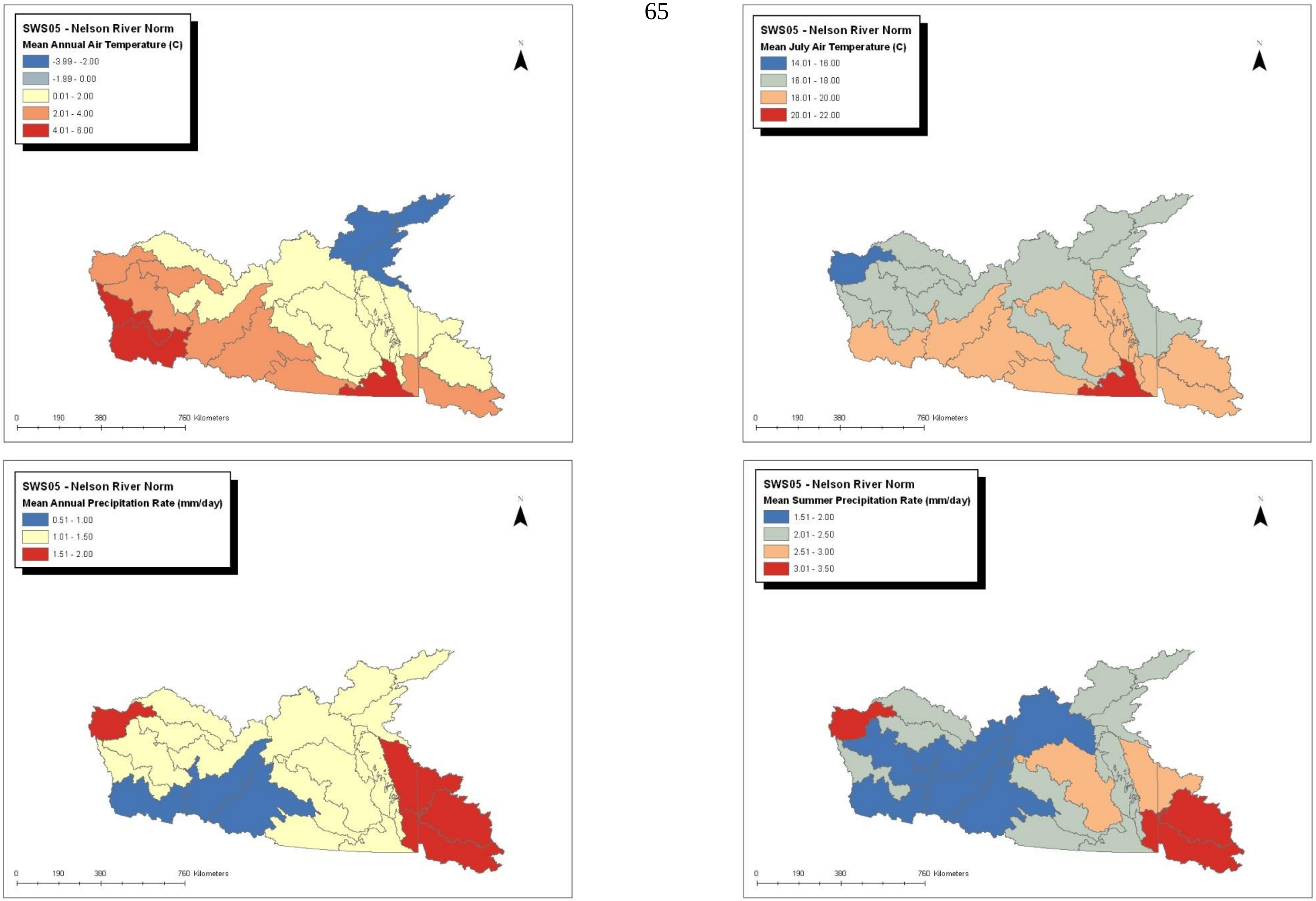


Figure B.2.1. A map of the Nelson R. drainage (05) secondary watersheds showing the 1971-2000 norms for mean annual and July air temperatures (°C) (Upper panels left and right) and for mean annual and summer precipitation rates (mm.d^{-1})(Lower panels left and right).

Table B.2.1. Summary by secondary watershed in the Nelson R. drainage (05) of the 1971-2000 norms mean annual air temperature (°C) and the ranges of projected changes for the 2011-2041, 2041-2070, and 2071-2100 periods from four GCMs given the B1and A2 emissions scenarios.

SWS	MAAT (°C)	Δ MAAT (°C) for B1 Scenario						Δ MAAT (°C) for A2 Scenario					
	1971-2000	2011-2040		2041-2070		2071-2100		2011-2040		2041-2070		2071-2100	
		min	max	min	max	min	max	min	max	min	max	min	max
05A	5.7	0.9	2.0	1.7	2.5	2.3	3.4	1.1	1.5	2.4	3.2	3.6	5.0
05B	4.0	0.8	1.9	1.6	2.5	2.2	3.3	1.0	1.5	2.3	3.1	3.5	4.8
05C	3.5	1.1	2.3	2.0	2.8	2.6	3.7	1.3	1.9	2.6	3.5	3.8	5.3
05D	2.8	-0.1	1.2	0.8	1.7	1.4	2.6	0.1	0.8	1.4	2.4	2.6	4.1
05E	1.8	0.8	2.2	1.6	2.6	2.4	3.4	1.0	1.7	2.3	3.5	3.6	5.3
05F	2.7	0.8	2.1	1.6	2.5	2.4	3.4	0.9	1.7	2.3	3.4	3.5	5.2
05G	1.9	1.1	2.4	2.0	2.8	2.7	3.7	1.2	2.0	2.7	3.7	4.0	5.6
05H	3.6	0.8	2.0	1.7	2.5	2.5	3.4	1.0	1.6	2.4	3.3	3.7	5.3
05J	3.4	0.9	2.1	1.8	2.5	2.6	3.4	1.0	1.6	2.4	3.3	3.8	5.6
05K	0.6	0.8	2.1	1.9	2.7	2.5	3.7	1.1	1.6	2.6	3.5	4.3	5.9
05L	1.8	1.0	2.3	2.0	2.9	2.8	3.9	1.2	1.8	2.6	3.7	4.2	6.2
05M	1.5	1.0	2.3	2.0	2.8	2.8	3.8	1.2	1.9	2.6	3.7	4.2	6.1
05N	3.4	0.8	2.0	1.7	2.4	2.6	3.4	1.0	1.6	2.4	3.2	3.8	5.6
05O	4.6	1.3	2.2	2.1	2.8	2.9	3.8	1.4	1.9	2.9	3.5	4.4	6.2
05P	2.9	1.3	2.2	2.1	3.0	2.9	3.9	1.4	1.8	3.0	3.7	4.5	6.2
05Q	1.6	1.2	2.2	2.2	2.9	2.9	3.9	1.4	1.9	3.0	3.7	4.7	6.2
05R	0.4	1.3	2.4	2.3	3.2	3.0	4.2	1.5	2.0	3.0	4.0	4.7	6.5
05S	1.1	1.1	2.3	2.1	3.0	2.9	4.0	1.3	1.9	2.8	3.8	4.4	6.4
05T	-2.1	0.9	2.1	2.0	2.9	2.6	4.0	1.2	1.7	2.7	3.8	4.6	6.1
05U	-2.3	1.1	2.3	2.1	3.1	2.7	4.2	1.3	1.9	2.9	4.0	4.8	6.3
Min	-2.3	-0.1	1.2	0.8	1.7	1.4	2.6	0.1	0.8	1.4	2.4	2.6	4.1
Max	5.7	1.3	2.4	2.3	3.2	3.0	4.2	1.5	2.0	3.0	4.0	4.8	6.5

Table B.2.2. Summary by secondary watershed in the Nelson R. drainage (05) of the 1971-2000 climate norms and the range of projected changes for the 2041-2070 period from four GCMs given the A2 emissions scenario.

SWS	1971-2000 Climate Normals						Projected changes under scenario A2 in the period 2041-2070											
	Temperature °C			Precipitation mm.d^{-1}			ΔTemperature °C						Δ Precipitation %					
	Ann	Sum	Jul	Ann	Sum	Jul	Ann		Sum		Jul		Ann		Sum		Jul	
							Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
05A	5.7	17.4	18.4	1.0	1.5	1.3	2.4	3.2	3.0	4.2	3.4	4.5	0.0	16.3	-14.6	19.2	-37.8	18.1
05B	4.0	15.2	16.1	1.1	2.1	2.0	2.3	3.1	2.6	4.0	3.0	4.3	-2.6	11.4	-16.9	2.4	-31.0	13.7
05C	3.5	16.1	17.0	1.1	1.9	1.9	2.6	3.5	3.1	4.4	3.2	4.5	-5.7	7.6	-13.7	2.6	-21.1	11.3
05D	2.8	13.4	14.3	1.6	3.2	3.7	1.4	2.4	2.1	3.4	2.1	3.4	-3.1	8.0	-16.7	1.2	-21.3	11.5
05E	1.8	15.4	16.3	1.2	2.3	2.4	2.3	3.5	2.4	3.8	2.3	3.7	5.2	15.7	5.3	17.8	4.2	27.1
05F	2.7	16.1	16.9	1.1	2.2	2.2	2.3	3.4	2.5	3.9	2.5	3.9	10.9	22.7	4.7	21.4	1.4	28.1
05G	1.9	16.2	17.0	1.1	2.0	2.2	2.7	3.7	2.7	4.0	2.9	4.1	2.8	13.1	2.1	6.2	1.4	12.2
05H	3.6	17.7	18.7	0.9	1.7	1.8	2.4	3.3	2.9	4.0	3.0	4.0	-4.3	8.7	-10.3	8.5	-20.4	26.0
05J	3.4	17.9	18.9	1.0	1.8	2.0	2.4	3.3	2.9	4.1	3.2	4.4	0.0	12.1	-9.6	-2.2	-9.7	24.6
05K	0.6	16.5	17.7	1.1	2.0	2.2	2.6	3.5	2.6	3.5	2.6	3.5	13.3	28.3	14.9	33.3	-4.6	8.3
05L	1.8	16.8	18.0	1.5	2.5	2.6	2.6	3.7	2.8	3.6	2.8	3.9	-0.7	15.5	-2.4	13.8	-15.6	0.0
05M	1.5	16.6	17.6	1.2	2.2	2.3	2.6	3.7	3.0	4.1	3.1	4.4	0.8	14.6	-4.9	4.0	-15.5	6.9
05N	3.4	18.0	19.0	1.2	2.1	2.2	2.4	3.2	2.8	4.0	3.0	4.4	1.7	12.6	-2.4	8.3	-25.3	6.0
05O	4.6	19.7	20.8	1.4	2.5	2.5	2.9	3.5	2.9	3.8	3.3	4.4	0.7	9.6	-14.2	15.0	-20.5	11.2
05P	2.9	17.5	18.8	1.9	3.2	3.1	3.0	3.7	2.8	3.6	3.4	4.3	1.6	8.4	-5.1	12.1	-11.4	11.7
05Q	1.6	17.1	18.4	1.9	3.1	3.1	3.0	3.7	2.7	3.4	3.0	4.0	2.6	11.1	-2.3	14.1	-6.4	19.6
05R	0.4	16.5	17.9	1.6	2.6	2.5	3.0	4.0	2.6	3.3	2.7	3.8	7.6	17.8	6.2	22.1	-7.3	17.6
05S	1.1	16.9	18.3	1.3	2.1	1.9	2.8	3.8	2.6	3.3	2.6	3.6	3.8	17.3	6.1	21.2	-6.2	17.0
05T	-2.1	15.1	16.7	1.4	2.3	2.4	2.7	3.8	2.3	3.1	2.1	3.2	4.4	19.7	2.7	15.5	-1.6	18.9
05U	-2.3	14.7	16.3	1.2	2.2	2.4	2.9	4.0	2.8	3.7	2.7	3.9	11.3	23.4	7.9	18.1	-0.8	13.9
Min	-2.3	13.4	14.3	0.9	1.5	1.3	1.4	2.4	2.1	3.1	2.1	3.2	-5.7	7.6	-16.9	-2.2	-37.8	0.0
Max	5.7	19.7	20.8	1.9	3.2	3.7	3.0	4.0	3.1	4.4	3.4	4.5	13.3	28.3	14.9	33.3	4.2	28.1

B.3 Abiotic Lake Responses

Ice break-up and freeze-up dates, duration of ice cover and open water

In the 05 drainage, the 1971-2000 norms for ice freeze-up date ranged from Julian day 331 to day 350 (Figure B.3.1 upper-left; Table B.3.1). By 2041-2070 under the A2 climate scenario, the freeze-up date will on average be 0 to 14 days later (Figure B.3.1 lower-left; Table B.3.1). The freeze-up date could be up to 2 days earlier or up to a maximum of 19 days later (Figure B.3.2). The ice break up date during the 1971-2000 norms ranged from 112 to 136 Julian days (Figure B.3.1 upper-right; Table B.3.1). The change in ice break up date is much smaller in comparison to freeze up. The projected change by 2041-2070 is 0 to -2 days on average (Figure B.3.1 lower-right; Table B.3.1) and ranges from +1 to -2 days (Figure B.3.2).

Given that maximum ice thickness is largely determined by the duration of ice cover, the ice duration and thickness results for the 05 drainage are similar (Figure B.3.4). Ice cover duration during the 1971-2000 norms ranged from 132 to 170 days and is projected to be reduced on average by 2 to 15 days (Table B.3.2) by 2041-2070. The possible range of reduction will be from 0 to 19 days. The 1971-2000 norms for ice thickness are projected to be between 75.79 cm and 108.07 cm (Table B.3.2). The projected change by 2041-2070 is an average reduction of 0.92 cm to 6.97 cm. The possible range of changes goes from -9.04 cm to +0.2 cm. The duration of open water (Figure B.3.7) is simply 365 minus the duration of ice cover and has a range of 169 to 233 days during the 1971-2000 norms. Increases in open water duration are equal to the reduction in ice cover duration.

Peak summer surface temperature and its timing

The projected summer peak water surface temperature for the 05 drainage during the 1971-2000 norms ranged from 18.53 °C to 27.13 °C (Figure B.3.9; Table B.3.3). This temperature is projected to increase by an average of 0.92 °C to 1.53 °C by 2041-2070 under the A2 scenario. The maximum and minimum increase for this period is 0.64 °C and 1.74 °C. The timing of the peak temperature changes very little in our projections. From a range of 205 to 212 Julian days in the 1971-2000 norms, the date of peak temperature will occur earlier by 1 to 2 days by 2041-2000.

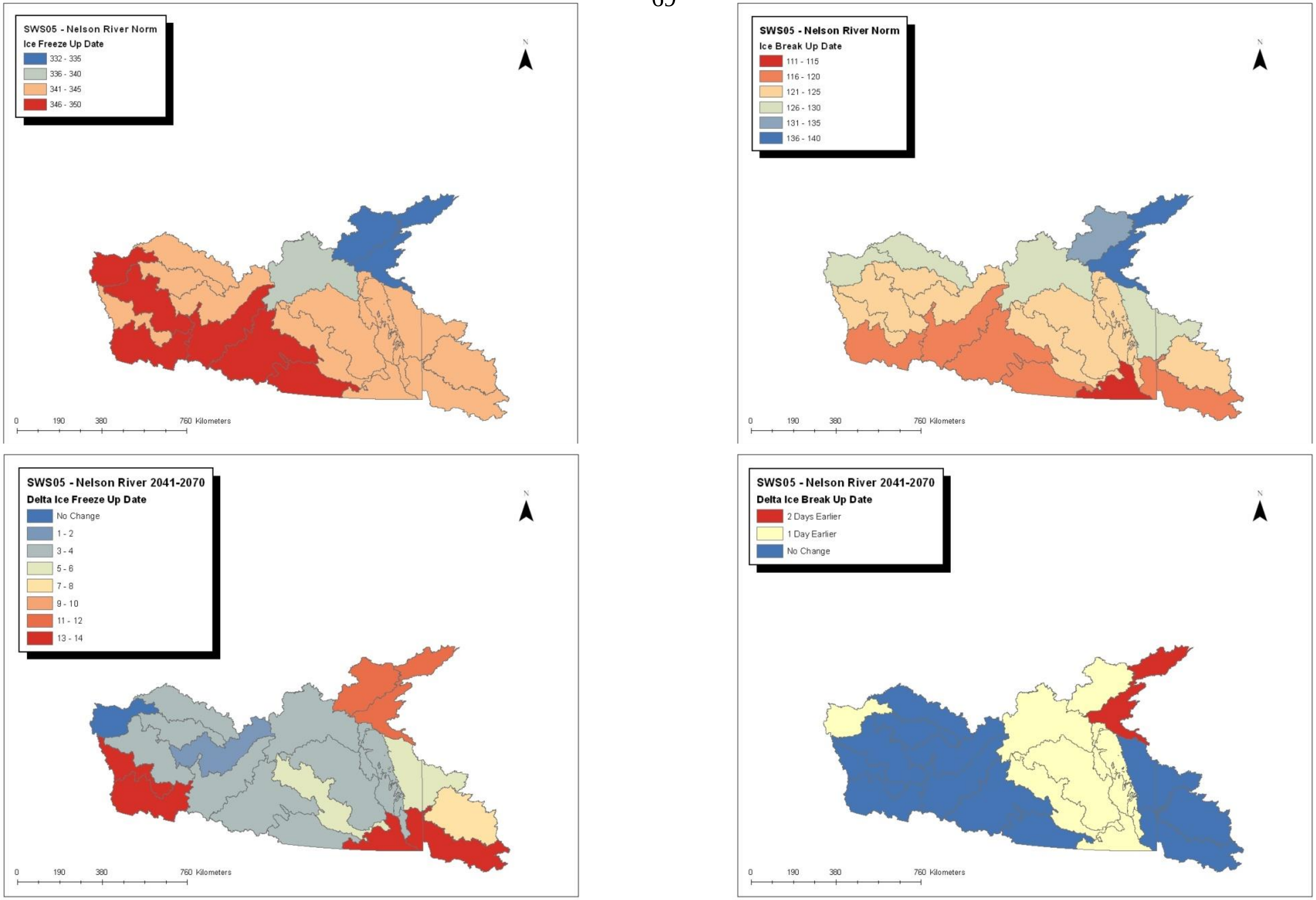


Figure B.3.1. Spatial variation in projected Julian ice-in and ice-out dates (upper panels left and right) for the 1971-2000 period by secondary watershed in the 05 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panels, left and right).

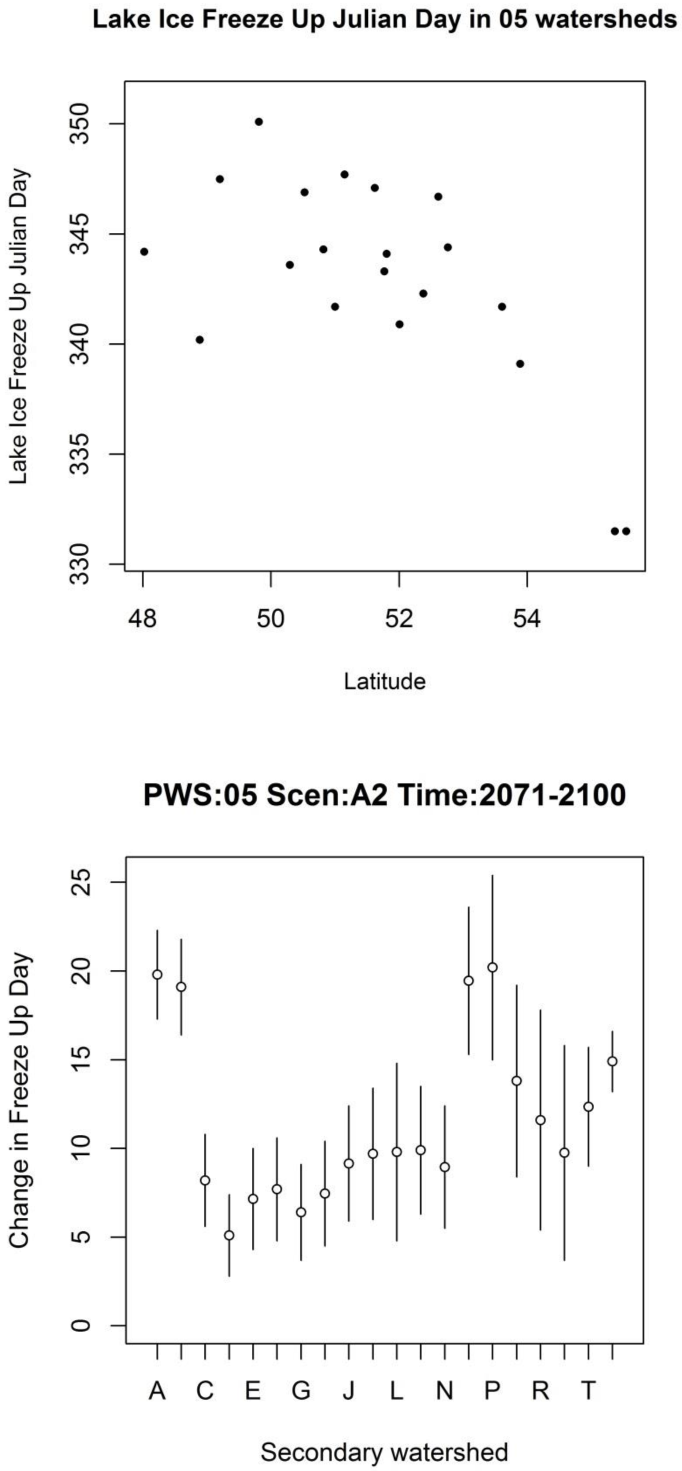
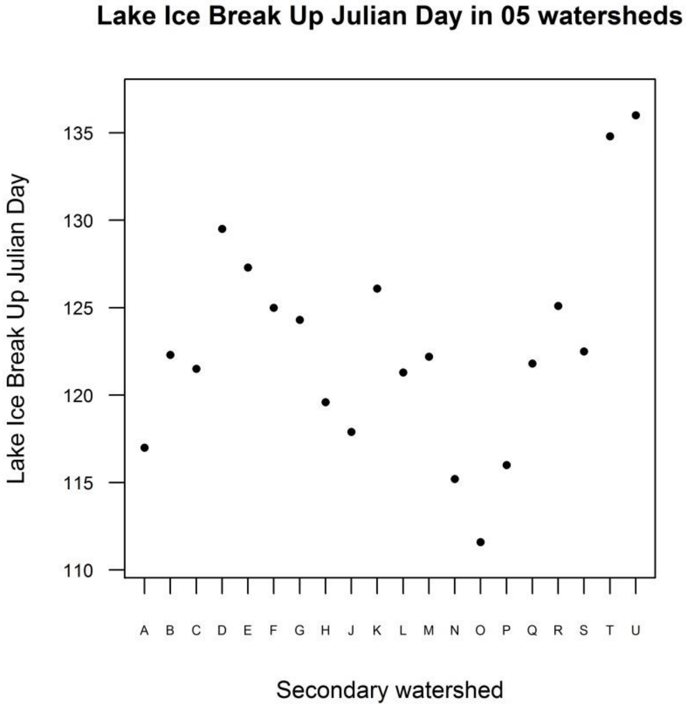


Figure B.3.2. Projected Julian ice-in dates for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).



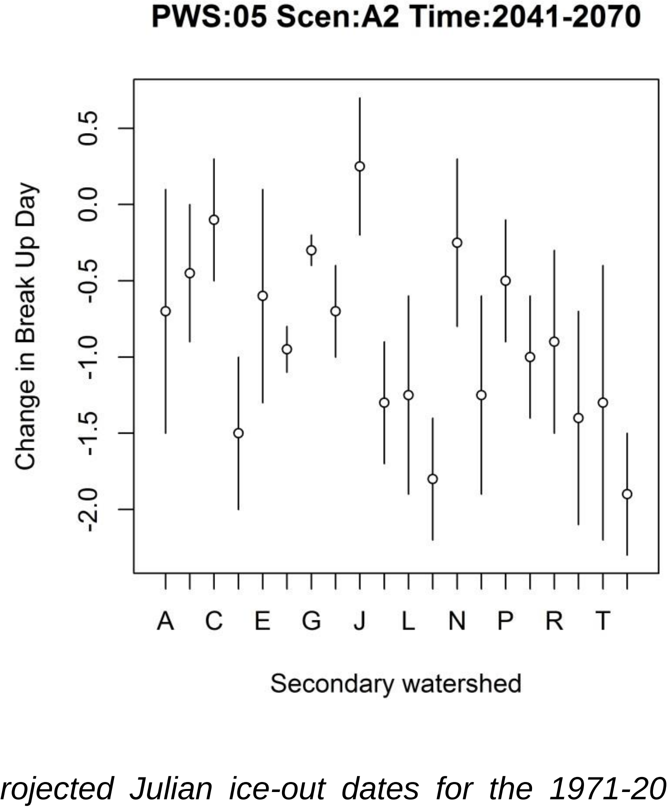


Figure B.3.3. Projected Julian ice-out dates for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

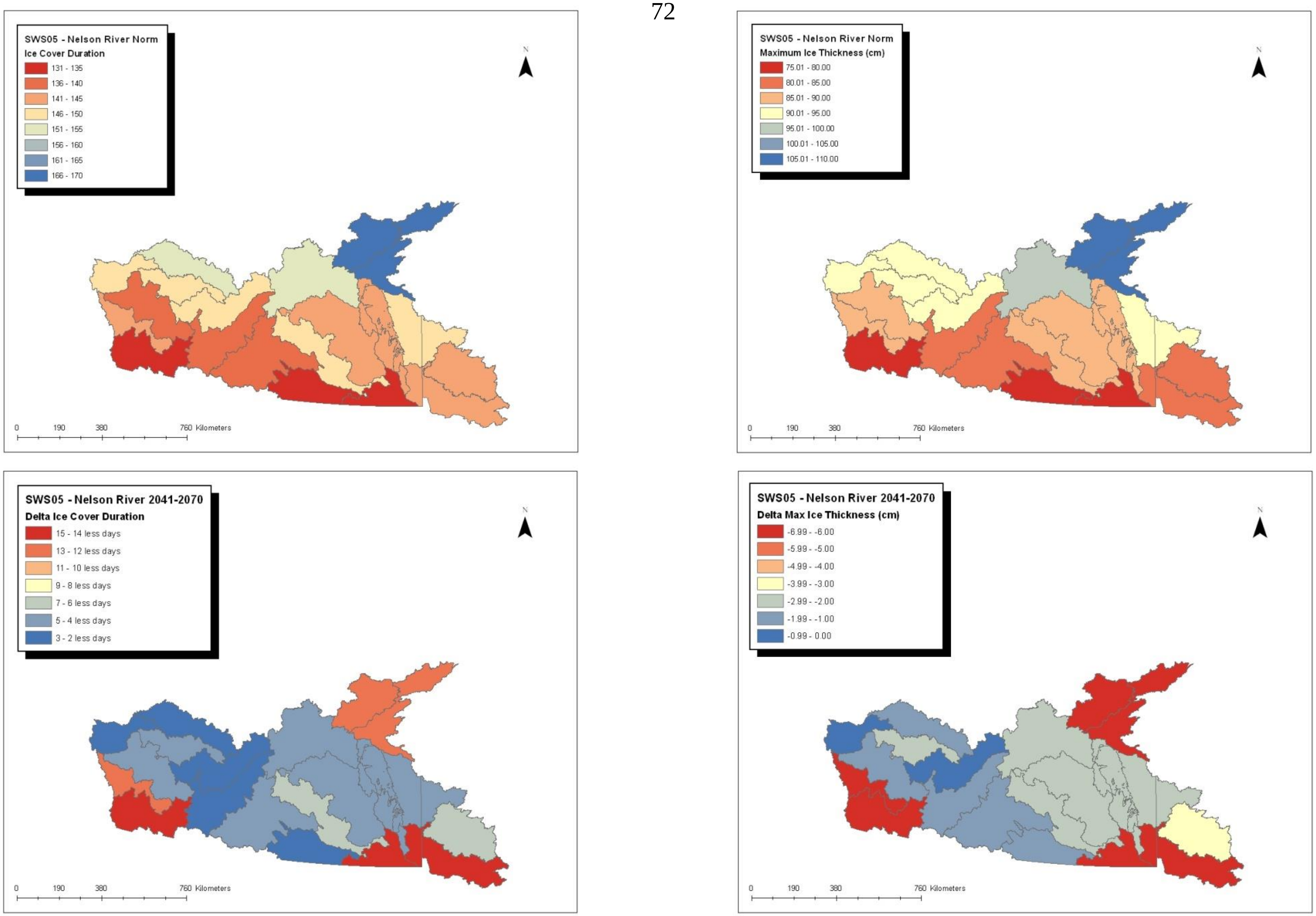


Figure B.3.4. Spatial variation in projected duration of ice cover (days) and maximum ice thickness (cm) (upper panels left and right) for the 1971-2000 period by secondary watershed in the 05 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panels, left and right.

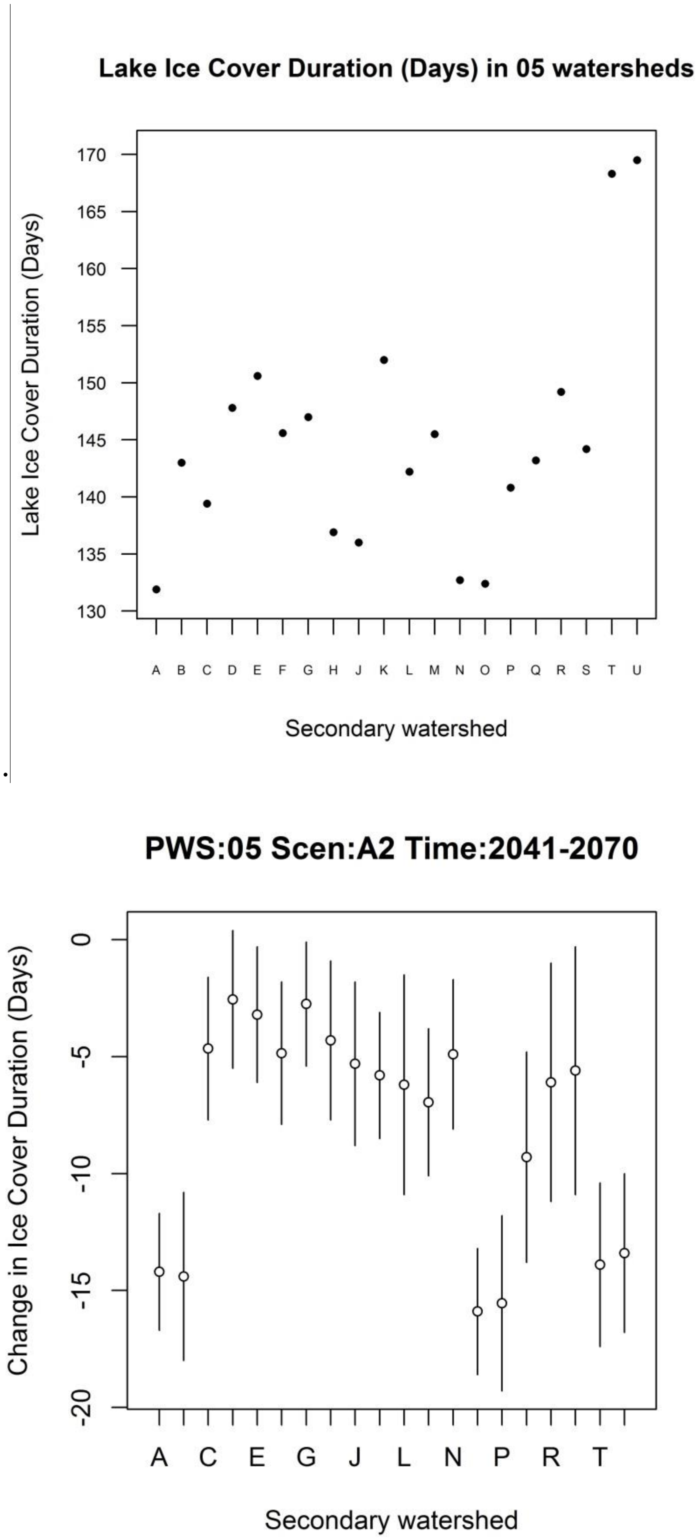


Figure B.3.5. Projected ice cover duration (Julian days) for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

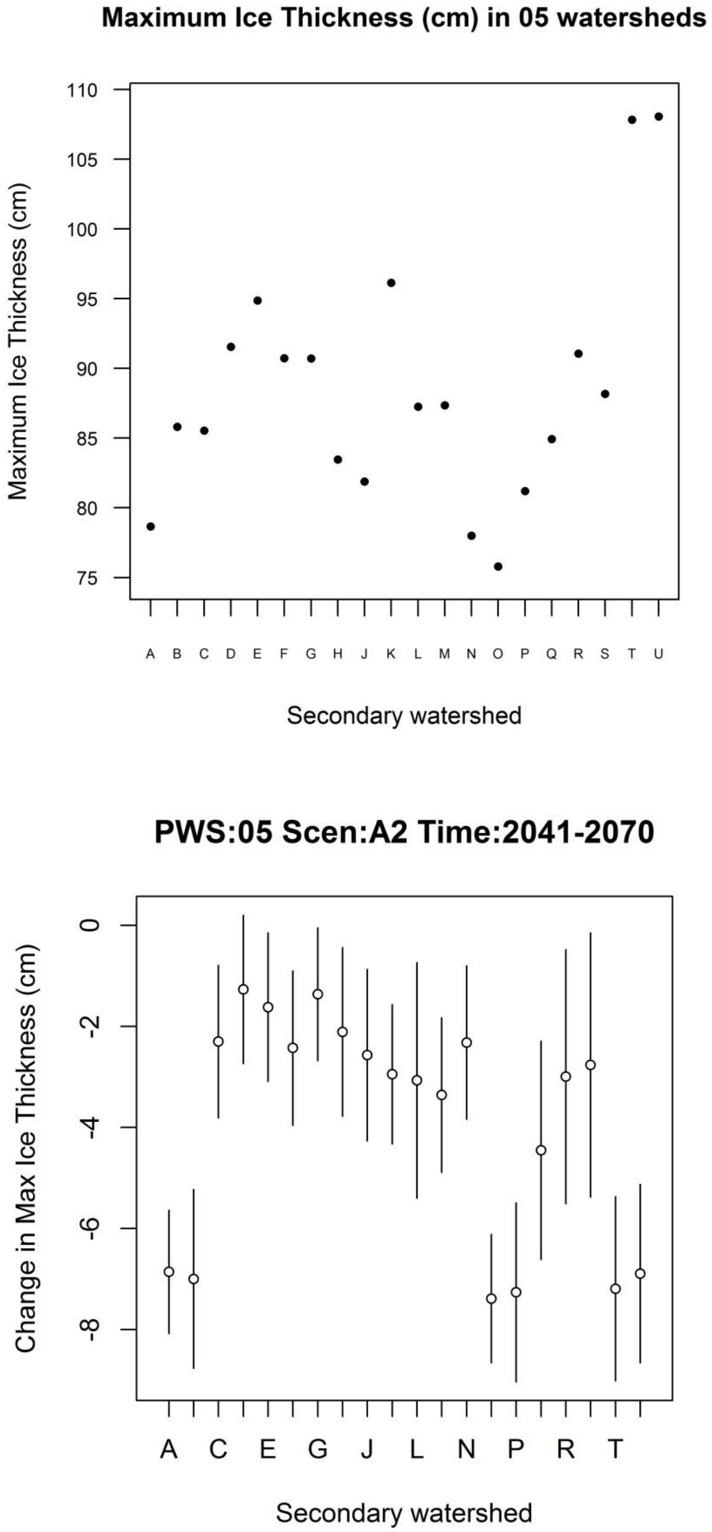


Figure B.3.6. Projected ice thickness (cm) for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

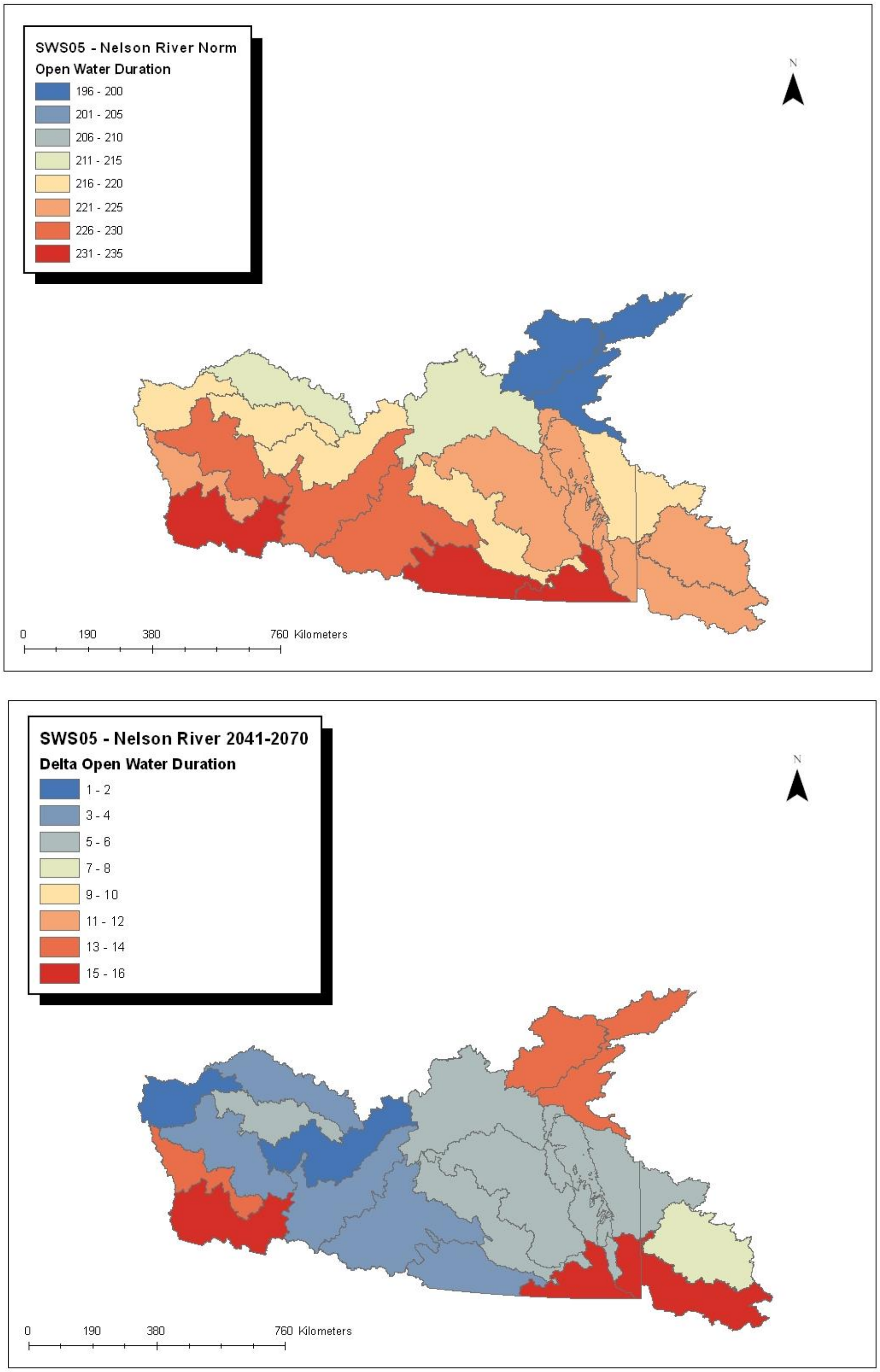


Figure B.3.7. Spatial variation in projected open water duration (Julian days) for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

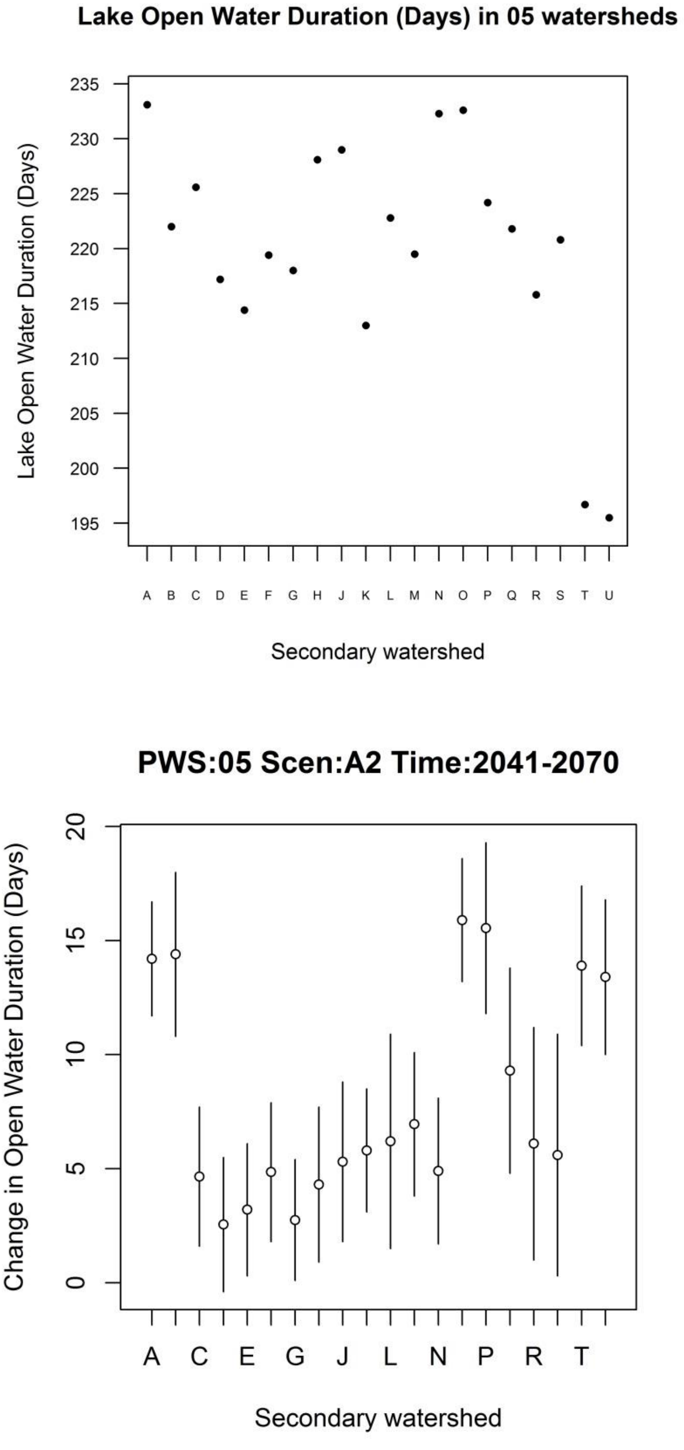


Figure B.3.8. Projected open water duration (Julian days) for the 1971-2000 period by secondary watershed in the 05 drainage (upper panel) along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower panel).

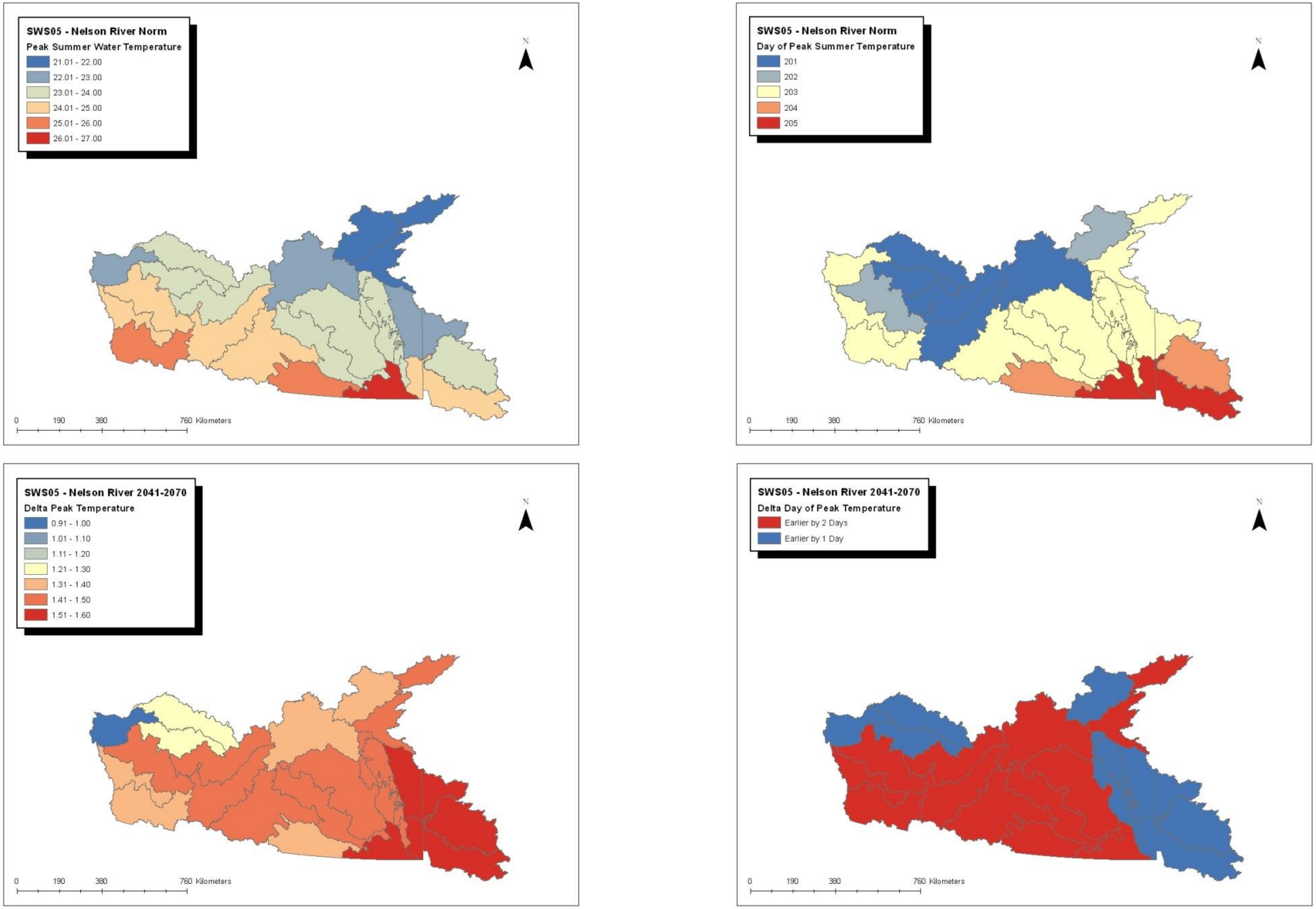


Figure B.3.9. Spatial variation in projected peak surface water temperature (°C) and its timing (Julian date) (upper left and right) for the 1971-2000 period by secondary watershed in the 05 drainage along with the mean of projected changes under the A2 emission scenario for the period 2014-2070 (lower left and right).

Table B.3.1. Projected break-up and freeze-up dates in the Nelson R. drainage under the 1971-2000 norms and the projected range and mean of projected changes under A2 emissions in the 2041-2070 period.

SWS	1971-2000 Climate Normals		Projected changes under scenario A2 in the period 2041-2070					
			∆ Break Up Date			∆ Freeze Up Date		
	Break Up	Freeze Up	Min	Max	Mean	Min	Max	Mean
05A	117.0	350.1	-1.5	0.1	-0.63	11.8	16.4	13.8
05B	122.3	344.3	-0.9	0.0	-0.45	10.5	17.2	12.73
05C	121.5	347.1	-0.5	0.3	-0.13	1.7	7.3	3.63
05D	129.5	346.7	-2.0	-1.0	-1.48	-1.7	3.5	0.38
05E	127.3	341.7	-1.3	0.1	-0.35	0.4	6.0	2.4
05F	125.0	344.4	-1.1	-0.8	-0.90	1.0	7.0	3.15
05G	124.3	342.3	-0.4	-0.2	-0.275	-0.2	5.2	1.58
05H	119.6	347.7	-1.0	-0.4	-0.75	0.5	7.0	2.43
05J	117.9	346.9	-0.2	0.7	0.175	2.1	8.7	3.9
05K	126.1	339.1	-1.7	-0.9	-1.4	1.6	6.8	3.43
05L	121.3	344.1	-1.9	-0.6	-1.175	0.9	9.0	3.73
05M	122.2	341.7	-2.2	-1.4	-1.75	2.2	8.3	4.2
05N	115.2	347.5	-0.8	0.3	-0.10	1.8	7.9	3.525
05O	111.6	344.2	-1.9	-0.6	-1.175	11.5	17.7	13.475
05P	116.0	340.2	-0.9	-0.1	-0.475	11.7	18.8	13.65
05Q	121.8	343.6	-1.4	-0.6	-0.975	4.1	12.4	6.725
05R	125.1	340.9	-1.5	-0.3	-0.775	0.7	10.3	4.4
05S	122.5	343.3	-2.1	-0.7	-1.4	-0.4	9.2	3.25
05T	134.8	331.5	-2.2	-0.4	-1.35	10	15.2	11.95
05U	136.0	331.5	-2.3	-1.5	-1.825	8.5	14.5	10.95
Min	111.6	331.5	-2.3	-1.5	-1.83	-1.7	3.5	0.38
Max	136.0	350.1	-0.2	0.7	0.18	11.8	18.8	13.8

Table B.3.2. Projected open water and ice cover duration (days) and maximum ice thickness (cm) under the 1971-2000 norms and projected the range and mean changes under A2 emissions in the 2041-2070 period.

SWS	1971-2000 Climate Normals			Projected changes under scenario A2 in the period 2041-2070								
	Open Water Duration	Ice Cover Duration	Max Ice Thickness	∆ Open Water Duration			∆ Ice Cover Duration			∆ Max Ice Thickness		
				Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
05A	233.1	131.9	78.67	11.7	16.7	14.425	-16.7	-11.7	-14.425	-8.08	-5.64	-6.97
05B	222	143	85.81	10.8	18	13.175	-18	-10.8	-13.175	-8.77	-5.23	-6.3975
05C	225.6	139.4	85.54	1.6	7.7	3.75	-7.7	-1.6	-3.75	-3.81	-0.79	-1.855
05D	217.2	147.8	91.54	-0.4	5.5	1.85	-5.5	0.4	-1.85	-2.74	0.2	-0.92
05E	214.4	150.6	94.87	0.3	6.1	2.75	-6.1	-0.3	-2.75	-3.09	-0.15	-1.3925
05F	219.4	145.6	90.73	1.8	7.9	4.05	-7.9	-1.8	-4.05	-3.96	-0.9	-2.0275
05G	218	147	90.7	0.1	5.4	1.85	-5.4	-0.1	-1.85	-2.68	-0.05	-0.9175
05H	228.1	136.9	83.46	0.9	7.7	3.175	-7.7	-0.9	-3.175	-3.78	-0.44	-1.5575
05J	229	136	81.89	1.8	8.8	3.725	-8.8	-1.8	-3.725	-4.27	-0.87	-1.8025
05K	213	152	96.13	3.1	8.5	4.825	-8.5	-3.1	-4.825	-4.33	-1.57	-2.4525
05L	222.8	142.2	87.25	1.5	10.9	4.9	-10.9	-1.5	-4.9	-5.4	-0.74	-2.42
05M	219.5	145.5	87.35	3.8	10.1	5.95	-10.1	-3.8	-5.95	-4.89	-1.83	-2.875
05N	232.3	132.7	77.99	1.7	8.1	3.625	-8.1	-1.7	-3.625	-3.84	-0.8	-1.715
05O	232.6	132.4	75.79	13.2	18.6	14.65	-18.6	-13.2	-14.65	-8.66	-6.12	-6.8
05P	224.2	140.8	81.2	11.8	19.3	14.125	-19.3	-11.8	-14.125	-9.04	-5.49	-6.59
05Q	221.8	143.2	84.93	4.8	13.8	7.7	-13.8	-4.8	-7.7	-6.62	-2.29	-3.6825
05R	215.8	149.2	91.06	1	11.2	5.175	-11.2	-1	-5.175	-5.51	-0.48	-2.5375
05S	220.8	144.2	88.17	0.3	10.9	4.65	-10.9	-0.3	-4.65	-5.38	-0.15	-2.2925
05T	196.7	168.3	107.84	10.4	17.4	13.3	-17.4	-10.4	-13.3	-9.02	-5.37	-6.88
05U	195.5	169.5	108.07	10	16.8	12.775	-16.8	-10	-12.775	-8.66	-5.13	-6.57
Min	195.5	131.9	75.79	-0.4	5.4	1.85	-19.3	-13.2	-14.65	-9.04	-6.12	-6.97
Max	233.1	169.5	108.07	13.2	19.3	14.65	-5.4	0.4	-1.85	-2.68	0.2	-0.9175

Table B.3.3. Projected peak summer temperatures and their timing for the 1971-2000 normals by secondary watershed in the Nelson R. drainage along with the range and mean of projected changes under the A2 emission scenario for the period 2014-2070.

SWS	1971-2000 Climate Normals		Projected changes under scenario A2 in the period 2041-2070					
	Peak Summer Water Temperature °C	Day of Peak Temperature	∆ Peak Temperature °C			∆ Day of Peak Temperature		
			Min	Max	Mean	Min	Max	Mean
05A	23.34	205.23	1.24	1.53	1.37	-1.96	-1.39	-1.75
05B	22.76	207.32	1.15	1.47	1.32	-1.81	-1.15	-1.52
05C	24.45	207.76	1.27	1.66	1.48	-2.11	-1.47	-1.82
05D	24.51	207.67	0.64	1.13	0.92	-1.81	-1.01	-1.36
05E	25.25	209.71	1.01	1.55	1.29	-2.00	-1.12	-1.46
05F	26.02	211.08	0.96	1.50	1.25	-1.91	-1.15	-1.48
05G	27.13	212.28	1.24	1.70	1.47	-1.88	-1.24	-1.54
05H	26.10	210.47	1.22	1.55	1.40	-1.93	-1.50	-1.78
05J	23.14	207.34	1.23	1.63	1.44	-1.73	-1.26	-1.53
05K	24.72	208.38	1.13	1.51	1.32	-1.77	-1.33	-1.52
05L	23.55	208.39	1.18	1.71	1.46	-1.72	-1.38	-1.55
05M	25.22	210.43	1.23	1.74	1.49	-1.88	-1.46	-1.64
05N	22.03	207.72	1.16	1.60	1.37	-1.79	-1.30	-1.59
05O	24.58	208.81	1.44	1.63	1.53	-1.82	-1.25	-1.54
05P	23.00	207.97	1.41	1.65	1.53	-1.63	-1.20	-1.41
05Q	20.60	207.44	1.36	1.64	1.50	-1.53	-1.12	-1.29
05R	20.51	206.60	1.28	1.72	1.51	-1.54	-1.23	-1.36
05S	20.68	206.31	1.21	1.67	1.46	-1.56	-1.30	-1.43
05T	18.96	205.84	1.16	1.59	1.36	-1.63	-1.16	-1.40
05U	18.53	206.30	1.24	1.71	1.46	-1.77	-1.41	-1.59
Min	18.53	205.23	0.64	1.13	0.92	-2.11	-1.50	-1.82
Max	27.13	212.28	1.44	1.74	1.53	-1.53	-1.01	-1.29

B.4 Biotic Lake Responses

Spawning, egg development and adult growth

Projections for a fall spawning species (Lake Trout) and a spring spawning species (Northern Pike) are shown in full in figures B.4.1 and B.4.2 and tables B.4.1 to B.4.6 (Lake Trout) and in figures B.4.3 and B.4.4 and tables B.4.7 to B.4.12 (Northern Pike).

The minimum and maximum changes for each fish species is aggregated over the entire Nelson River drainage. The 1971-2000 norms and the changes over the three future time periods are presented in tables B.4.13 to B.4.17 (time-dependent spawning date, temperature-dependent spawning date, hatching date, hatching success, and adult growth). The only fish species which is not viable in certain secondary watersheds under historical norms is Smallmouth Bass. Its future viability in those Nelson River watersheds was summarized in along with the other three spring spawning species (Northern Pike, Walleye and Yellow Perch).

The projection results are similar to the ones in the St Lawrence watersheds. Fall spawning species will experience a delay of up to one to three weeks in spawning and hatching dates under the temperature dependent spawning scenario. Hatching success will not be greatly affected. Under the time dependent spawning scenario, the hatching date will be two to six weeks earlier by 2041-2070 and up to one to two months earlier by 2071-2100. Hatching success will also increase. Length of growth period will not change much.

For spring spawning species, temperature dependent spawning and hatching will be earlier by one to six days in 2041-2070 and by up to 10 days in 2071-2100. Hatching success will experience a slight decrease. Under time dependent spawning, hatching date will be earlier by two to four days, but the hatching success will be greatly reduced.

Species distribution

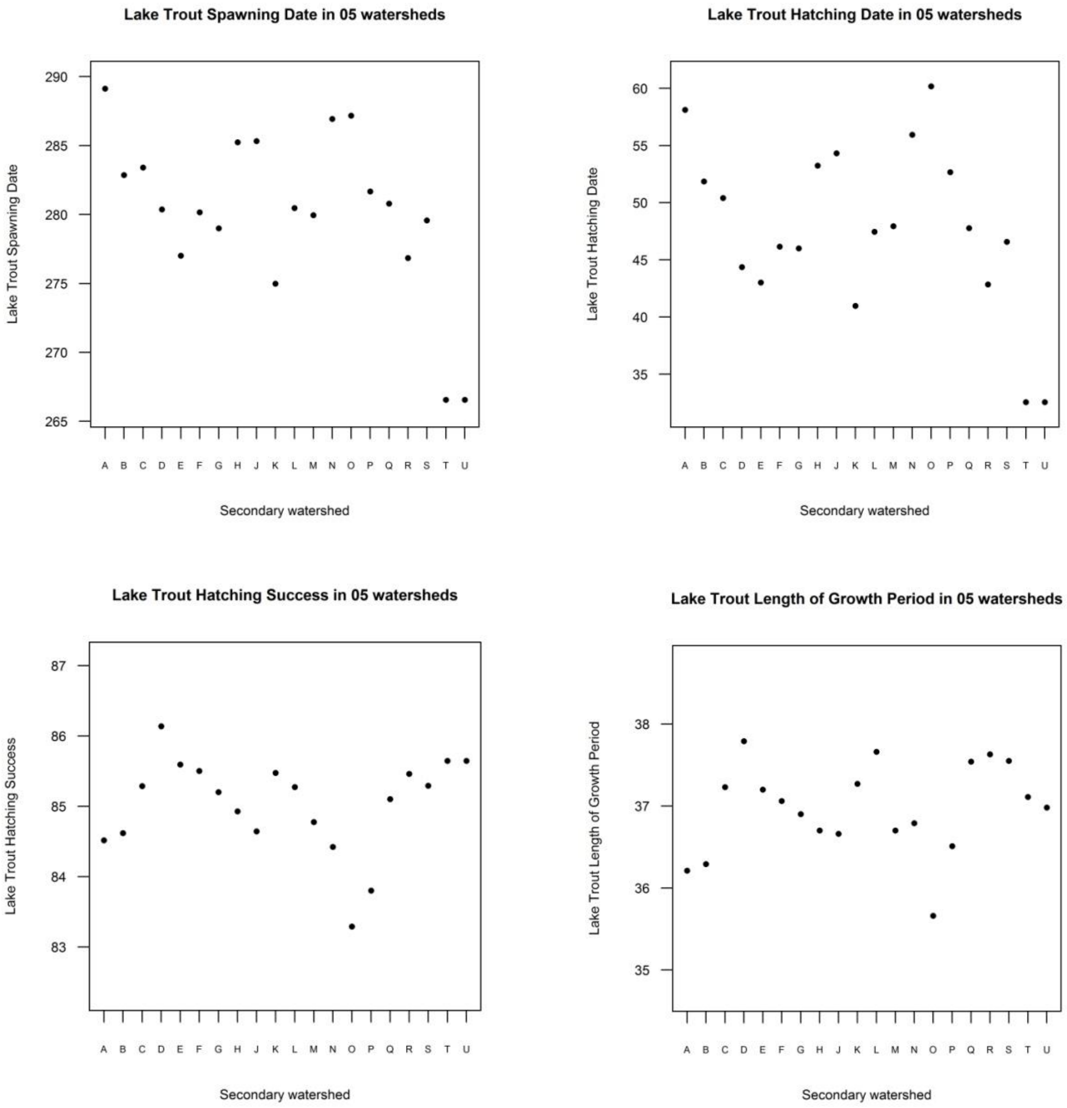
The Nelson R. watersheds have fish species richness that range from 17 to 93 (Table B.4.18). As the drainages gather together northward there is considerable potential for species to spread north. There is a wide array of warm water fish species already with a limited presence making spread with warming relatively easy.

Potential sustainable yield (total)

The total potential sustainable fish yield of lakes in the 02 drainage for the 1971-2000 climate norms was 93,012 MT/y with much of it accounted for in the yields of the Great Lakes (Table B.4.19). Projected percentage changes for future time periods ha a wide range. The lowest ranges of percentage change were for the B1*2011-2040 combination with a minima range of -0.7 to +13.9% and a maxima range of +12.4 to +27.8%. The highest ranges were for the A2*2071-2100 combination with a minima range of +30.5 to +63.3% and a maxima range of +50.0 to +92.9%. The ranges of the reference A2*2041-2070 combination were in between with a minima range of +14.7 to +35.6% and a maxima range of +27.6 to +50.9%.The spatial locations of minima and maxima varied across emission scenarios and time periods though minima were more common in far western watersheds and maxima more common in far eastern watersheds.

Potential sustainable yield (selected species)

For the three fish species considered (Lake Whitefish, Northern Pike and Walleye) projected decreases are the most common outcome across the watersheds of the 05 drainage (Table B.4.20). The few projected increases are in the two northernmost watersheds. Thus increases in overall fish yield will have to be achieved through increases in species which currently contribute little or become established in the future.



Lake Trout Spawning Date in 05 watersheds

Lake Trout Hatching Date in 05 watersheds

Lake Trout Hatching Success in 05 watersheds

Lake Trout Length of Growth Period in 05 watersheds

Figure B.4.1. Summary of projected Lake Trout spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by secondary watershed in the 05 drainage area.

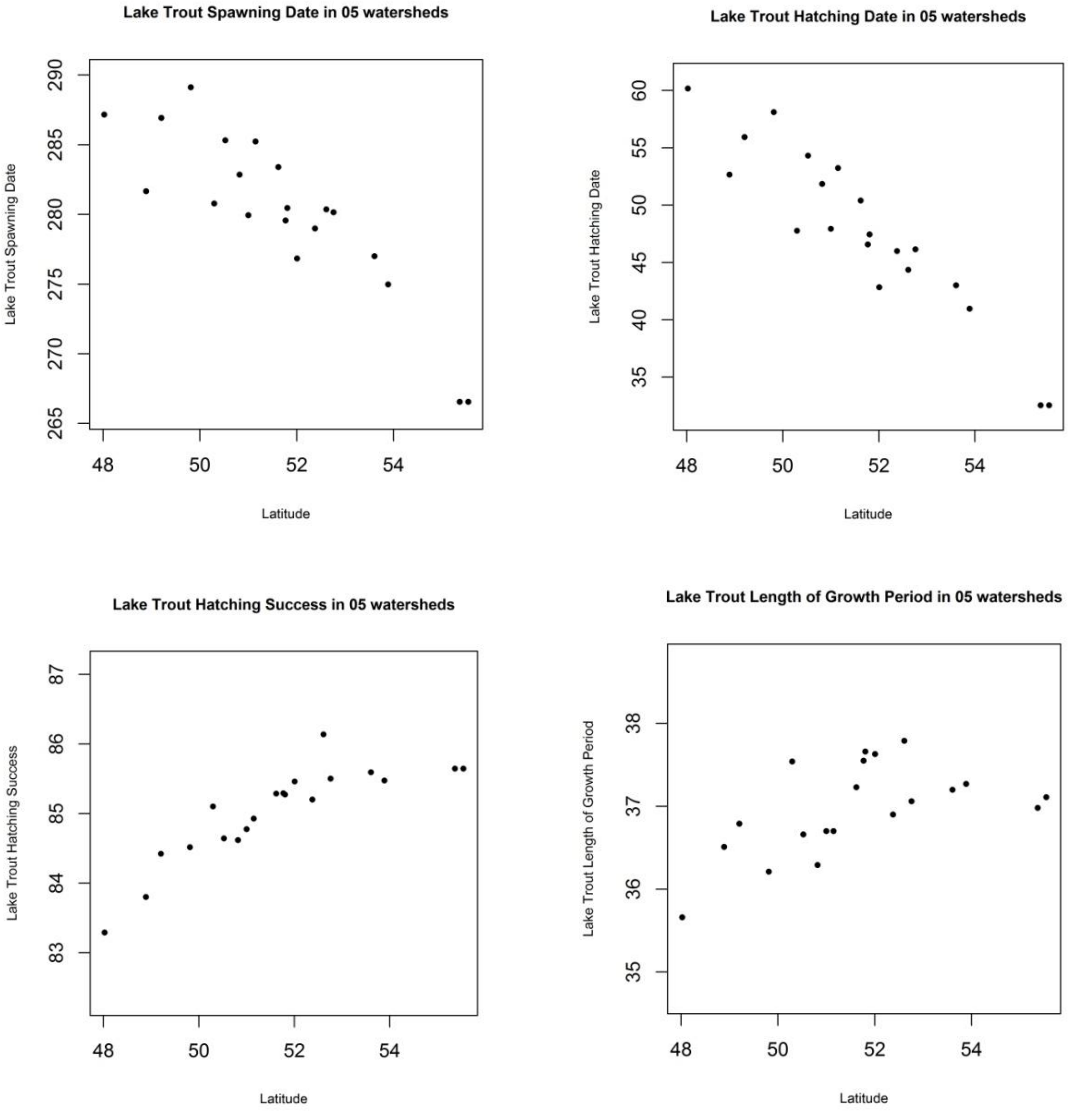


Figure B.4.2. Summary of projected Lake Trout spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by latitude in the 05 drainage area.

Table B.4.1. Summary of projected temperature dependent spawning dates for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods

SWS 05 – Lake Trout Temperature Dependent Spawning Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	289	4	8	9	13	13	17
05B	283	4	8	8	13	13	17
05C	283	0	3	3	8	6	11
05D	280	0	0	0	4	4	8
05E	277	2	3	2	7	6	10
05F	280	-1	3	3	7	6	10
05G	279	1	3	2	6	6	10
05H	285	-1	2	2	7	6	10
05J	285	-1	3	4	8	7	12
05K	275	2	6	4	7	7	12
05L	280	-1	3	3	9	6	14
05M	280	2	5	4	8	7	13
05N	287	-1	2	3	8	7	12
05O	287	5	9	10	14	13	19
05P	282	5	10	9	14	13	20
05Q	281	0	5	5	11	9	16
05R	277	2	5	3	10	7	16
05S	280	0	3	2	9	6	14
05T	267	4	6	8	12	11	14
05U	267	3	5	7	12	12	16
Min	267	-1	0	0	4	4	8
Max	289	5	10	10	14	13	20

Table B.4.2. Summary of projected temperature dependent hatching dates for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Lake Trout Temperature Dependent Hatching Date

SWS	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
05A	58	3	5	7	10	10	14
05B	52	2	4	6	9	9	12
05C	50	2	4	4	8	6	11
05D	44	0	2	2	5	5	9
05E	43	2	3	4	7	7	10
05F	46	1	3	5	7	7	10
05G	46	3	3	4	7	8	11
05H	53	1	2	4	7	7	10
05J	54	1	3	5	7	7	11
05K	41	3	4	5	8	8	12
05L	47	1	4	5	9	7	13
05M	48	3	4	6	8	8	13
05N	56	1	3	5	8	7	12
05O	60	3	5	7	10	10	14
05P	53	4	6	7	10	10	15
05Q	48	2	5	6	10	10	14
05R	43	4	5	6	10	9	15
05S	47	2	4	4	8	7	12
05T	33	2	4	6	9	10	13
05U	33	2	4	6	9	11	15
Min	33	0	2	2	5	5	9
Max	60	4	6	7	10	11	15

Table B.4.3. Summary of projected time dependent hatching dates for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Lake Trout Time Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	58	-28	-13	-46	-32	-66	-49
05B	52	-28	-14	-48	-29	-64	-46
05C	50	-9	2	-23	-9	-35	-19
05D	44	0	3	-12	1	-23	-10
05E	43	-10	-4	-20	-5	-33	-16
05F	46	-7	5	-21	-6	-33	-16
05G	46	-9	-1	-19	-4	-31	-15
05H	53	-6	6	-22	-5	-34	-16
05J	54	-9	4	-27	-9	-40	-21
05K	41	-18	-3	-21	-9	-42	-21
05L	47	-8	6	-28	-7	-48	-18
05M	48	-15	-4	-26	-9	-44	-20
05N	56	-5	6	-24	-8	-39	-20
05O	60	-33	-17	-52	-33	-75	-48
05P	53	-35	-14	-54	-32	-78	-46
05Q	48	-15	2	-36	-14	-60	-28
05R	43	-16	-3	-31	-7	-57	-20
05S	47	-9	2	-29	-4	-51	-16
05T	33	-20	-13	-42	-27	-48	-36
05U	33	-18	-11	-42	-24	-57	-41
Min	33	-35	-17	-54	-33	-78	-49
Max	60	0	6	-12	1	-23	-10

Table B.4.4. Summary of projected temperature dependent hatching success for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Lake Trout Temperature Dependent Hatching Success

SWS	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
05A	84.52%	0.38%	1.09%	0.65%	1.10%	1.12%	1.62%
05B	84.62%	0.53%	1.21%	0.52%	1.29%	0.82%	1.64%
05C	85.29%	-0.65%	-0.09%	-0.70%	-0.06%	-0.66%	0.04%
05D	86.14%	-0.51%	0.06%	-0.91%	-0.27%	-0.80%	-0.13%
05E	85.59%	-0.38%	0.28%	-0.80%	-0.13%	-0.71%	-0.02%
05F	85.50%	-0.65%	-0.05%	-0.69%	-0.02%	-0.62%	0.09%
05G	85.20%	-0.67%	0.05%	-0.99%	-0.37%	-0.94%	-0.25%
05H	84.93%	-0.73%	-0.10%	-0.74%	-0.02%	-0.74%	0.03%
05J	84.64%	-0.67%	-0.05%	-0.54%	0.18%	-0.69%	0.22%
05K	85.48%	-0.31%	0.65%	-0.71%	-0.15%	-0.66%	0.31%
05L	85.27%	-0.80%	-0.15%	-0.72%	0.04%	-0.74%	0.35%
05M	84.78%	-0.54%	0.38%	-0.62%	0.00%	-0.66%	0.15%
05N	84.42%	-0.79%	-0.19%	-0.56%	0.05%	-0.67%	0.15%
05O	83.29%	0.47%	1.21%	0.59%	1.23%	0.54%	1.55%
05P	83.80%	0.33%	1.31%	0.49%	1.32%	0.40%	1.69%
05Q	85.10%	-0.67%	0.18%	-0.49%	0.43%	-0.51%	0.81%
05R	85.46%	-0.80%	0.14%	-0.82%	0.11%	-0.82%	0.54%
05S	85.29%	-0.84%	0.21%	-0.77%	0.16%	-0.79%	0.51%
05T	85.65%	0.30%	0.69%	0.53%	1.00%	-0.67%	0.86%
05U	85.65%	0.16%	0.55%	0.31%	0.86%	0.28%	0.62%
Min	83.29%	-0.84%	-0.19%	-0.99%	-0.37%	-0.94%	-0.25%
Max	86.14%	0.53%	1.31%	0.65%	1.32%	1.12%	1.69%

Table B.4.5. Summary of projected time dependent hatching success for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Lake Trout Time Dependent Hatching Success							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	84.52%	3.27%	6.96%	7.74%	11.02%	11.71%	13.62%
05B	84.62%	3.40%	6.95%	6.98%	11.47%	10.98%	13.73%
05C	85.29%	-0.71%	2.04%	1.94%	5.43%	4.42%	8.17%
05D	86.14%	-0.73%	0.11%	-0.38%	2.81%	2.33%	5.50%
05E	85.59%	0.78%	2.42%	1.05%	4.65%	3.65%	7.67%
05F	85.50%	-1.41%	1.67%	1.31%	5.05%	3.74%	7.80%
05G	85.20%	0.13%	2.23%	0.82%	4.36%	3.42%	7.21%
05H	84.93%	-1.70%	1.41%	1.08%	5.17%	3.68%	7.91%
05J	84.64%	-1.17%	2.08%	2.03%	6.33%	4.91%	9.33%
05K	85.48%	0.76%	4.55%	2.03%	5.01%	4.89%	9.90%
05L	85.27%	-1.76%	1.83%	1.46%	6.60%	4.10%	11.08%
05M	84.78%	0.95%	3.75%	2.09%	6.15%	4.78%	10.29%
05N	84.42%	-1.54%	1.28%	1.86%	5.72%	4.63%	9.23%
05O	83.29%	4.17%	8.08%	7.87%	11.92%	10.96%	12.11%
05P	83.80%	3.49%	8.60%	7.76%	12.39%	9.66%	11.37%
05Q	85.10%	-0.54%	3.75%	3.32%	8.65%	6.67%	12.76%
05R	85.46%	0.63%	3.96%	1.47%	7.42%	4.64%	12.49%
05S	85.29%	-0.83%	2.18%	0.76%	6.79%	3.55%	11.64%
05T	85.65%	3.17%	4.89%	6.53%	10.10%	8.10%	11.13%
05U	85.65%	2.62%	4.40%	5.75%	9.97%	9.62%	12.17%
Min	83.29%	-1.76%	0.11%	-0.38%	2.81%	2.33%	5.50%
Max	86.14%	4.17%	8.60%	7.87%	12.39%	11.71%	13.73%

Table B.4.6. Summary of projected length of growth period for Lake Trout in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Lake Trout Length of Growth Period							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	36	0	1	0	1	0	1
05B	36	0	1	0	1	0	1
05C	37	-1	-1	-2	-1	-2	-1
05D	38	-1	0	-2	-1	-2	-1
05E	37	-1	0	-2	-1	-2	-1
05F	37	-1	0	-2	-1	-2	-1
05G	37	-1	0	-2	-2	-3	-2
05H	37	-1	-1	-2	-1	-2	-1
05J	37	-1	-1	-2	-1	-2	-1
05K	37	-1	1	-2	-1	-2	-1
05L	38	-1	-1	-2	-1	-2	-1
05M	37	-1	0	-2	-1	-2	-1
05N	37	-1	-1	-2	-1	-2	-1
05O	36	0	1	0	1	-1	1
05P	37	0	1	0	1	-1	1
05Q	38	-1	0	-1	0	-2	0
05R	38	-1	0	-2	-1	-3	-1
05S	38	-1	0	-2	-1	-2	-1
05T	37	0	1	0	0	-2	0
05U	37	0	0	0	0	-1	0
Min	36	-1	-1	-2	-2	-3	-2
Max	38	0	1	0	1	0	1

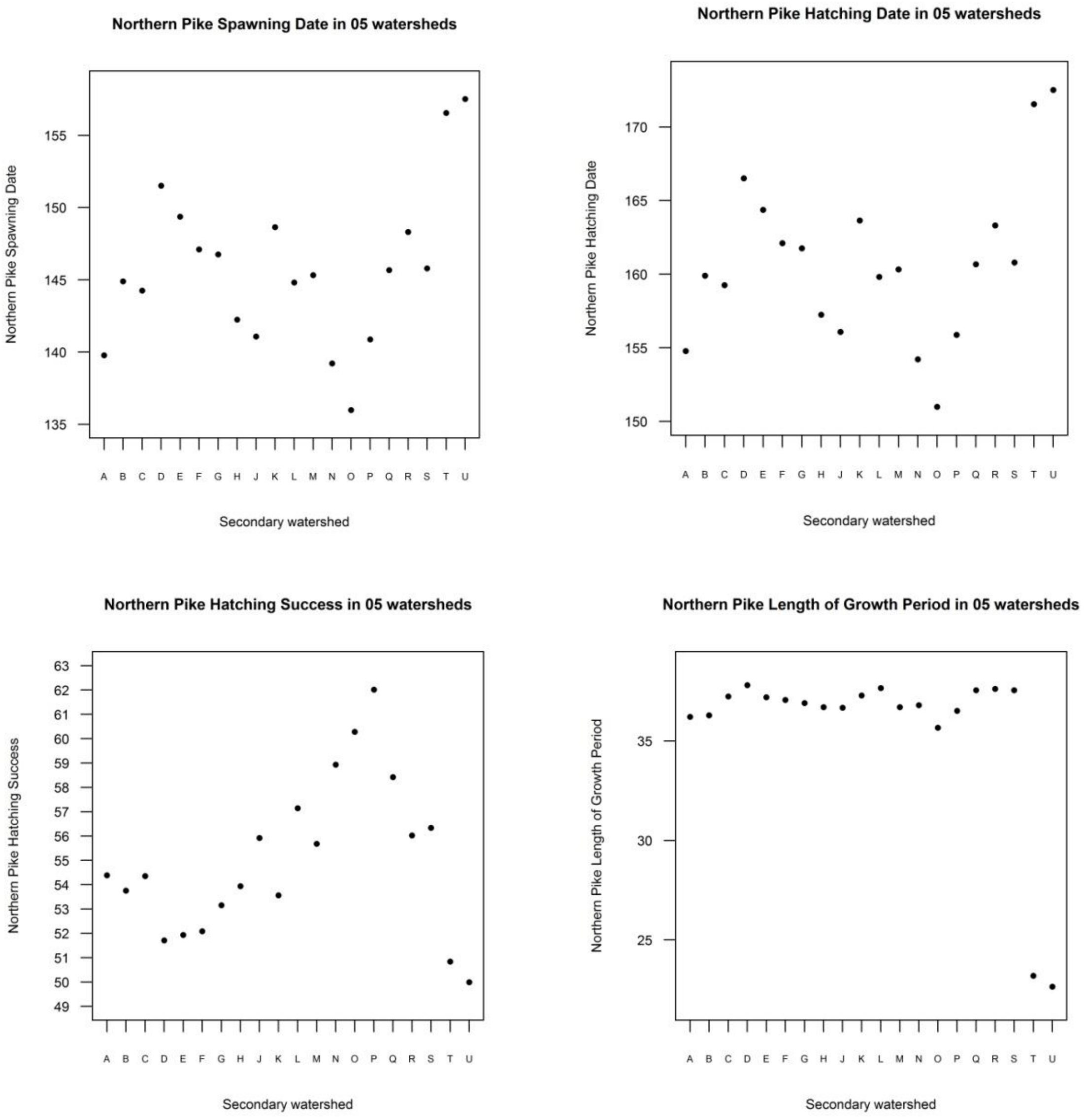
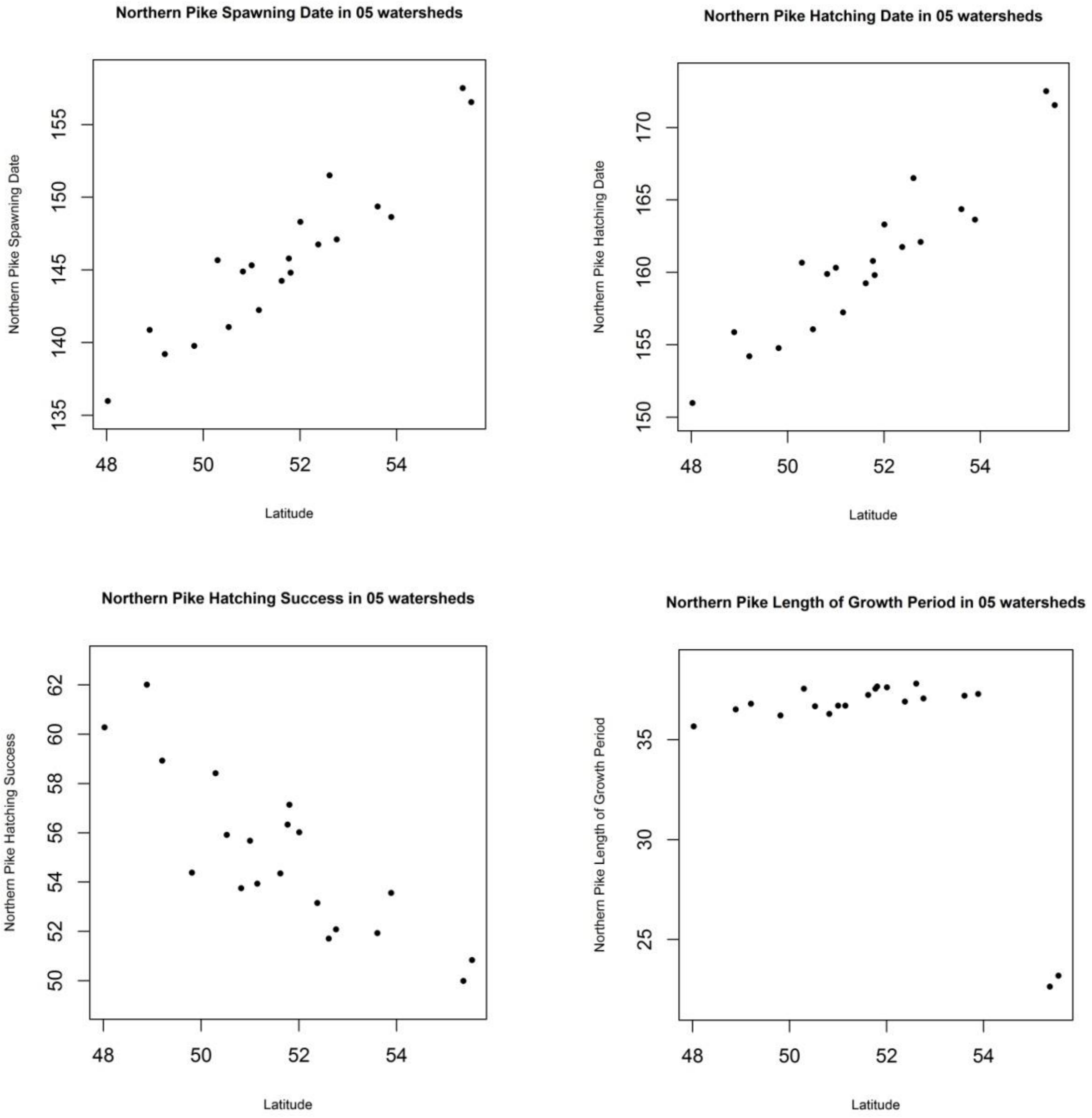


Figure B.4.3. Summary of projected Northern Pike spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by secondary watershed in the 05 drainage.


Northern Pike Spawning Date in 05 watersheds

Northern Pike Hatching Date in 05 watersheds

Northern Pike Hatching Success in 05 watersheds

Northern Pike Length of Growth Period in 05 watersheds

Figure B.4.4. Summary of projected Northern Pike spawning date (upper left), hatching date (upper right), hatching success (lower left) and growth period (lower right) for the 1971-2000 period by latitude in the 05 drainage.

Table B.4.7. Summary of projected temperature dependent spawning dates for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Temperature Dependent Spawning Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	140	-1	0	-3	-1	-5	-3
05B	145	-1	0	-2	-1	-5	-3
05C	144	-1	0	-2	-1	-5	-3
05D	152	-2	-1	-3	-2	-5	-3
05E	149	-2	0	-3	-1	-5	-3
05F	147	-2	-1	-2	-2	-5	-3
05G	147	-2	-1	-2	-2	-4	-3
05H	142	-2	0	-3	-2	-5	-3
05J	141	-1	0	-2	-1	-5	-3
05K	149	-2	-1	-3	-2	-5	-4
05L	145	-2	-1	-3	-2	-6	-4
05M	145	-2	-1	-4	-3	-6	-4
05N	139	-1	0	-2	-1	-5	-3
05O	136	-2	-2	-3	-2	-6	-4
05P	141	-2	-1	-2	-2	-6	-3
05Q	146	-2	-1	-3	-2	-6	-4
05R	148	-1	-1	-3	-2	-5	-3
05S	146	-2	-1	-3	-2	-6	-4
05T	157	-2	0	-4	-2	-6	-4
05U	158	-2	-1	-4	-3	-7	-5
Min	136	-2	-2	-4	-3	-7	-5
Max	158	-1	0	-2	-1	-4	-3

Table B.4.8. Summary of projected temperature dependent hatching dates for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Temperature Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	155	-1	0	-3	-1	-5	-3
05B	160	-1	0	-2	-1	-5	-3
05C	159	-1	0	-2	-1	-6	-3
05D	167	-2	-1	-3	-2	-6	-3
05E	164	-2	0	-3	-1	-6	-3
05F	162	-2	-1	-3	-2	-6	-3
05G	162	-2	-1	-3	-2	-5	-3
05H	157	-2	0	-3	-2	-6	-3
05J	156	-1	0	-2	-1	-5	-3
05K	164	-2	-1	-3	-2	-6	-4
05L	160	-2	-1	-3	-2	-6	-4
05M	160	-2	-1	-4	-3	-6	-4
05N	154	-1	0	-2	-1	-5	-3
05O	151	-2	-2	-3	-2	-6	-4
05P	156	-2	-1	-2	-2	-6	-3
05Q	161	-2	-1	-3	-2	-6	-4
05R	163	-1	-1	-3	-2	-6	-3
05S	161	-2	-1	-3	-2	-6	-4
05T	172	-2	0	-5	-3	-7	-5
05U	173	-2	-1	-5	-4	-8	-6
Min	151	-2	-2	-5	-4	-8	-6
Max	173	-1	0	-2	-1	-5	-3

Table B.4.9. Summary of projected time dependent hatching dates for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Time Dependent Hatching Date							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	155	-1	0	-2	-1	-3	-2
05B	160	-1	0	-2	-1	-3	-2
05C	159	-1	0	-2	-1	-3	-2
05D	167	-1	-1	-2	-1	-3	-2
05E	164	-1	-1	-2	-1	-3	-2
05F	162	-1	-1	-2	-1	-3	-2
05G	162	-1	-1	-2	-1	-3	-2
05H	157	-1	0	-2	-1	-3	-2
05J	156	-1	0	-1	-1	-3	-2
05K	164	-1	-1	-2	-1	-3	-2
05L	160	-1	0	-2	-1	-3	-2
05M	160	-1	-1	-2	-2	-3	-2
05N	154	-1	0	-1	-1	-3	-1
05O	151	-1	-1	-2	-1	-3	-2
05P	156	-1	0	-1	-1	-3	-2
05Q	161	-1	-1	-2	-1	-3	-2
05R	163	-1	-1	-2	-1	-3	-2
05S	161	-1	-1	-2	-1	-4	-2
05T	172	-1	-1	-2	-1	-4	-3
05U	173	-2	-1	-3	-2	-4	-3
Min	151	-2	-1	-3	-2	-4	-3
Max	173	-1	0	-1	-1	-3	-1

Table B.4.10. Summary of projected temperature dependent hatching success for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Temperature Dependent Hatching Success							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	54.39%	-3.63%	-2.76%	-5.69%	-3.52%	-6.71%	-3.37%
05B	53.76%	-3.13%	-1.59%	-5.27%	-4.60%	-6.79%	-4.79%
05C	54.36%	-3.87%	-2.77%	-6.63%	-5.63%	-6.79%	-2.91%
05D	51.71%	-1.32%	-0.02%	-3.81%	-1.74%	-4.56%	-0.69%
05E	51.94%	-2.66%	-1.37%	-4.81%	-1.89%	-5.03%	-0.50%
05F	52.09%	-2.36%	-0.74%	-4.94%	-0.67%	-5.25%	-0.90%
05G	53.16%	-3.09%	-2.20%	-6.13%	-1.83%	-6.40%	-3.71%
05H	53.94%	-2.88%	-2.48%	-5.73%	-4.47%	-5.48%	-2.60%
05J	55.92%	-4.17%	-1.86%	-6.51%	-5.58%	-8.69%	-5.71%
05K	53.56%	-2.47%	-0.44%	-4.84%	-3.59%	-5.95%	-2.14%
05L	57.14%	-3.03%	-1.45%	-5.48%	-4.89%	-8.37%	-5.45%
05M	55.68%	-2.70%	-1.65%	-5.60%	-3.91%	-8.16%	-5.09%
05N	58.93%	-3.52%	-2.41%	-6.59%	-5.56%	-8.24%	-5.76%
05O	60.28%	-2.70%	-1.43%	-5.69%	-4.56%	-8.71%	-5.79%
05P	62.02%	-3.25%	-2.37%	-6.59%	-5.24%	-9.79%	-6.81%
05Q	58.42%	-3.01%	-1.24%	-5.78%	-5.42%	-8.98%	-6.22%
05R	56.03%	-3.94%	-1.56%	-6.13%	-5.39%	-7.83%	-5.07%
05S	56.34%	-2.77%	-1.12%	-5.31%	-4.65%	-8.28%	-5.58%
05T	50.84%	-3.72%	-0.42%	0.06%	0.35%	-4.00%	-0.08%
05U	49.99%	-2.53%	-0.65%	-0.52%	0.81%	-4.09%	-0.78%
Min	49.99%	-4.17%	-2.77%	-6.63%	-5.63%	-9.79%	-6.81%
Max	62.02%	-1.32%	-0.02%	0.06%	0.81%	-4.00%	-0.08%

Table B.4.11. Summary of projected time dependent hatching success for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Time Dependent Hatching Success

SWS	1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
		Min	Max	Min	Max	Min	Max
05A	54.39%	-5.87%	-2.92%	-14.76%	-10.85%	-31.13%	-19.41%
05B	53.76%	-7.65%	-4.01%	-13.71%	-9.59%	-28.71%	-21.02%
05C	54.36%	-8.53%	-5.28%	-14.60%	-11.12%	-31.80%	-20.73%
05D	51.71%	-6.80%	0.60%	-15.07%	-9.96%	-30.04%	-14.53%
05E	51.94%	-9.22%	-0.13%	-15.11%	-8.21%	-28.58%	-17.27%
05F	52.09%	-9.70%	-0.70%	-14.55%	-11.18%	-31.11%	-20.35%
05G	53.16%	-10.10%	-2.84%	-13.51%	-11.36%	-27.80%	-20.03%
05H	53.94%	-8.65%	-4.09%	-15.33%	-13.33%	-32.18%	-21.60%
05J	55.92%	-8.04%	-4.66%	-15.60%	-8.46%	-29.10%	-18.38%
05K	53.56%	-9.96%	-5.24%	-18.34%	-13.07%	-33.19%	-25.74%
05L	57.14%	-9.82%	-7.66%	-21.18%	-14.16%	-41.16%	-26.11%
05M	55.68%	-13.67%	-3.46%	-21.12%	-14.39%	-39.62%	-25.80%
05N	58.93%	-10.43%	-2.95%	-17.26%	-9.42%	-34.26%	-19.88%
05O	60.28%	-13.47%	-9.22%	-19.44%	-15.93%	-39.32%	-24.20%
05P	62.02%	-10.64%	-6.78%	-18.04%	-14.72%	-38.88%	-20.09%
05Q	58.42%	-9.65%	-5.13%	-16.91%	-15.87%	-38.08%	-24.91%
05R	56.03%	-8.18%	-3.99%	-18.27%	-13.69%	-35.33%	-23.08%
05S	56.34%	-12.10%	-4.88%	-19.95%	-14.43%	-39.29%	-25.82%
05T	50.84%	-10.03%	-0.75%	-21.23%	-10.74%	-37.06%	-23.99%
05U	49.99%	-11.50%	-5.21%	-19.62%	-14.43%	-40.15%	-27.09%
Min	49.99%	-13.67%	-9.22%	-21.23%	-15.93%	-41.16%	-27.09%
Max	62.02%	-5.87%	0.60%	-13.51%	-8.21%	-27.80%	-14.53%

Table B.4.12. Summary of projected length of growth period for Northern Pike in the 05 drainage under 1971-2000 normals and the projected change over three future time periods.

SWS 05 – Northern Pike Length of Growth Period							
	1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
SWS		Min	Max	Min	Max	Min	Max
05A	36	0	1	0	1	0	1
05B	36	0	1	0	1	0	1
05C	37	-1	-1	-2	-1	-2	-1
05D	38	-1	0	-2	-1	-2	-1
05E	37	-1	0	-2	-1	-2	-1
05F	37	-1	0	-2	-1	-2	-1
05G	37	-1	0	-2	-2	-3	-2
05H	37	-1	-1	-2	-1	-2	-1
05J	37	-1	-1	-2	-1	-2	-1
05K	37	-1	1	-2	-1	-2	-1
05L	38	-1	-1	-2	-1	-2	-1
05M	37	-1	0	-2	-1	-2	-1
05N	37	-1	-1	-2	-1	-2	-1
05O	36	0	1	0	1	-1	1
05P	37	0	1	0	1	-1	1
05Q	38	-1	0	-1	0	-2	0
05R	38	-1	0	-2	-1	-3	0
05S	38	-2	0	-2	-1	-2	-1
05T	23	4	7	11	14	12	14
05U	23	5	8	11	14	13	14
Min	23	-2	-1	-2	-2	-3	-2
Max	38	5	8	11	14	13	14

Table B.4.13. Summary of projected time dependent spawning dates in the 05 watershed under 1971-2000 normals.

	SWS 05 - Time Dependent Spawning Date						
	Fall Spawners			Spring Spawners			
SWS	Brook Trout	Lake Trout	Lake Whitefish	Northern Pike	Smallmouth Bass	Walleye	Yellow Perch
05A	289	289	317	140	176	36	148
05B	282	283	311	145	181	36	153
05C	283	283	313	144	181	35	152
05D	280	280	311	152	**NG**	24	159
05E	276	277	307	149	**NG**	24	157
05F	280	280	310	147	183	29	155
05G	278	279	308	147	183	29	155
05H	285	285	314	142	179	37	150
05J	285	285	314	141	178	37	149
05K	274	275	305	149	**NG**	22	156
05L	280	280	310	145	183	30	153
05M	279	280	308	145	183	31	153
05N	286	287	315	139	178	37	148
05O	287	287	314	136	175	36	144
05P	281	282	309	141	181	37	150
05Q	280	281	310	146	184	29	154
05R	276	277	306	148	**NG**	23	156
05S	279	280	309	146	183	28	154
05T	266	267	297	157	**NG**	7	164
05U	266	267	297	158	**NG**	6	165
Min	266	267	297	136	175	6	144
Max	289	289	317	158	184	37	165

*NG = No Growth

Table B.4.14. Summary of projected change in temperature dependent spawning date in the 05 watersheds over three future time periods.

SWS 05 - Temperature Dependent Spawning Date								
		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
Species			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	266	-1	0	0	4	4	8
	Max	289	5	10	10	14	13	20
Lake Trout	Min	267	-1	0	0	4	4	8
	Max	289	5	10	10	14	13	20
Lake Whitefish	Min	297	-3	0	-1	4	3	8
	Max	317	6	12	11	16	15	22
Spring Spawner								
Northern Pike	Min	136	-2	-2	-4	-3	-7	-5
	Max	158	-1	0	-2	-1	-4	-3
Smallmouth Bass	Min	175	-3	-3	-6	-5	-10	-7
	Max	184	-2	-1	-5	-3	-8	-5
Walleye	Min	140	-2	-2	-4	-3	-7	-5
	Max	161	-1	0	-2	-1	-5	-3
Yellow Perch	Min	144	-2	-2	-4	-3	-7	-5
	Max	165	-1	0	-3	-2	-5	-3

Table B.4.15. Summary of projected change in hatching date in the 05 drainage over three future time periods.

SWS 05 - Temperature Dependent Hatching Date

Species		1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	6	-1	0	0	4	4	8
	Max	363	4	9	9	13	13	19
Lake Trout	Min	33	0	2	2	5	5	9
	Max	60	4	6	7	10	11	15
Lake Whitefish	Min	56	-3	0	-1	4	3	8
	Max	76	6	11	11	15	15	21
Spring Spawner								
Northern Pike	Min	151	-2	-2	-5	-4	-8	-6
	Max	173	-1	0	-2	-1	-5	-3
Smallmouth Bass	Min	185	-3	-3	-6	-5	-10	-7
	Max	195	-2	-1	-5	-3	-8	-5
Walleye	Min	156	-2	-2	-4	-3	-8	-5
	Max	177	-1	0	-2	-1	-5	-3
Yellow Perch	Min	162	-3	-2	-5	-4	-8	-5
	Max	182	-1	0	-3	-2	-5	-3

SWS 05 - Time Dependent Hatching Date

Species		1971-2000 Normals	Δ as of 2011-2040		Δ as of 2041-2070		Δ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	6	-2	-1	-3	-2	-4	-2
	Max	363	0	1	0	0	-1	0
Lake Trout	Min	33	-35	-17	-54	-33	-78	-49
	Max	60	0	6	-12	1	-23	-10
Lake Whitefish	Min	56	-13	-6	-21	-11	-32	-17
	Max	76	-1	2	-4	0	-7	-3
Spring Spawner								
Northern Pike	Min	151	-2	-1	-3	-2	-4	-3
	Max	173	-1	0	-1	-1	-3	-1
Smallmouth Bass	Min	185	-1	-1	-2	-2	-4	-3
	Max	194	-1	-1	-2	-2	-3	-2
Walleye	Min	156	-1	-1	-2	-2	-4	-3
	Max	177	0	0	-1	-1	-2	-1
Yellow Perch	Min	162	-2	-1	-3	-2	-5	-4
	Max	182	0	0	-2	-1	-3	-2

Table B.4.16. Summary of projected change in hatching success in the 05 drainage over three future time periods.

SWS 05 - Temperature Dependent Hatching Success

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	82.45%	-0.82%	-0.20%	-0.91%	-0.35%	-0.84%	-0.20%
	Max	85.16%	0.47%	1.37%	0.69%	1.38%	1.07%	1.72%
Lake Trout	Min	83.29%	-0.84%	-0.19%	-0.99%	-0.37%	-0.94%	-0.25%
	Max	86.14%	0.53%	1.31%	0.65%	1.32%	1.12%	1.69%
Lake Whitefish	Min	72.91%	-0.33%	-0.07%	-0.36%	-0.14%	-0.34%	-0.07%
	Max	73.97%	0.17%	0.52%	0.24%	0.52%	0.42%	0.66%
Spring Spawner								
Northern Pike	Min	49.99%	-4.17%	-2.77%	-6.63%	-5.63%	-9.79%	-6.81%
	Max	62.02%	-1.32%	-0.02%	0.06%	0.81%	-4.00%	-0.08%
Smallmouth Bass	Min	84.49%	-3.20%	-2.25%	-6.25%	-4.74%	-7.24%	-5.07%
	Max	91.20%	-1.71%	-0.64%	-3.82%	-2.88%	-5.34%	0.74%
Walleye	Min	48.46%	-3.65%	-2.49%	-5.98%	-4.96%	-8.81%	-6.15%
	Max	59.03%	-1.20%	-0.02%	-3.34%	-1.49%	-4.91%	-2.81%
Yellow Perch	Min	40.91%	-3.67%	-2.46%	-5.90%	-4.86%	-8.72%	-6.09%
	Max	47.31%	0.96%	2.12%	-0.91%	0.11%	-3.19%	-1.00%

SWS 05 - Time Dependent Hatching Success

Species		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	82.45%	-1.45%	0.11%	-0.43%	1.30%	1.05%	2.81%
	Max	85.16%	2.37%	4.93%	4.30%	6.64%	6.16%	7.14%
Lake Trout	Min	83.29%	-1.76%	0.11%	-0.38%	2.81%	2.33%	5.50%
	Max	86.14%	4.17%	8.60%	7.87%	12.39%	11.71%	13.73%
Lake Whitefish	Min	72.91%	-1.50%	0.18%	-0.46%	1.80%	1.45%	3.67%
	Max	73.97%	3.04%	6.57%	5.66%	8.35%	8.13%	8.69%
Spring Spawner								
Northern Pike	Min	49.99%	-13.67%	-9.22%	-21.23%	-15.93%	-41.16%	-27.09%
	Max	62.02%	-5.87%	0.60%	-13.51%	-8.21%	-27.80%	-14.53%
Smallmouth Bass	Min	84.49%	-26.14%	-13.91%	-54.48%	-34.35%	-86.38%	-56.80%
	Max	91.20%	-16.71%	-4.24%	-41.29%	-21.05%	-72.36%	-42.97%
Walleye	Min	48.46%	-14.52%	-11.31%	-23.29%	-18.27%	-41.33%	-27.79%
	Max	59.03%	-6.67%	-3.49%	-16.38%	-9.08%	-29.75%	-17.99%
Yellow Perch	Min	40.91%	-13.05%	-8.69%	-21.42%	-14.85%	-37.16%	-24.21%
	Max	47.31%	-6.08%	-0.36%	-13.80%	-7.54%	-26.82%	-13.24%

Table B.4.17. Summary of projected change in length of growth period in the 05 watershed over three future time periods.

SWS 05 - Length of Growth Period								
		1971-2000 Normals	∆ as of 2011-2040		∆ as of 2041-2070		∆ as of 2071-2100	
Species			Min	Max	Min	Max	Min	Max
Fall Spawner								
Brook Trout	Min	36	-2	-1	-2	-2	-3	-2
	Max	38	0	1	0	1	0	1
Lake Trout	Min	36	-1	-1	-2	-2	-3	-2
	Max	38	0	1	0	1	0	1
Lake Whitefish	Min	36	-2	-1	-2	-2	-3	-2
	Max	38	0	1	0	1	0	1
Spring Spawner								
Northern Pike	Min	23	-2	-1	-2	-2	-3	-2
	Max	38	5	8	11	14	13	14
Smallmouth Bass	Min	5	3	6	8	9	7	9
	Max	28	7	8	13	16	17	25
Walleye	Min	6	-1	-1	-2	-1	-2	-1
	Max	37	5	8	11	16	19	26
Yellow Perch	Min	36	-1	-1	-2	-2	-3	-2
	Max	38	0	1	0	1	0	1

Table B.4.18. Species occurrences by secondary watershed in the 05 drainage with columns ordered from low to high by the mean annual air temperature in the 1961-1990 norms period when most species occurrences were recorded and with rows ordered by species frequencies from high to low.

		05 SWS	U	T	K	R	S	M	E	Q	L	D	G	F	P	N	J	H	C	B	O	A	#
		MAAT C	-2.6	-2.5	0.2	0.3	0.9	1.4	1.4	1.4	1.6	1.9	2.0	2.5	2.7	2.9	3.1	3.4	3.5	3.8	4.4	5.6	
Code	Common name	Species name																					
S080	Brook trout	Salvelinus fontinalis	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	19
S131	Northern pike	Esox lucius	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	19
S281	Brook stickleback	Culaea inconstans	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	19
S331	Yellow perch	Perca flavescens	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	19
S163	White sucker	Catostomus commersoni	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	18
S196	Emerald shiner	Notropis atherinoides	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	18
S076	Rainbow trout	Oncorhynchus mykiss	0	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	0	1	1	1	17
S091	Lake whitefish	Coregonus clupeaformis	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	17
S201	Spottail shiner	Notropis hudsonius	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	17
S209	Fathead minnow	Pimephales promelas	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	1	17
S211	Longnose dace	Rhinichthys cataractae	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	17
S291	Trout-perch	Percopsis omiscomaycus	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	17
S151	Goldeye	Hiodon alosoides	1	0	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	16
S183	Finescale dace	Phoxinus neogaeus	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	1	1	16
S338	Iowa darter	Etheostoma exile	0	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	1	0	1	1	16
S171	Shorthead redhorse	Moxostoma macrolepidotum	1	0	1	1	1	1	1	1	1	1	0	1	1	1	0	0	1	0	1	1	15
S185	Lake chub	Couesius plumbeus	1	0	1	0	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	15
S271	Burbot	Lota lota	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	0	1	0	1	1	15
S152	Mooneye	Hiodon tergisus	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	0	14
S182	Northern redbelly dace	Phoxinus eos	1	0	1	0	1	0	1	1	1	1	1	0	1	1	0	1	0	0	1	1	13
S334	Walleye(yellow pickerel)	Stizostedion vitreum	1	1	1	1	1	1	1	1	1	0	0	0	1	1	0	0	1	0	1	0	13
S341	Johnny darter	Etheostoma nigrum	1	1	1	1	1	1	0	1	1	0	1	0	1	1	1	0	0	0	1	0	13
S093	Cisco(lake herring)	Coregonus artedi	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	1	0	0	0	0	12
S162	Longnose sucker	Catostomus catostomus	1	0	1	1	1	0	1	1	0	1	0	1	1	0	0	0	1	1	0	1	12
S180e	river shiner	Notropis blennius	0	0	1	0	1	1	1	0	0	1	0	0	1	1	1	1	1	0	1	1	12
S180i	flathead chub	Platygobio gracilis	0	0	1	0	1	1	1	0	1	1	1	0	0	1	0	1	1	0	1	1	12
S200	Blacknose shiner	Notropis heterolepis	0	1	1	1	1	1	0	1	1	0	1	0	1	1	1	0	0	0	1	0	12
S283	Ninespine stickleback	Pungitius pungitius	1	1	1	1	1	1	0	1	1	0	1	1	1	0	0	0	0	0	1	0	12
S078	Brown trout	Salmo trutta	0	0	1	0	0	1	1	0	0	1	1	0	1	1	1	1	1	1	0	0	11
S168	Silver redhorse	Moxostoma anisurum	1	0	1	1	1	1	1	1	1	1	0	0	1	0	0	0	0	0	1	0	11
S214	Pearl dace	Margariscus margarita	0	0	1	1	1	1	0	1	1	1	0	0	1	0	0	0	1	0	1	1	11
S081	Lake trout	Salvelinus namaycush	0	1	1	1	0	1	0	1	1	0	1	0	1	0	1	1	0	0	0	0	10
S316	Smallmouth bass	Micropterus dolomieu	0	0	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	0	1	0	10
S332	Sauger	Stizostedion canadense	0	0	0	1	1	1	1	1	1	1	0	0	1	0	0	0	1	0	1	0	10
S345	River darter	Percina shumardi	1	0	1	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	10
S383	Spoonhead sculpin	Cottus ricei	0	0	1	1	1	0	1	1	0	1	0	0	1	0	0	0	1	1	0	1	10
S141	Central mudminnow	Umbra limi	0	0	1	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	9
S186	Carp	Cyprinus carpio	0	0	0	1	1	1	0	1	1	0	0	0	1	1	1	0	0	0	1	0	9
S234	Channel catfish	Ictalurus punctatus	1	0	0	1	1	1	0	0	1	0	0	0	1	1	0	0	1	0	1	0	9
S382	Slimy sculpin	Cottus cognatus	1	1	1	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	0	0	9
S031	Lake sturgeon	Acipenser fulvescens	0	0	1	1	1	0	1	1	1	0	0	0	1	0	0	1	0	0	0	0	8
S161	Quillback	Carpiodes cyprinus	0	0	0	0	1	1	0	1	1	1	0	0	1	0	0	0	1	0	1	0	8
S189	Brassy minnow	Hybognathus hankinsoni	0	0	0	0	0	1	0	1	1	0	0	0	1	0	1	1	1	0	1	0	8
S198	Common shiner	Luxilus cornutus	0	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	8

S233	Brown bullhead	Ameiurus nebulosus	0	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	8
S311	Rock bass	Ambloplites rupestris	0	0	0	1	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	8
S342	Logperch	Percina caprodes	0	0	1	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	1	0	8
S344	Blackside darter	Percina maculata	0	0	1	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	8
S070b	cutthroat trout	Oncorhynchus clarki	0	0	0	0	0	1	0	0	1	1	0	0	1	0	0	0	0	1	1	1	7
S194	Golden shiner	Notemigonus crysoleucas	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	7
S210	Blacknose dace	Rhinichthys atratulus	0	0	0	1	0	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	7
S212	Creek chub	Semotilus atromaculatus	0	0	0	1	0	1	0	1	1	0	0	0	1	1	0	0	0	0	1	0	7
S231	Black bullhead	Ameiurus melas	0	0	0	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	7
S236	Tadpole madtom	Noturus gyrinus	0	0	0	1	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	7
S381	Mottled sculpin	Cottus bairdi	0	0	0	1	1	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	7
S074	Sockeye salmon	Oncorhynchus nerka	0	0	1	1	0	1	0	0	0	0	1	0	1	1	0	0	0	0	0	0	6
S132	Muskellunge	Esox masquinongy	0	0	0	1	0	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	6
S166	Bigmouth buffalo	Ictiobus cyprinellus	0	0	0	0	1	1	0	0	1	0	0	0	1	0	1	0	0	0	1	0	6
S206	Mimic shiner	Notropis volucellus	1	0	0	1	1	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	6
S313	Pumpkinseed	Lepomis gibbosus	0	0	1	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	1	0	6
S317	Largemouth bass	Micropterus salmoides	0	0	0	0	1	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	6
S319	Black crappie	Pomoxis nigromaculatus	0	0	0	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	6
S371	Freshwater drum	Aplodinotus grunniens	1	0	0	0	1	1	0	0	1	0	0	0	1	0	0	0	0	0	1	0	6
S016	chestnut lamprey	Ichthyomyzon castaneus	0	0	0	1	0	1	0	0	0	0	0	0	1	0	1	0	0	0	1	0	5
S090g	mountain whitefish	Prosopium williamsoni	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	1	5
S111	Arctic grayling	Thymallus arcticus	0	0	1	0	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	0	5
S199	Blackchin shiner	Notropis heterodon	0	0	0	0	0	1	0	1	1	0	0	0	1	1	0	0	0	0	0	0	5
S203	Spotfin shiner	Cyprinella spiloptera	0	0	0	0	0	1	0	1	1	0	0	0	1	0	0	0	0	0	1	0	5
S204	Sand shiner	Notropis ludibundus	0	0	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	1	0	5
S235	Stonecat	Noturus flavus	0	0	0	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	5
S302	White bass	Morone chrysops	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	5
S013	Silver lamprey	Ichthyomyzon unicuspis	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	4
S070c	bull trout	Salvelinus confluentus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	1	0	1	4
S100	Shortjaw cisco	Coregonus zenithicus	0	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
S160c	mountain sucker	Catostomus platyrhynchus	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	1	4
S170	Golden redhorse	Moxostoma erythrurum	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	4
S180f	bigmouth shiner	Notropis dorsalis	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0	4
S180g	weed shiner	Notropis texanus	0	0	0	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	4
S191	Silver chub	Macrhybopsis storeriana	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	4
S192	Hornyhead chub	Nocomis biguttatus	0	0	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
S208	Bluntnose minnow	Pimephales notatus	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	4
S121	Rainbow smelt	Osmerus mordax	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	3
S384	Deepwater sculpin	Myoxocephalus thompsoni	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	3
S079	Arctic char	Salvelinus alpinus	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2
S092	Longjaw cisco	Coregonus alpenae	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S098	Nipigon cisco	Coregonus nipigon	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S102	Round whitefish	Prosopium cylindraceum	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S261	Banded killifish	Fundulus diaphanus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	2
S282	Threespine stickleback	Gasterosteus aculeatus	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2
S314	Bluegill	Lepomis macrochirus	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S315	Longear sunfish	Lepomis megalotis	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S387	Fourhorn sculpin	Myoxocephalus quadricornis	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	2
S012	Northern brook lamprey	Ichthyomyzon fossor	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S051	Bowfin	Amia calva	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S070d	dolly varden	Salvelinus malma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
S094	Bloater	Coregonus hoyi	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
S097	Blackfin cisco	Coregonus nigripinnis	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
S1101	Arapaima	Arapaima gigas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
S1201	Mosquitofish	Gambusia affinis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1

S1202	sailfin molly	Poecilia latipinna	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
S1203	guppy	Poecilia reticulata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
S172	Greater redhorse	Moxostoma valenciennesi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S180b	western silvery minnow	Hybognathus argyritis	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S181	goldfish	Carassius auratus	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
S202	Rosyface shiner	Notropis rubellus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S213	Fallfish	Semotilus corporalis	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S232	Yellow bullhead	Ameiurus natalis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
S312	Green sunfish	Lepomis cyanellus	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S318	White crappie	Pomoxis annularis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
S337	Rainbow darter	Etheostoma caeruleum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S339	Fantail darter	Etheostoma flabellare	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S340	Least darter	Etheostoma microperca	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
S346	Tessellated darter	Etheostoma olmstedi	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1
S503	jewel cichlid	Hemichromis bimaculatus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
#			29	21	46	57	62	68	35	63	63	32	20	18	93	44	26	17	29	24	63	28	

Table B.4.18. Projected potential sustainable fish yield for the 1971-2000 normals by secondary watershed in the 05 drainage along with the range of projected percentage changes under the B1 and A2 emission scenarios for the future periods 2011-2040, 2014-2070, and 2070-2100.

SWS	Yield MT.y^{-1}		Percentage increases B1 Scenario						Percentage increases A2 Scenario					
	1971-2000		2011-2040		2041-2070		2071-2100		2011-2040		2041-2070		2071-2100	
			min	max	min	max	min	max	min	max	min	max	min	max
05A	927.5		9.7	22.1	19.4	29.5	26.2	41.4	11.9	16.8	27.4	38.0	44.5	67.1
05B	419.0		8.2	21.0	18.2	28.5	24.5	40.0	10.4	16.5	25.8	36.9	43.0	63.8
05C	1737.1		11.9	26.2	22.2	33.0	29.8	45.1	13.8	21.4	30.2	42.7	47.7	70.9
05D	522.9		-0.7	12.4	8.1	19.4	15.2	30.5	0.9	8.8	14.7	27.6	30.5	52.0
05E	2557.6		8.2	24.7	17.8	30.1	27.4	42.0	10.3	19.4	26.5	42.3	44.3	71.3
05F	1113.5		8.3	24.2	17.9	29.5	27.3	41.3	10.1	19.2	26.2	41.4	43.3	69.2
05G	1756.5		11.5	27.2	22.4	33.0	31.8	45.1	13.5	22.1	31.0	45.5	50.3	77.5
05H	1545.2		8.9	22.9	19.4	28.8	28.6	40.8	10.4	17.5	27.4	39.5	45.6	72.1
05J	5205.8		9.0	23.6	19.8	29.0	29.8	41.7	10.3	17.9	28.1	40.3	47.6	76.2
05K	8893.5		8.6	23.4	21.1	31.7	28.5	45.6	11.9	17.8	30.6	43.3	55.5	82.6
05L	21834.6		10.4	25.8	22.4	33.7	32.9	48.5	12.5	20.5	30.9	45.1	53.4	88.5
05M	2988.4		10.6	26.8	22.2	32.7	33.2	46.7	12.4	21.4	30.9	45.1	52.6	86.0
05N	758.8		8.6	22.5	18.7	28.0	29.9	41.4	10.3	18.2	27.4	39.1	47.4	77.7
05O	578.6		13.9	25.3	24.0	33.6	34.1	47.9	15.8	21.6	34.1	43.3	57.1	87.5
05P	5810.2		13.6	24.6	23.7	35.1	33.7	49.3	15.6	20.5	35.2	45.2	58.5	88.7
05Q	4264.9		12.7	24.9	24.7	34.9	33.8	48.8	15.3	20.9	35.6	46.4	60.8	87.1
05R	1726.0		13.6	27.8	26.5	37.8	35.8	53.1	16.4	23.1	35.6	50.3	61.1	92.9
05S	22771.6		11.6	26.3	24.0	35.3	34.1	50.6	14.0	21.4	32.3	47.1	55.8	91.2
05T	2654.5		10.1	24.4	22.0	34.2	29.7	50.0	13.4	19.3	32.2	47.7	59.8	86.8
05U	4945.8		11.3	26.3	23.5	36.9	31.7	52.9	14.6	21.4	34.1	50.9	63.3	90.8
Total	93011.9	Min	-0.7	12.4	8.1	19.4	15.2	30.5	0.9	8.8	14.7	27.6	30.5	52.0
		Max	13.9	27.8	26.5	37.8	35.8	53.1	16.4	23.1	35.6	50.9	63.3	92.9

*Table B.4.19. Projected potential qualitative changes in sustainable fish yield of selected species by secondary watershed in the 05 drainage from the 1971-2000 climate normals to the range of projected climate under the A2 emission scenario in the future period 2014-2070.**

		Climate		Projected qualitative change in species sustainable yield								
SWS	1971-2000	Δ MAAT A2 2041-2070		Lake Whitefish (TOPT -1.5°C)			Northern Pike (TOPT 1.0°C)			Walleye (TOPT 2.0°C)		
	Norm °C	Min °C	Max °C	P/A	Min	Max	P/A	Min	Max	P/A	Min	Max
05A	5.7	2.4	3.2	1	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05B	4.0	2.3	3.1	0	Decrease	Decrease	0	Decrease	Decrease	0	Decrease	Decrease
05C	3.5	2.6	3.5	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05D	2.8	1.4	2.4	0	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05E	1.8	2.3	3.5	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05F	2.7	2.3	3.4	1	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05G	1.9	2.7	3.7	1	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05H	3.6	2.4	3.3	1	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05J	3.4	2.4	3.3	1	Decrease	Decrease	1	Decrease	Decrease	0	Decrease	Decrease
05K	0.6	2.6	3.5	1	Decrease	Decrease	1	No change	Decrease	1	No change	Decrease
05L	1.8	2.6	3.7	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05M	1.5	2.6	3.7	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05N	3.4	2.4	3.2	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05O	4.6	2.9	3.5	0	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05P	2.9	3.0	3.7	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05Q	1.6	3.0	3.7	1	Decrease	Decrease	1	Decrease	Decrease	1	Decrease	Decrease
05R	0.4	3.0	4.0	1	Decrease	Decrease	1	No change	Decrease	1	No change	Decrease
05S	1.1	2.8	3.8	1	Decrease	Decrease	1	Decrease	Decrease	1	No change	Decrease
05T	-2.1	2.7	3.8	1	No change	Decrease	1	Increase	Increase	1	Increase	Increase
05U	-2.3	2.9	4.0	1	No change	Decrease	1	Increase	Increase	1	Increase	Increase

**P/A shows Species presence/absence from Chu et al.(2003)*

DISCUSSION

A summary of limitations, feasible additions and research needs is presented by major component (Resources, Climate, Abiotic Responses, Primary Biotic Responses, and Secondary Biotic Responses) in Tables 3 to 7. A synoptic overview follows:

RESOURCES

While we know roughly how many lakes and where they are in Canada, there is still a limited ability to characterize their attributes on a regional basis with respect to features such as depth, basic water chemistry (nutrients, dissolved organic carbon (DOC), pH, etc.), their biotic diversity, and their landscape context. Many provinces have previously had lake inventory programs, notably Nova Scotia, Ontario and British Columbia, but most others either do not have them or have not made such datasets available. The lack of these resource inventories makes it difficult to apply current knowledge and models for assessing cumulative and large-scale regional changes in aquatic resources. The Ontario Ministry of Natural Resources has recently established a new “Broad-scale Monitoring Program” (Lester et al. 2003) for its lakes fishery resources, taking a more statistical and regional approach to on-going assessment of its prime fisheries and their stressors.

The St. Lawrence Great Lakes were not addressed in this report because potential responses to climate change have been addressed elsewhere, e.g., Meisner et al. (1987), Kling et al. (2003) and Lynch et al. (2010). The Laurentian Great Lakes and Lake Winnipeg have been examined, there are still many large lakes in Canada’s interior regions that are poorly understood (Minns 2010).

CLIMATE

Considerable uncertainty remains at a local scale as to the outcome of global climate change. The GCM simulation output used in this study only represents a beginning point for framing future projections for lakes and their biotic resources, especially fisheries. As GCM models improve, the tools developed here for abiotic and biotic responses can be reapplied with i for the 2015-2016 freshwater risk assessment.

Those researchers and organizations taking the lead in the implementation and application of GCMs need to pay more attention to the data requirements of downstream user groups. The webserver developed at the Canadian Forestry Service (CFS, NRCAN) by McKenney et al. (2011) was used here to great effect. Using the best available spatial extrapolation tools with full accounting for elevation, the CFS webserver allows users to obtain site-specific estimates of an array of temperature and precipitation-related climate metrics for both past observation periods (30 year norms and individual years) and projected future periods for an array of GCMs and emission scenarios. Expansion of this webserver or a similar application to cover more and newer GCMs/emission scenarios such as those due to appear in the 2013 IPPC assessment report would be of considerable aid to downstream users like limnologists and fishery scientists. In addition, downstream users would also be aided if the array of standard climate metrics were enlarged to include ones that have been shown to be useful in projecting limnological and biological phenomenon, e.g. the spring and fall dates when the 31-day running average temperature passes through significant values like 0, 4, and 10 °C; degrees-days above a range of temperature thresholds, monthly evapotranspiration rates, and seasonal wind speed and direction summaries.

The proximity effects of large bodies of water (e.g. the many large lakes in central-northern Canada or Hudson’s and James Bays) are probably underappreciated and underestimated in most current GCMs. Winter climates immediately downwind of the Great

Lakes are less reliably predicted than elsewhere in Ontario. The feedback role of large water bodies, both marine and fresh, in the global and local climate regimes needs more attention.

ABIOTIC RESPONSES

Given that climate inputs are specified, most abiotic responses in lakes related to the thermal regime are highly predictable. Semi-mechanistic models have demonstrated that the fundamental mechanisms of the thermal and hydrological regimes are well-understood. In many instances reliable predictors of key features of thermal regimes, such as ice-on/off dates, onset/end of thermal stratification, peak summer surface temperatures, and stratification depth, are available. Appreciation of the intrinsic factors (i.e., lake morphometry, light penetration control by nutrient and DOC levels) that determine the length, depth, and sharpness of thermal stratification in lakes is improving (Stasko et al. 2012).

Projected changes in precipitation are highly variable but given a specified climate input, hydrological outcomes are likely highly predictable once precipitation uncertainties can be removed. Hydrological modelling is a well-developed field. The main concern for lake resources with respect to precipitation are lake levels, both seasonal and longer-term, as they affect the size of lake habitats for fish and the ability of fishers to safely navigate the lakes. As many water bodies across Canada are regulated for a variety of human uses (e.g. hydro-power, irrigation, and flood protection), greater attention is needed to projecting future lake levels with and without regulation plans.

Keller (2007) reviewed the range of potential interacting impacts in Boreal lakes. Climate-induced changes on the landscape (drought/flooding, forest fires, vegetation change, etc.) may lead to changes in DOC and nutrient inputs to lakes, thereby affecting productivity and thermal regimes through chemical budgets and physical characteristics of lakes like light extinction.

PRIMARY BIOTIC RESPONSES

Biota other than fish

The responses of non-fish biota which will undoubtedly have implications for fish resources and productivity were not considered in this preliminary assessment. Algal primary production in lakes is primarily controlled by incident radiation and ice cover with somewhat lesser temperature effects (Lewis 2011) and climate-induced changes in nutrient and DOC levels maybe more likely to have an impact. However, the increasing recognition of the important contributions of benthic primary production and terrestrial inputs of organic matter (Vander Zanden et al. 2011) has been reshaping the understanding of how fish production is ecologically regulated in lakes. Benthic algae, both epilithic and epiphytic, probably respond in a manner similar to that of planktonic algae. Macrophytes have much lower P:B ratios, they are much more regulated by temperature, and their distributions are strongly influenced by climate.

Zooplankton and benthos

Incorporating the dynamic responses of non-fish biota into impact assessment models may require the use of semi-mechanistic dynamic ecosystem-scale food-web production models, such as Ecopath (Christensen and Pauly 1992; Walters et al. 1999) and inverse analysis (Van Oevelen et al. 2010). Although existing empirical models relating production indicators such as P:B to climatic variables, e.g. Plante and Downing (1993; Fish) and Shuter and Ing (1997; Zooplankton), could be used to forecast potential changes in overall production at different trophic levels. While abiotic responses have been modelled on large regional scales using the kinds of models described in the previous section, implementing models of similar or greater complexity for biota on similar spatial and temporal scales would be a significant undertaking.

Fish

Downing and Plante (1993) showed how lake fish production is shaped primarily by body size through P:B ratios with other factors like climate and nutrient status contributing. In recent years much of the evolution of fish population models has striven to incorporate the effects of environmental conditions and habitat constraints alongside the stresses induced by exploitation (see Hayes et al*.* 2009 for further information).

SECONDARY BIOTIC RESPONSES

Biota other than fish

This topic has been reviewed elsewhere. However changes in food web dynamics can be triggered by decline among previously important species and/or the arrival/increase of other species, e.g., the decline of Diaporea and the expansion of Dreissenid mussels in the Great Lake basin.

Fish

The three fishery species examined here with respect to projected yield changes demonstrated the risks involved in using a model that projects increases in total fish yield. Species like Lake Whitefish, Northern Pike and Walleye may be expected to decrease in the southern warmer watersheds and increase in the northern colder watersheds. Better species-specific models of potential sustainable fish yield for a much wider range of species in response to climatic and morpho-edaphic factors are needed as species distributions change with the climate. Losses among existing dominant fishery species will have to be offset by increases in other species already present or in species arriving through range expansions which climate change will facilitate.

Resource users

Resource users have traditionally been viewed as static sources of demand in fishery assessment but increasingly the responses of users to changing circumstances due to climate change have been recognized (Shuter et al. 1998). Indeed resource users can be considered a further dynamic component of the ecosystem. Each type of resource user has its own set of potential responses; e.g., recreational anglers have more choices than commercial or subsistence fishers. In each fishery sector, better assessment tools are being developed. The inland commercial and subsistence fisheries, outside a few of the largest lakes, have not been assessed sufficiently in recent decades compared to analytical efforts expended on marine fisheries.

GAPS AND LIMITATIONS

- Resources: Existing databases on Canadian lake are not sufficiently organized or available, making large-scale risk assessments difficult.

- Climate: While climate projections are available from numerous GCMs for many time periods and alternate emissions scenarios, the data are usually not organized or extended into ecologically useful metrics sufficiently for non-climate science users.

- Climate: More effort needs to be directed to the precipitation projections given the importance of hydrological regimes to water levels and flushing rates in lakes.

- Abiotic Responses: Given accurate climate projections the thermal responses of lakes are highly predictable although effects of climate change on terrestrial and aquatic production processes may modify outcomes as DOC and nutrient levels change (thereby changing light environments and the relative sources of primary production).

- Abiotic Responses: Thermal stratification was not addressed but effects may vary across size classes of lakes and consequently hypolimnetic oxygen conditions may be altered.
- Biotic responses: Most of the projections for biota are based on correlational studies limiting the ability to examine secondary interactions and changes resulting from primary responses.
- Resource users: Little attention has been given to fishers in this climate change risk assessment. For aboriginal, subsistence, commercial and recreational fishers more effort need to be invested to assess adaptive capacity of each type of fisher in various regions where freshwater fishery resources are exploited.

Table 3. Summary overall of the limitations of the resource models used in this study, additional elements that are already feasible, areas where further research is warranted.

Component	Limitations	Feasible Additions	Research Needs
Size of resource	Only 2 of 11 primary watershed regions in Canada have been considered here.	Risk assessment should examine freshwater resources in all 11 primary watersheds. Refine lake size classes and stratify classes to reflect fish community composition by ichthyofaunal region.	Expand regional lake databases to allow improved characterization of lake resources and to better delimit regional patterns of association between lake characteristics and fish community composition and structure.
Landscape	Landscape factors not considered explicitly. Cumulative levels of human development impacts are not explicitly considered	Terrestrial vegetation types and productivity an important backdrop because so much of aquatic production is driven by terrestrial inputs.	Examine the relationship between terrestrial primary production levels (based on routine remote sensing data) and aquatic primary and fisheries productivity in freshwaters.
Water quality	Factors such as nutrient status, transparency, oxygen, and DOC status were not considered; Only Total Dissolved Solids (TDS) was used at Secondary Watershed (SWS) level. Impact of pre-existing factors like acidic deposition, atmospheric loadings of contaminants.	Build national lacustrine WQ database to provide a better appraisal of factors which indirectly shape the impact of climate change factors.	Develop lake models to project how nutrients and DOC might respond to climate and landscape changes and thereby affect the direct effects of climate change.
Case studies	No individual case study lakes were examined	Long-term study areas and prominent lakes can be assessed in more detail, e.g., for Ontario, Dorset, Opeongo, Turkey Lakes, ELA, Great Lakes, Laurentian, Bay of Quinte can be examined. Similar long-term sites exist in other parts of the country.	Develop cross-Canada network of long-term monitoring areas, each with several lakes and streams, similar to the NSF LTER network in the US and building on/ strengthening the framework of pre-existing areas.

Table 4. Summary overall of the limitations of the climate models used in this study, additional elements that are already feasible, areas where further research is warranted.

Component	Limitations	Feasible Additions	Research Needs
GCMs	GCMs used here are outdated and downscaled output was not used for the target regions.	Use current GCMs with provision to obtain site-specific projections. Composite results from ensembles of GCMs should be used to develop reference percentile projection (e.g. 25, 50, and 75%) which would allow the amount of climate data required for downstream analyses to be reduced.	Climate modelers need to start producing output products geared to the requirements of non-climate researchers. For example, mean monthly air temperature, the dates when running averages of air temperature cross thresholds like 0 and 4 °C, division of precipitation into snow and rain on a monthly basis.
Scenarios	Old B1 and A2 emission scenarios were used	Update the scenario being used as reference points and concentrate on those tracking likely emission trajectories.	Centralized facilitation and delivery of ensemble projections from groups of GCMs for selected emission scenarios.
Ice	Effects of sea and lake ice on regional climates are not completely addressed in the model outputs being used by non-climate scientists.	Newer GCMs, including ice.	Assess impact of lake ice on regional climate especially where there are concentrations of large lakes.

Table 5. Summary overall of the limitations of the abiotic response models used for lakes in this study, additional elements that are already feasible, areas where further research is warranted.

Component	Limitations	Feasible Additions	Research Needs
Abiotic Responses	Only surface ice and temperature phenomena were examined	Add open water stratification depth, maximum ice thickness, and durations of ice cover and stratification.	Develop application tools to deliver an array of predictive models (statistical to mechanistic) for use in projecting changes in lakes at various spatial scales (single lakes, regions, and national).
	Generic lakes were used	Expand scope to predict for a wide variety of lake classes based on area, depth, water quality characteristics (Nutrient levels, DOC), and fish assemblages.	Develop a national lake typology (similar to those being developed in Europe) to facilitate risk assessment activities.
	Water level changes not considered	As many water bodies are regulated, climate change may cause regulation plans to fail or lead to adaptation measures that damage or destroy valued fisheries production. Simple models of water level under climate change are available (Chu and Minns 2004).	A systematic multi-site analysis of past water level records from a variety of lakes and reservoirs should provide a valuable guide to how changing climate may affect the regulation plans and the fisheries productivity of those water bodies.
	Oxygen levels in hypolimnion and under ice were not considered	Winter and summer oxygen depletion models do exist, varying from statistical (Molot et al. 1992) to mechanistic (Livingstone and Imboden 1996). Such models could be applied selectively to classes of lakes with conditions that make them prone to severe oxygen depletion and hence generating detrimental effects for fish and other biota. Winter depletion problems might be expected to decrease as duration of ice cover declines.	A multi-model evaluation program using records from a range of long-term monitoring sites would provide guidance on the best ways to assess the large-scale potential for predicting low oxygen conditions during summer stratification. Also insights into the correspondence of winter and summer oxygen depletion patterns across lake types would be very useful.
	The light regime of lakes was not considered.	Light extinction is an important determinate of biotic living space. It is determined mainly by three factors: DOC which depends in terrestrial and aquatic primary production and metabolism rates, Phosphorus levels which determine the accumulation of chlorophyll in algae, epiphytes and macrophytes, and suspended sediment levels which are shaped by soils and hydrology.	The means of assessing light extinction in lakes are well established but need to be applied systematically on a regional and national scale to improve the characterization of lake habitat space. (There may be an expanded role for remote sensing in this arena, e.g. application of SeaWIFS in Canada’s many large lakes).

Table 6. Summary overall of the limitations of the first order biotic response models used in this study, additional elements that are already feasible, areas where further research is warranted.

Component	Limitations	Feasible Additions	Research Needs
Non-fish such as plankton, benthos, aquatic vegetation	These components were not assessed here.	Changes in primary and secondary producers are expected. Primary production is strongly determined by incident radiation, ice cover, and temperature. The latter mainly affects metabolism and thereby affects NPP more than GPP (Lewis 2011). Beyond those factors, nutrient and DOC changes may be important for local outcomes (Lewis 2011). Secondary producers are more strongly influenced by temperature changes. Changes in aquatic vegetation (periphyton and macrophytes) may profoundly alter competitive and predator-prey interactions in the fish assemblage.	Need to increase the ability to infer likely status of these components and how they influence outcomes for fish communities and species.
Fish			
Spawning	Representative species assessed	A much wider range of species can be examined.	Need to know how much spawning timing is controlled by competing factors (temperature, light, etc.) with particular attention to the distinctions between spring and fall spawners.
Egg development	Representative species assessed	More species can be examined.	Assemble and analyze egg development rates and hatching success versus temperature for more fish species with the aim of developing a general predictive model (e.g., Teletchea et al 2009b).
Growth	Only surface water season considered here so full growth assessment was not feasible except for species that live their lives in the surface layers	Examine the seasonally suitable growth space over the full vertical profile for specified lake size and depth characteristics (Christie and Regier 1988).	Extend the recently completed seasonal temperature –profile model (STM) for lakes (Minns and Shuter 2013) by modeling key parameters in relation to lake and climate characteristics.
Mortality	Not assessed explicitly here	Overwinter survival is a key determinant of persistence at the northern limits of range (Shuter and Post 1990; Shuter et al 2012).	Greater synthesis of mortality rates by life stage and species is needed with a systematic analysis of the factors causing variation, building on work like that of Lorenzen (1996).

Table 7. Summary overall of the limitations of the second order biotic response models used in this study, additional elements that are already feasible, areas where further research is warranted.

Component	**Limitations**	**Feasible Additions**	**Research Needs**
Non-fish	Not assessed here. Climate-induced changes in key non-fish biota may trigger cascading responses through food webs	Phenology indicators for a range of biota across the trophic levels.	Dynamic ecosystem-scale modeling of food-webs at selected sites where long-term multi-trophic level studies have been sustained.
Fish			
Distribution	Only a cursory assessment was presented here.	Recent developments, particularly with respect to invasive species, are greatly expanding the potential to project species expansions and contractions.	Closer examination of the role of climate in the establishment and expansion of species that have been widely introduced or inadvertently released in the past, e.g. Brook Trout, Common Carp, Smallmouth and Largemouth Bass, Rainbow Smelt etc.
Population dynamics	Not addressed here.	The ability to model population dynamics of selected fish stocks in relation to their supply of suitable fish habitat has expanded greatly in recent years (Hayes et al 2009).	Build on recent modeling advances with respect to key freshwater fisheries stocks, e.g. Lake Trout, Walleye, Smallmouth Bass, and Brook Trout, to develop regional impact assessments for those species based on regional resource inventories.
Ecosystem dynamics	Not addressed here.	Tools allowing food-web simulation models are improving rapidly (Pauly et al. 2000; van Oevelen et al. 2010; and Boit et al. 2012) aided in great part by the continuing expanded use of stable isotopes to unravel food web connections (e.g. Vander Zanden et al. 1999).	Expansion of existing efforts to apply ecosystem models to on-going studies in Canadian freshwaters to allow more integrated assessment of the consequences of climate change.
Fishery Production	Simple first order models were used to project future production and yields without close attention to how future changes in landscape and species composition may shape the outcomes.	A wider array of species-specific yield models could provide a more direct connection to the resource users.	Increased emphasis on fish population-habitat supply based modeling.
Fisheries Harvest and Resource Users (Commercial, Recreational, Cultural)	Not assessed here.	There are regional models emerging to describe the dynamic responses of recreational anglers to changing lake conditions (Hunt et al 2007; Post et al 2008). Such models could be applied to examining the dynamic response to climate change.	Commercial fishery yields for numerous lakes in central Canada (NW Ontario through to NWT on the Shield) are reported by the Canadian Freshwater Fish Marketing Corporation There is need to assess the sustainability of these fisheries and to project the long-term viability given expected climate change. In selected freshwater regions, model dynamics of angler response to changing resource composition and availability under climate change.

CONCLUSIONS

Large-scale changes to the climate are likely therefore there is a high degree of certainty that a wide array of impacts can be projected for Canada’s lakes, their biota, and their fisheries. Much of the uncertainty with regard to aquatic ecosystem and fisheries responses to climate change stem from the uncertainties in the climate forecasts.

RECOMMENDATIONS

The potential implications of the projected changes in climate, lakes, and biota will be summarized within some assessment of their likelihood.

- The scope of the freshwater ecoregion assessment should be expanded to cover lakes and rivers in all 11 primary watershed basins across Canada.
- Make use of the network of continuous freshwater ecosystem monitoring sites maintained by DFO and federal and provincial agencies across Canada to produce a cumulative record of changes in key lake ecosystem indicators showing how climate change and variability affect abiotic and biotic lake attributes.
- Implement a continuous, coordinated impact assessment process for freshwater fishery resources mediated through an integrated network of simulation models whereby improvements in predictive capability for any module can be incorporated. Thus a standing impact assessment capacity could be maintained.

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