Selected Social Implications of Climate Change for Ontario’s Ecodistrict 3E-1 (The Clay Belt)
Climate change will affect all MNR programs and the natural resources for which it has responsibility. This strategy confirms MNR’s commitment to the Ontario government’s climate change initiatives such as the Go Green Action Plan on Climate Change and outlines research and management program priorities for the 2011-2014 period.

**Theme 1: Understand Climate Change**
MNR will gather, manage, and share information and knowledge about how ecosystem composition, structure and function – and the people who live and work in them – will be affected by a changing climate.

**Strategies:**
- Communicate internally and externally to build awareness of the known and potential impacts of climate change and mitigation and adaptation options available to Ontarians.
- Monitor and assess ecosystem and resource conditions to manage for climate change in collaboration with other agencies and organizations.
- Undertake and support research designed to improve understanding of climate change, including improved temperature and precipitation projections, ecosystem vulnerability assessments, and improved models of the carbon budget and ecosystem processes in the managed forest, the settled landscapes of southern Ontario, and the forests and wetlands of the Far North.
- Transfer science and understanding to decision-makers to enhance comprehensive planning and management in a rapidly changing climate.

**Theme 2: Mitigate Climate Change**
MNR will reduce greenhouse gas emissions in support of Ontario’s greenhouse gas emission reduction goals. Strategies:
- Continue to reduce emissions from MNR operations through vehicle fleet renewal, converting to other high fuel efficiency/low-emissions equipment, demonstrating leadership in energy-efficient facility development, promoting green building materials and fostering a green organizational culture.
- Facilitate the development of renewable energy by collaborating with other Ministries to promote the value of Ontario’s resources as potential green energy sources, making Crown land available for renewable energy development, and working with proponents to ensure that renewable energy developments are consistent with approval requirements and that other Ministry priorities are considered.
- Provide leadership and support to resource users and industries to reduce carbon emissions and increase carbon storage by undertaking afforestation, protecting natural heritage areas, exploring opportunities for forest carbon management to increase carbon uptake, and promoting the increased use of wood products over energy-intensive, non-renewable alternatives.
- Help resource users and partners participate in a carbon offset market, by working with our partners to ensure that a robust trading system is in place based on rules established in Ontario (and potentially in other jurisdictions), continuing to examine the mitigation potential of forest carbon management in Ontario, and participating in the development of protocols and policies for forest and land-based carbon offset credits.

**Theme 3: Help Ontarians Adapt**
MNR will provide advice and tools and techniques to help Ontarians adapt to climate change. Strategies include:
- Maintain and enhance emergency management capability to protect life and property during extreme events such as flooding, drought, blowdown and wildfire.
- Use scenarios and vulnerability analyses to develop and employ adaptive solutions to known and emerging issues.
- Encourage and support industries, resource users and communities to adapt, by helping to develop understanding and capabilities of partners to adapt their practices and resource use in a changing climate.
- Evaluate and adjust policies and legislation to respond to climate change challenges.
Selected Social Implications of Climate Change for Ontario’s Ecodistrict 3E-1 (The Clay Belt)

Len M. Hunt and Brian Kolman

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Summary

Climate change will likely affect both social and ecological systems in Ecodistrict 3E-1 in northeastern Ontario. Projected increases in temperature and changes to the type and amount of precipitation may affect ecosystems and how people interact with, and benefit from, ecosystem values and resources. We report projected changes to season length for snowmobiling and ice fishing and expected changes to revenues of float plane-accessible tourism establishments based on changes in walleye (*Sander vitreum*) productivity and smallmouth bass (*Micropterus dolomieu*) presence in lakes as social indicators of vulnerability to climate change. These projections are derived from an ensemble and the CGCM3 model for two common climate change scenarios for the short- (year 2040), mid- (year 2070), and long- (year 2100) term. Winter recreation (snowmobiling and ice fishing) is projected to be moderately affected by climate change in the short and mid-term. The longer-term implications of climate change may be more pronounced. Under the more extreme climate change scenario, by 2100 both the snowmobile and ice fishing seasons may be as much as one month shorter. Walleye lakes with floatplane-accessible tourism establishments may benefit from increased carrying capacity for this desired species, resulting in increased revenue of 0.9%. However, climate change may have mixed effects on these systems as the introduction of small-mouthed bass may reduce revenue by 8.5%. Larger-scale effects of climate change (provincial—global) may have compounding effects on what happens in Ecodistrict 3E-1 as social-ecological systems at these scales may influence local activities. A few considerations and conclusions are provided to assist resource managers and stakeholders in the development and implementation of adaptation strategies related to climate change.
Acknowledgements

We thank Brian Shuter and Ken Minns for providing ice cover data. Gilbert Racine of the Northeast Geomatics Service Centre developed mapping products to support the study. We thank Paul Gray and Will Wistowsky for reviewing an earlier version of the manuscript and Trudy Vaittinen for report production support.

Résumé

Répercussions sociales particulières des changements climatiques dans l’écorégion 3E-1 de l’Ontario (ceinture d’argile)

Les changements climatiques auront probablement des effets sur les systèmes sociaux et écologiques de l’écorégion 3E-1 qui est située dans le Nord-Est de l’Ontario. Les projections de hausses de température et de changements de type et de quantité de précipitations peuvent toucher les écosystèmes ainsi que la façon dont les gens interagissent avec les valeurs et les ressources des écosystèmes, et en retirent des avantages. Nous faisons rapport des projections de changements de durée de la saison de la motoneige et de la pêche sous la glace ainsi que des revenus des établissements de tourisme accessibles par hydravion, en fonction des changements de productivité liée au doré jaune (Sander vitreum) et à la présence de l’achigan à petite bouche (Micropterus dolomieu) dans les lacs à titre d’indicateurs de vulnérabilité aux changements climatiques. Ces projections sont extraites d’un ensemble et du modèle CGCM3 relatifs à deux hypothèses de changements climatiques communs à court terme (2040), à moyen terme (2070) et à long terme (2100). On prévoit que les changements climatiques à court et à moyen terme auront des effets modérés sur les loisirs d’hiver (motoneige et pêche sous la glace). Les répercussions à plus long terme des changements climatiques seront peut-être moins prononcées. Dans le cas d’une hypothèse de changements climatiques plus radicaux, la saison de la motoneige et de la pêche sous la glace pourrait, d’ici 2100, être écourtée d’un mois. Les lacs où vit le doré jaune, auxquels les établissements de tourisme ont accès par hydravion, peuvent tirer un avantage de la quantité accrue de cette espèce recherchée dans leurs eaux en entraînant une hausse des revenus de 0,9 %. Cependant, les changements climatiques peuvent avoir des effets mixtes sur ces systèmes puisque l’introduction de l’achigan à petite bouche peut réduire les revenus de 8,5 %. Les répercussions à plus grande échelle des changements climatiques (échelle provinciale, mondiale) peuvent avoir des effets cumulatifs sur ce qui se produit dans l’écorégion 3E-1. En effet, ces systèmes socio-écologiques peuvent avoir, à ces échelles, une influence sur les activités locales. Quelques réflexions et conclusions sont fournies dans le but d’aider les gestionnaires de ressources et les parties concernées à adapter les stratégies relatives aux changements climatiques.

Acknowledgements

We thank Brian Shuter and Ken Minns for providing ice cover data. Gilbert Racine of the Northeast Geomatics Service Centre developed mapping products to support the study. We thank Paul Gray and Will Wistowsky for reviewing an earlier version of the manuscript and Trudy Vaittinen for report production support.
Foreword

This is one in a series of reports to help resource managers evaluate the vulnerability of natural assets to climate change. Given that vulnerability assessment techniques continue to evolve, it is important for resource managers to learn by doing and to pass on knowledge gained to support MNR and others engaged in adaptive management. Accordingly, the vulnerability assessment reports included in the Climate Change Research Report Series have been prepared using the best available information under the circumstances (e.g., time, financial support, and data availability). Collectively, these assessments can inform decisionmaking, enhance scientific understanding of how natural assets respond to climate change, and help resource management organizations establish research and monitoring needs and priorities.

Cameron Mack

Acting Director, Applied Research and Development Branch
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Introduction

Climate change has the potential to affect many elements in both human and natural systems. While researchers have made many efforts to understand these potential effects, often their efforts have taken a purposefully narrow approach that does not account for the dynamic relationships and feedbacks among human and natural systems (Westley et al. 2002, Brunner and Lynch 2010). Simply put, changes to a natural system such as a forest will affect how people use forest resources, which may subsequently affect both people and forests. In many cases, these feedbacks result in surprises that can only be predicted and addressed when a coupled social-ecological system is considered (Liu et al. 2007, Westley et al. 2011). As such, climate change research, planning, and policy development should explicitly acknowledge and address the coupled relationship between social and ecological systems. Leisure-based activities are one dimension within the larger human (social) system that are likely to be affected by climate change. Other aspects of the social system (e.g., health and industrial economic activity) are either outside the expertise of the authors and/or are covered elsewhere (e.g., Stern 2006).

Within leisure-based activities, we narrow the focus to two types: winter-based recreation and nature-based tourism. The most popular winter recreational pursuits on northern Ontario Crown lands are snowmobiling and ice fishing (Hunt and McFarlane 2003). In Ontario and in Ecodistrict 3E-1, also referred to as the Clay Belt, in northeastern Ontario, snowmobiling is a common recreational pursuit that contributes significantly to both the provincial and regional tourism economy (Gardner Pinfold Consulting 1999, Gilmour 2010). In fact, it was estimated that the approximately 168,000 snowmobile participants in Ontario spent over $670 million on snowmobile related-recreation, tourism, and products in 2009-10 (OFSC 2011). The Ontario Federation of Snowmobile Clubs (OFSC) has over 43,000 km of trails in Ontario, of which some 1,200 km are in Ecodistrict 3E-1. Snowmobiling is not limited to OFSC trails as snowmobile enthusiasts can also use networks of forest access roads, trails, and frozen water bodies. People can pursue snowmobiling as an end (i.e., a form of recreation) or means to an end (e.g., travel to pursue work or other outdoor recreation activities).

Snowmobiling’s popularity, economic significance, use as a mode of transportation, and dependence on suitable snow and ice conditions make changes to its season length an especially useful indicator of climate change vulnerability. Indeed, several researchers have focused on the effects of climate change on snowmobiling across Ontario and elsewhere (Scott and Jones 2006, McBoyle et al. 2007, Gilmour 2010). Their results suggest that the quality (or season length) of snowmobiling will decrease in southerly areas of the province.

Fishing is a popular recreational activity in Ontario that more than 1.2 million adult anglers pursue each year, resulting in over $2.5 billion per year in expenditures on consumables and fishing-related investments (OMNR 2009). About 18% of these anglers (214,000 people) participate in fishing on frozen waters (i.e., ice fishing). Ice fishing contributes to regional economies through regular trips, fishing tournaments, and expenditures at tourism accommodations. Numerous small, on-ice fishing communities emerge each winter with ice huts, some elaborate, forming distinctive winter communities where people interact with one another and the natural environment. As such, ice fishing is not only an important economic consideration, it is also a cultural one (Abbott 2005).

Given its economic significance (Hunt et al. 2008), strong support for its viability in Ontario by the Government (OMNR 2001), and the availability of related research, the susceptibility of nature-based tourism (often termed resource-based tourism in Ontario) to climate change is also of interest (e.g., Hunt et al. 2005, Hunt et al. unpublished). Northern Ontario’s nature-based tourism sector primarily caters to and accommodates guests who seek recreational fishing experiences (Hunt et al. 2002, Browne et al. 2004). In 2000, it was estimated that at least 1,150 tourism establishments offered sport fishing opportunities to guests at accommodations that were not directly accessible by road (Hunt et al. 2005). Of those establishments, 770 were only accessible by float plane. By 2010, the number of float plane accessible establishments declined to 648, with only 545 of the original 770 still operating (Hunt et al. unpublished). For Ecodistrict 3E-1, the number of float plane accessible establishments decreased from 17 in 2000 to 13 in 2011 (Figure 1).
Viewing winter-based recreation and nature-based tourism as part of a coupled social-ecological system highlights the importance of considering both direct and indirect effects from climate change on these activities (Browne and Hunt 2007, Sunstein 2007). Direct effects arise from changes in temperature, precipitation, and extreme weather events that all might influence the timing and amount of recreational activity that occurs (e.g., Hunt et al. 2007). While direct effects are important, it is more likely that climate will affect these activities through changes to resource systems (e.g., snow and ice covered landscapes) and valued resources within these systems (e.g., fish populations). For example, changes in climate might influence the productivity of fish species and increase the susceptibility of water to invasive species. These changes could influence the types, numbers, and sizes of species available to anglers and influence their fishing efforts (Hunt et al. 2007) or cause substitution of fishing sites and/or fish species (Hunt et al. 2002).

As part of a larger initiative to assess the vulnerability of Ontario’s Clay Belt to expected climate change (see Lalonde et al. 2012 for details), we examined specific linkages in social-ecological systems focused on select leisure-based activities in Ecodistrict 3E-1. Within leisure-based activities, we narrowed the focus to two types: winter-based recreation and nature-based tourism to determine potential effects of climate change on season length and fish catch rates.

*Figure 1. Select recreational features in Ecodistrict 3E-1 (The Clay Belt) in Ontario.*
Methods

We report projected changes to season length for snowmobiling and ice fishing and expected changes to revenues of float plane accessible tourism establishments resulting from changing walleye (*Sander vitreum*) productivity and smallmouth bass (*Micropterus dolomieu*) presence in lakes. These projections are derived using an ensemble and the CGCM3 models for the A2 and B1 climate change scenarios. The A2 scenario projects an increase in human population and a significant increase in pollution and carbon dioxide (CO$_2$) levels over the 1971 to 2000 period. The B1 scenario projects slower population growth and less dramatic, yet elevated, levels of CO$_2$ concentrations in the atmosphere (Nakićenović et al. 2000). The projections include short- (2011-2040), mid- (2041-2070), and long-term (2071-2100) futures. The ensemble model was created by averaging outputs from four global circulation models:

- Canadian General Circulation Model 3 (CGCM-3);
- U.S. National Center for Atmospheric Research (NRCAR-3 model);
- Japanese Model for Interdisciplinary Research on Climate (MIROC32); and
- Australian Commonwealth Scientific & Industrial Research Organisation (CSIRO model).

Snowmobiling depends on the duration of snow cover and snow depth in a given region (Gilmour 2010). As such, an evaluation of existing and potential snow accumulation and melting scenarios is an effective way to assess the potential effects of climate change on snow regimes and the likely viability of snowmobiling in Ecodistrict 3E-1 (McBoyle et al. 2007). To assess snow accumulation and melt, the Thornthwaite Monthly Water Balance Model (Thornthwaite 1948, McCabe and Markstrom 2007) was used to determine snow storage during months with snow cover. The model produces values for snow cover in millimetres of snow water equivalents (SWE). Three densities (200, 300, and 400 kg m$^{-3}$) were used to estimate the range of snow depth that would reflect the range of possible snow characteristics from fresh and fluffy (200 kg m$^{-3}$) to dense or melting (400 kg m$^{-3}$) (Brown and Braaten 1998). To convert SWE to snow depth (in metres), we used the following equation:

\[
\text{Depth (m)} = \frac{\text{SWE (mm)}}{\text{density (kg m}^{-3}\text{)}}
\]

Following McBoyle et al. (2007) and Gilmour (2010), we chose a 30 cm minimum snow depth threshold as that required to maintain viable snowmobile trails and to use grooming equipment, even over rough terrain. Snow depth for each day was estimated by first using the Thornthwaite model to estimate mean monthly snow depth. Next, a direct linear relationship was assumed for snow depth change for each day between months (e.g., if January had 70 cm and February had 100 cm, the snowdepth from January 15 would increase by one cm per day [30 cm per month] until February 14). We calibrated the Thornthwaite model to ensure that the predictions for no snow would correspond to the historic timing of snow accumulation and melting in Ecodistrict 3E-1 (Natural Resources Canada 2011). We also selected a snow density and season length to fit anecdotal reports that the length of the snow season in Kapuskasing was historically 15 weeks (105 days) (Gilmour 2010).

Projected changes to the length of the ice fishing season in Ecodistrict 3E-1 were determined from two multiple regression models that predict the onset and end of ice cover on lakes (Minns et al. 2012). These models were applied to 173 walleye lakes in Ecodistrict 3E-1. The ice-on date model used mean lake depth, mean fall temperatures, and the Julian day of fall when the 31-day running average air temperature reached 0 °C. The model for projected ice break-up dates was based on the surface area of the water body, the solar elevation (zenith angle), degrees longitude, and Julian day of spring when the 31-day running average air temperature reached 0 °C. Each model projected a Julian calendar date when ice would form (freeze-up date) or when the ice surface would start to break up (break-up date). While ice fishing does not occur until ice thickness is sufficient to hold a person, we used the difference between the ice-on and off dates as a crude proxy for the ice fishing season.

For nature-based tourism, we used projections from Chu and Fischer (in prep.) for walleye productivity and lake suitability for smallmouth bass. Walleye productivity estimates were based on a logistic growth model for walleye (Schaefer 1954) and on a thermal optical habitat area model to estimate carrying capacity and the intrinsic rate of
increase of walleye (Lester et al. 2004). We used this model to project changes to carrying capacity of walleye at 10 lakes with floatplane only accessible tourism establishments. These changes to carrying capacity are naively assumed to relate directly to increased catch rates at these lakes.

Connecting changes in walleye catch rates to tourism revenues was accomplished by building a hedonic model of week-long fishing package prices charged by operators of Ontario tourism establishments. Use of this model allowed us to estimate how different prices charged by tourism operators are influenced by setting (e.g., catch-related fishing quality) and site (e.g., provision of food) characteristics. This model builds directly from earlier work by Hunt et al. (2005) and incorporates catch-related fishing quality measures (e.g., operator-reported expected catch rates) and smallmouth bass presence. We used data from a survey of tourism operators and estimated the hedonic model from 324 float plane accessible sites across Ontario (Hunt et al. 2002). We estimated how the projected changes to catch rates would likely affect the prices charged by tourism operators at average-priced float plane accessible tourism establishments. We also projected how introductions of smallmouth bass would affect these prices (Wuellner et al. 2011). The expected catch rate and fish size was positive and statistically significant while the presence of smallmouth bass was negatively and statistically significant (see Appendix 1). These relative changes in price provide an indication of possible changes to tourism revenues and profits (Hunt et al. unpubl.).

Results

Projected season length for snowmobiling depends on assumptions about snow density. Given the belief that the historical snowmobiling season in the western part of 3E-1 was about 15 weeks or 105 days, which equates to a snow density of 300 kg m\(^{-3}\), we estimated the expected changes to snowmobiling seasons using this snow density estimate.

The length of the snowmobiling season was projected to decrease slightly or moderately in the short-term (2011-2040). For the western half of Ecodistrict 3E-1, the projected decline was 4 to 10% depending on the assumed climate change scenario, while in the eastern half the projected decline was 2 to 7% (Figure 2). In the longer-term under the A2 scenario, the projected decline was larger (18 to 22%). However, under the B1 scenario projected declines were 5 to 6%.

![Figure 2. Projected changes to snowmobile season length in east and west regions of Ecodistrict 3E-1 based on an ensemble model and the A2 and B1 climate change scenarios (see text for description) for three timeframes (snowmobile season defined by days with projected snow cover >30 cm).](image)
Not surprisingly, a warmer climate is projected to shorten the ice fishing season in Ecodistrict 3E-1. Under current conditions, the average duration of ice cover for the 173 lakes was projected to be 171 days. In the short-term, changes in season length are expected to be small, with a projected decline of 4.6% under the A2 scenario and 5% under the B1 scenario (Figure 3). In the longer term (2071-2100), a decline of 14.6% is projected under the A2 scenario and 6.4% is projected under the B1 scenario.

Figure 3. Projected changes to ice fishing season in Ecodistrict 3E-1 based on A2 and B1 climate change scenarios for three timeframes (After Minns et al. 2012).

Figure 4 summarizes the projected changes in walleye carrying capacities (kg ha⁻¹) at 10 walleye lakes with floatplane accessible tourism establishments in Ecodistrict 3E-1 for the A2 and B1 scenarios. While considerable variability existed among the projections for the lakes, the average effect was an increase in walleye carrying

Figure 4. Projected changes in walleye carrying capacities at float plane-accessible tourism establishments in Ecodistrict 3E-1 based on A2 and B1 climate change scenarios for three timeframes (bars represent +/- one standard deviation, whiskers represent 10 and 90th percentiles) (After Chu and Fischer, in prep., and Lester et al. 2004).
capacity. This increase was most pronounced under the A2 scenario and for the mid- and longer-term with projections indicating it could be 10%. Assuming a direct relationship between carrying capacity and catch rates, walleye catch rates may increase slightly.

Tourism operators at floatplane accessible establishments reported average catch rates (fish per hour) of 5.49 (from Hunt et al. 2002). Assuming that relative changes in walleye carrying capacity are identical to changes in catch rates (because of low fishing pressure), the projected maximum increases to catch rates were to 6.10 and 6.08 fish per hour under the A2 and B1 scenarios, respectively. This change to catch rates was projected to increase revenues by about 0.9% for the mid-term A2 and long-term B1 scenarios (Figure 5). The projected effect of a smallmouth bass introduction on revenues was estimated to be -8.5%. Given the uncertainty about whether these introductions will occur, the effect of smallmouth bass introductions was held constant for all scenarios and timeframes (i.e., it either occurred or not).

![Figure 5. Projected changes to revenues at float plane accessible tourism establishments in Ecodistrict 3E-1 using the ensemble model and A2 and B1 climate change scenarios, three timeframes, and scenarios of increased catch of walleye and smallmouth bass introductions (Note: Effect of smallmouth bass introduction is a constant, i.e., it either occurs or not).](image-url)
Discussion

Understanding the potential effects of climate change on leisure-based activities requires viewing the activities as part of a social-ecological system. Our projections of the effects of climate change on these activities focused on changes in resource conditions (e.g., snow depth, ice cover duration, walleye productivity) and translating these changes into measurable indicators of climate change.

In Ecodistrict 3E-1 the projected snowmobile season length, though shortened, will likely remain viable. Under most scenarios, the projected snowmobile season remained December to March. However, with higher snow densities (wetter snow), snow depth is expected to decrease dramatically and the snowmobile season will shorten considerably to a three month season (January to March). Based on these projections, temperature increases in Ecodistrict 3E-1 will likely result in winter temperatures, including snowmobile season length, similar to those experienced in present day central Ontario.

Our results corroborate findings by Gilmour (2010) that although the winter temperatures will likely be warmer, suitable snow conditions for snowmobiling will exist well into the future. In fact, Ecodistrict 3E-1 is likely to be the most resilient part of the present-day OFSC snowmobile network (Gilmour 2010). As was the case for other researchers, we did not account for the potential for extreme weather events such as rainfall during the winter months that could substantially reduce snow accumulation for any given year. More studies are required to understand how extreme weather events affect snow and ice conditions required for winter leisure-based activities.

The decrease in the duration of ice cover on lakes from an average of 171 days to 146 days under the A2 scenario by 2100 will affect ice fishing in Ecodistrict 3E-1. Ice cover duration will influence when anglers can participate in this recreational activity and their relative economic contribution to local and regional economies. The shorter ice season will also have serious implications beyond recreational activities in Ecodistrict 3E-1. For example, a range of industrial sectors that depend on ice roads as a means of transportation for a variety of economic activities will also be affected. A remaining unknown is the link between ice cover duration and ice thickness, a key factor for transport-related activities.

Although nature-based tourism in Ecodistrict 3E-1 is only moderately vulnerable to the effects of climate change, we estimated a mixed net effect on fishing-related tourism. On the one hand, increased walleye catch rates are projected to increase tourism revenues; on the other, smallmouth bass introductions may reduce prices charged by tourism operators. While the effect of increased catch rates of walleye on prices and revenues was expected (e.g., Hunt et al. 2005), the negative effect of smallmouth bass introductions was not. Perhaps, the presence of smallmouth bass affects the quality of fishing for other preferred species such as walleye although evidence for this effect is mixed (Wuellner et al. 2011).

Changes to other conditions and human activities within the broader social-ecological system can antagonize or mitigate some of the projected effects of climate change on leisure-based activities in 3E-1. These changes are best characterized as having social, technological, ecological, economic, and policy dimensions, referred to as STEEP effects (Voros 2001). For example, while the snowmobile season length may remain viable in Ecodistrict 3E-1, it could be affected by changes in the snowmobile industry and society (technology, economics, and social) elsewhere. Projected declines in winter season length in more temperate latitudes such as central and southern Ontario, and reduced snowmobile use in Quebec and the Lake States (e.g., New York, Minnesota) may result in lost seasons and decreased demand elsewhere. Significant changes in snowmobile use in areas that now have the most use (e.g., central Ontario and southern Quebec; McBoyle et al. 2007, Gilmour 2010) could affect the entire snowmobile industry. The effects will likely be variable, however, significantly reduced demand for snowmobiles across North America might curtail both production and likely future demand for this type of recreational vehicle. Already, in more temperate latitudes, all terrain vehicle (ATV) sales exceed that of
snowmobiles (Suthey Holler Associates 2003). Further shifts toward greater ATV-focused recreation will likely affect snowmobiling in northeastern Ontario, regardless of future climate (Scott and Jones 2006). These and other types of STEEP effects within the larger social-ecological system need to be considered when interpreting our projections and conclusions.

Assessment of vulnerabilities and adaptive capacity

All natural resources systems are vulnerable to the expected changes in climate. These systems are vulnerable to climate change as humans will not likely be able to adapt quickly or effectively enough to address the magnitude of the projected negative, or even positive, changes (Brunner and Lynch 2010, Chapin et al. 2010, Hoffman, 2010). The effects of climate warming will, in many ways, change fundamental elements of the structure, composition, and function of various ecosystems and in turn affect how people interact with these ecosystems (Chapin et al. 2010). These effects may be compounded by the high degree of uncertainty of our knowledge about climate change and society’s ability to adapt to changing conditions.

We describe both current and future vulnerabilities for snowmobiling, ice fishing, and nature-based tourism activities in Ecodistrict 3E-1. Vulnerability here includes the exposure of activities to climate change (e.g., loss of ice for ice fishing), the sensitivity of the activity to these exposures (e.g., the loss of season length), and the adaptive capacity of the system (e.g., concentrating ice fishing activities in a shorter season).

Our results indicate that snowmobiling and ice fishing have moderate exposure and sensitivity to climate change in Ecodistrict 3E-1 (Table 1). Both of these activities require suitable natural conditions (snow and ice) that are likely to be negatively affected by climate change. Potential for adaptive capacity is high as changes to season length will likely be minimal and can easily be absorbed by concentrating participation in these activities in a shorter season. In the medium-term, we expect little change in the exposure and sensitivity of these activities to climate change. However, eventually adaptive capacity will decrease to a medium level as increasingly shortened seasons make accommodating equivalent participation in a shorter period without degrading the experience (e.g., increased perceptions of crowding) unlikely.

Given the potential for smallmouth bass introductions that might cause economic harm to fishing-based tourism operations, we rate the current sensitivity and exposure of nature-based tourism to climate change as medium. The adaptive capacity of the industry is low because tourism operators have fixed investments (tourism lodges and camps) and existing clientele that primarily prefer pursuing fishing-related activities. In the medium-term, the sensitivity and exposure ratings remain unchanged, while the adaptive capacity increases to medium. This increased adaptive capacity relates to opportunities for tourism operators to attract new clientele and to move existing lodges and camps to areas that might become more desirable for clients.

Table 1. Current and medium-term future (2041-2070) vulnerability to climate change ratings for snowmobiling, ice fishing, and nature-based tourism in Ontario’s Ecodistrict 3E-1 based on projections using climate models.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Sensitivity and exposure to climate</th>
<th>Adaptive capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snowmobiling</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Ice fishing</td>
<td>Medium</td>
<td>Medium</td>
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<tr>
<td>Nature-based tourism</td>
<td>Medium</td>
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</tbody>
</table>
Conclusions

Future conditions in Ecodistrict 3E-1 will vary depending on which of the many possible climate change scenarios occurs, but it is likely that they will differ from present conditions. Adapting to this new reality will be challenging and will require both significant insight and difficult decisions. When making complex and difficult decisions, such as how to adapt to climate change, it is important to consider as many pertinent variables as possible (Hoffman 2010). Examining and addressing climate change as a social-ecological system is a good first step. We undertook a preliminary examination of select linkages among various social and ecological systems and determined that these systems, while fairly resilient, are likely to be affected by a warming climate. Further research and monitoring of these systems are required to make informed decisions that will aid in the formulation of policy and planning decisions to facilitate adaptation. These future research and monitoring activities should include a broader perspective of the effects of climate change on leisure and economic-based activities. For example, the quality of some leisure-based activities such as hiking, canoeing, and camping might improve with increased temperatures (Scott and Jones 2006) while other winter activities such as cross country skiing could be less vulnerable than ice fishing and snowmobiling given the relatively small areas of ski trails and the efforts and expenditures by motivated participants.

It is hoped that decisionmaking processes will mirror some of the themes presented in this paper and that resource managers formally grapple with the complex process of planning and managing both the social and ecological dimensions of climate change. We finish with two considerations for readers:

1) Tourism, recreation and other social elements in Ecodistrict 3E-1 are part of much larger social-ecological systems. Addressing and developing pragmatic adaptation strategies requires a much deeper understanding of the links and feedbacks within these larger systems. For example, suitable weather for winter recreation in 3E-1 may continue but activities such as snowmobiling may be undermined by the more pronounced effect of climate change on the snowmobile industry in more temperate areas such as southern Ontario and southern Quebec. Understanding how key drivers influence and affect these larger social systems will help to inform decision makers about the best possible adaptation strategies.

2) Good quality social information and data for Ecodistrict 3E-1 are fragmented or are largely unavailable. Key social measures need to be identified and developed to facilitate research and monitoring related to social implications of climate change. These could include data on snowmobiling’s direct economic contribution to the local and regional economies and the social implications of a shortened winter forest harvesting season.
References


Appendix

Parameter estimates from hedonic model of logarithm prices for a week long fishing trip per person at a float plane-accessible only establishment fishing trip in Ontario in 2000 (adjusted $R^2 = 0.60$) (* p < 0.05).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Parameter estimate</th>
<th>Standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>5.837 *</td>
<td>0.102</td>
</tr>
<tr>
<td>Provision of food with price (1-yes, 0-no)</td>
<td>0.335 *</td>
<td>0.037</td>
</tr>
<tr>
<td>Provision of air transport with price (1-yes, 0-no)</td>
<td>0.244 *</td>
<td>0.072</td>
</tr>
<tr>
<td>Provision of guide with price (1-yes, 0-no)</td>
<td>0.135 *</td>
<td>0.200</td>
</tr>
<tr>
<td>Presence of running water and shower (1-yes, 0-no)</td>
<td>0.327 *</td>
<td>0.025</td>
</tr>
<tr>
<td>Accommodation type (1-lodge, 0 Outpost camp)</td>
<td>0.135 *</td>
<td>0.036</td>
</tr>
<tr>
<td>Logarithm of flying distance (km)</td>
<td>0.076 *</td>
<td>0.017</td>
</tr>
<tr>
<td>Logarithm of reported catch rate of primary fish</td>
<td>0.085 *</td>
<td>0.014</td>
</tr>
<tr>
<td>Logarithm of reported average size of primary fish</td>
<td>0.101 *</td>
<td>0.030</td>
</tr>
<tr>
<td>Presence of smallmouth bass (1-yes, 0-no)</td>
<td>-0.089 *</td>
<td>0.031</td>
</tr>
</tbody>
</table>
Reports


CCRR-09 Varrin, R. J. Bowman and P.A. Gray. 2007. The Known and Potential Effects of Climate Change on Biodiversity in Ontario’s Terrestrial Ecosystems: Case Studies and Recommendations for Adaptation.


Notes


