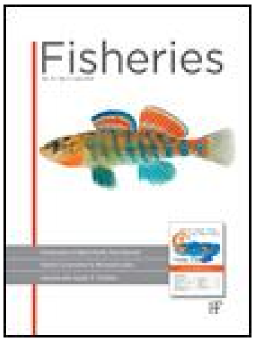

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FEATURE

Identifying Alternate Pathways for Climate Change to Impact Inland Recreational Fishers

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Fisheries and human dimensions literature suggests that climate change influences inland recreational fishers in North America through three major pathways. The most widely recognized pathway suggests that climate change impacts habitat and fish populations (e.g., water temperature impacting fish survival) and cascades to impact fishers. Climate change also impacts recreational fishers by influencing environmental conditions that directly affect fishers (e.g., increased temperatures in northern climates resulting in extended open water fishing seasons and increased fishing effort). The final pathway occurs from climate change mitigation and adaptation efforts (e.g., refined energy policies result in higher fuel costs, making distant trips more expensive). To address limitations of past research (e.g., assessing climate change impacts for only one pathway at a time and not accounting for climate variability, extreme weather events, or heterogeneity among fishers), we encourage researchers to refocus their efforts to understand and document climate change impacts to inland fishers.

Identificación de vías alternas de impacto del cambio climático en pescadores de pesca recreativa en aguas continentales

La literatura sobre las dimensiones humana y de las pesquerías sugieren que el cambio climático influencia a los pescadores recreativos en aguas continentales de Norte América de tres formas principales. La forma más ampliamente reconocida es que el cambio climático impacta a las poblaciones de peces y a su hábitat (e.g. la temperatura del agua impacta la supervivencia de los peces) y se transfiere hasta eventualmente afectar a los pescadores. El cambio climático también puede alterar las condiciones ambientales que directamente impactan a los pescadores recreativos (e.g. incremento de temperatura en climas norteños que resultan en una prolongación de las temporadas de pesca y en un aumento en el esfuerzo de pesa). La tercera forma de impacto proviene de los esfuerzos de adaptación y mitigación al cambio climático (e.g. el refinamiento de políticas energéticas se ve reflejado en un aumento en el costo de los combustibles, encareciendo los viajes de pesca). Con el fin de superar las limitaciones de trabajos en el pasado (e.g. evaluar los impactos del cambio climático para una sola vía por vez y no tomar en cuenta la variabilidad climática, eventos meteorológicos extremos o heterogeneidad entre pescadores) en este estudio se invita a los investigadores a enfocar sus esfuerzos para comprender y documentar los impactos del cambio climático en los pescadores de aguas continentales.

Identification de voies alternatives sur l'impact du changement climatique sur les pêcheurs sportifs continentaux

Les pêches et la littérature à dimension humaine suggèrent que le changement climatique influence les pêcheurs sportifs en Amérique du Nord par le biais de trois voies principales. La voie la plus largement reconnue suggère que le changement climatique a un impact sur l'habitat et la population de poissons (par exemple, la température de l'eau ayant une incidence sur la survie des poissons), lequel se répercute sur les pêcheurs. Le changement climatique a également un impact sur les pêcheurs sportifs en influençant les conditions environnementales qui les affectent directement (par exemple, l'augmentation des températures dans les climats nordiques qui induit l'extension des saisons de pêche en eau libre et l'augmentation de l'effort de pêche). L'atténuation du changement climatique et les efforts d'adaptation (par exemple, les politiques énergétiques affinées entraînent des coûts plus élevés en carburant, ce qui rend les voyages lointains plus chers) sont les voies ultimes. Pour faire face aux limitations de recherches antérieures (par exemple, l'évaluation des impacts du changement climatique pour une seule voie à la fois et sans tenir compte de la variabilité du climat, des phénomènes météorologiques extrêmes, ou de l'hétérogénéité entre les pêcheurs), nous encourageons les chercheurs à recentrer leurs efforts de compréhension et à documenter les effets du changement climatique sur les pêcheurs continentaux.

KEY POINTS

- Climate change impacts on fishers arise from changes to fish, changes to other environmental conditions, and possibly from climate change mitigation and adaptation efforts.
- Changes to nonfish pathways can change fishers' behaviors that disrupt existing equilibriums between fish stocks and fishing effort.
- In some U.S. states, fish species targeted by recreational fishers appear to have changed from coldwater to warmwater species since 1991.
- Managing these impacts requires an understanding of connections and feedbacks within and between ecological and social systems.
- Future research should focus on impacts from climate variability including extreme weather events and impacts to subpopulations of fishers (e.g., southern U.S. fishers).

INTRODUCTION

Understanding how climate change might influence fishers remains a major challenge for North American inland fisheries research. This challenge is heightened by the facts that human behavior is complex, and many social and ecological variables influence fishers, leading to changes in a fishery. Though researchers understand some relationships among marine fish communities, fishers, and climate change (Pinsky and Fogarty 2012), such insights about fishers are rare within inland fisheries. In fact, identifying alternate pathways that link climate change to fishers within inland fisheries remain elusive.

Inland fisheries consist of commercial, subsistence, and recreational activities. Among these activities, recreational fishing is a dominant form, especially for industrialized nations such as Canada and the United States (Cooke et al. 2016). In fact, about 28 million individuals participated in freshwater (inland) recreational fishing in the United States in 2011, taking a total of 368 million trips and spending more than US$25 billion (USDOI et al. 1993, 2011). In 2015, recreational fishers contributed almost $700 million in revenue to state agencies through a variety of licenses, tags, stamps, and permit options (Figure 1). Given the importance of recreational fishing, we focus on climate change impacts on recreational inland fishers from North America.

Contemporary climate models and scenarios for North America predict widespread increases in annual surface air temperatures ranging from a low of about 1°C on the southern coasts of the United States to greater than 6°C for the Boreal Shield and Canadian Prairies (IPCC 2013). Annual precipitation is expected to increase, especially in far northern areas with an exception in the southwest United States where decline is possible (IPCC 2013). Beyond these average changes, climate change is expected to increase the frequency and severity of drought, flood, and damaging extreme weather events (IPCC 2014). These kinds of climatic changes will impact ecosystems and society; thus, these changes are of concern to inland recreational fisheries and fishers.

Our current understanding of climate change impacts on inland recreational fisheries is largely based on how alterations to aquatic ecosystems affect habitat and fish (see reviews by Lynch et al., this issue; Whitney et al., this issue). However, we focus here on assembling and reviewing the nascent literature on climate change and North American inland fishers to identify the relevant general pathways through which climate change impacts inland fishers. We limit this review to impacts on recreational fishers; a companion paper provides managerial advice including climate change adaptation strategies for inland fisheries (Paukert et al., this issue).

Assessing the impacts of climate change on fishers is complicated. Fishers are embedded in a social–ecological system (SES) where human behaviors and institutions guiding those behaviors are tightly coupled to ecosystems (Post 2013). Inland recreational fisheries consist of feedbacks among fishers, fish, managers, and the broader environment (Fenichel et al. 2013a). These feedbacks suggest that climate change impacts on fishers not only influence the well-being of fishers but that the subsequent (adaptive) responses by fishers will also impact fish and fisheries management (Lewin et al. 2006). Fishers are also highly heterogeneous in terms of their preferences (see reviews by Fenichel et al. 2013a; Hunt et al. 2013), which complicates attempts to generalize the impacts of climate change on fishers and to identify effective management solutions (Johnston et al. 2010). These issues, combined with the fact that a recreational fisheries SES is nested in a hierarchical societal and environmental context (Hunt et al. 2013), greatly complicate assessments of climate change impacts on fishers.

Assessing impacts of climate change on inland recreational fishers also requires researchers to articulate changes to human well-being given its increasing prominence as a fisheries management objective (Hunt et al. 2013). "Well-being" is defined as net benefits that accrue to fishers from recreational fishing and to nonfishers from fishery-related environmental management (e.g., biodiversity conservation). Researchers have used several disciplinary-specific indicators to quantify aspects of well-being or net benefits including satisfaction (Arlinghaus 2006) and economic welfare (Train 1998), which collectively measure how much people prefer fishing compared to other options (Fenichel et al. 2013b). The value of these net benefits can be thought of as ecosystem services such as food provisioning and cultural services (MEA 2005) and are connected to wealth-based and sustainability metrics (World Bank 2011; Fenichel et al. 2016). However, measuring well-being also provides a model of human behavioral adaptation to environmental and policy change (Abbott and Fenichel 2013) that is critical for planning for climate change.

We illustrate a deliberately simple recreational fishery SES nested within a larger social, political, and environmental context (see the conceptual model; Figure 2) drawing upon concepts from Ostrom (1990). The model highlights general pathways by which climate change impacts fishers. Consequently, the model hides many connections among fisheries habitat and fish communities (see Hansen et al. 2015 for more details), and feedbacks such as the ability of fishers and managers to influence general environmental policy.

The inland fishery SES includes a resource system (e.g., aquatic ecosystems), but we focus here on fish. The social

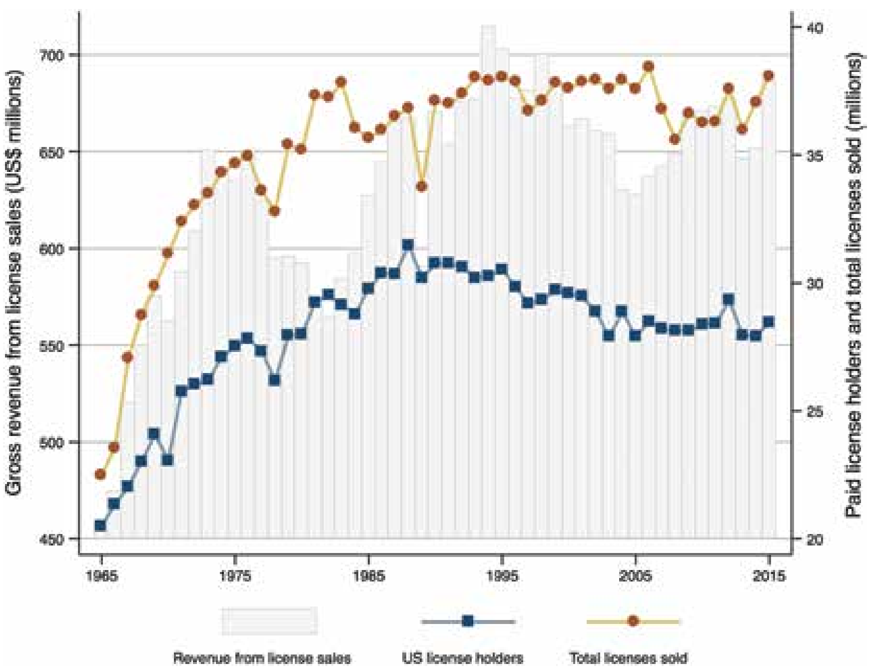

Figure 1. Recreational fishing activity and revenues in the United States, 1965–2015. Revenue from license sales in 2015 US$.

system includes fishers and managers, although our attention is centered on fishers (see Paukert et al., this issue, for a focus on managers). This fishery SES is nested within a wider context that we highlight only with environmental policy (e.g., climate change mitigation and adaptation) and environmental conditions. Environmental conditions refer to large-scale biogeophysical processes (e.g., hydrologic cycles, air circulation) along with the terrestrial environment that, though related, may operate without much direct influence from a fishery SES. Climate change acts as a catalyst that impacts environmental conditions and possibly anticipatory environmental policy. Connections within the conceptual model illustrate three pathways through which climate change can impact inland recreational fishers:

1. environmental conditions that affect fish and thus, fishers;
2. environmental conditions that directly affect fishers; and
3. general environmental policies that influence fishers.

The first pathway describes how climate change impacts environmental conditions that in turn affect fish (e.g., community, abundance, and behavior) and sequentially fishers. Within this pathway, we describe the strength of connections that link fishers to fish, and we describe the few studies that estimate changes to well-being from climate change.

Second, we consider how changing environmental conditions can influence recreational fishers independent of changes to fish. There is strong evidence that recreational fishers' choices of whether, when, where, and how much to fish are in part based on non-catch-related attributes of a potential fishing location (Hunt 2005). Many of these non-catch attributes are susceptible to climate change impacts independent of fish.

Third, we consider how climate change mitigation and adaptation through environmental policy could influence recreational fishers. For example, mitigation attempts (e.g., carbon tax policies) can result in increases to fishers' travel

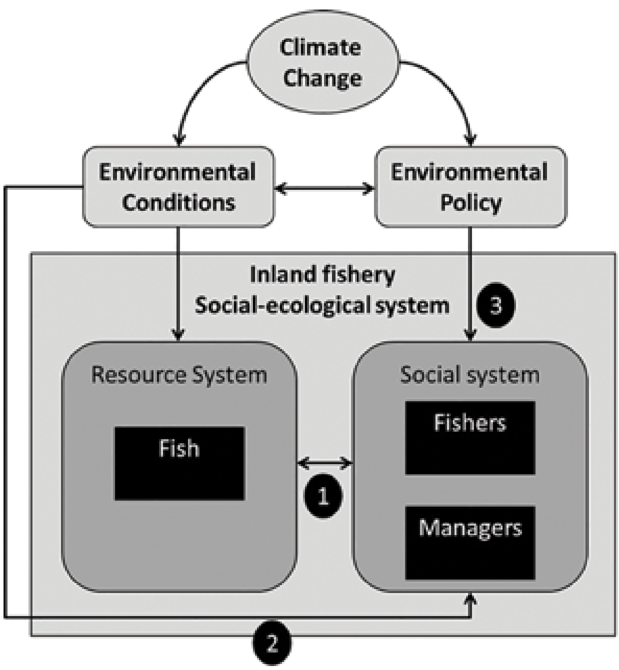

Figure 2. Pathways for climate change impacts on fishers within a social-ecological system of inland recreational fisheries. (The numbers correspond to climate change pathways that impact fishers).

costs, reducing well-being, and effort. We also include adaptations within the pathway from environmental policy through environmental conditions (e.g., water allocation policies) here because environmental policy is the catalyst for impacts to fishers through pathways 1 and 2.

This review identifies an important, but relatively untouched, research agenda focused on the critical role that fishers and even environmental policymakers play in fisheries ecology and management. The strength of each pathway influences the ability of fishers and fisheries managers to mitigate and adapt to climate change impacts on fishers and fish.

PATHWAY 1: FISH-MEDIATED IMPACTS OF CLIMATE CHANGE ON RECREATIONAL FISHERS

Climate change impacts mediated by fish (see pathway 1 in Figure 2) are implicitly believed to dominate fishers' behaviors especially for commercial marine fisheries (Fenichel et al. 2016). Though there is little doubt that fish affect fishers' well-being and behaviors, the strength of these effects are debatable and likely variable (see Box 1). We review the handful of studies that predict well-being impacts to fishers from this pathway and point interested readers to Lynch et al. (this issue) and Whitney et al. (this issue) for information about how climate change impacts fish. We also summarize existing data to describe how the target species of North American inland fishers have changed from 1991 to 2011.

Fishers' well-being is affected through cultural and food provisioning ecological services (MEA 2005). Though there are several ways to measure well-being, here we describe three studies that use economic nonmarket valuation techniques to link climatic changes through fish to inland fishers' well-being. The results of these studies suggest that climate change potentially can result in large negative impacts to well-being primarily through reduced distribution and abundance of coldwater fish species, but there is also the potential for positive impacts to well-being in some regions.

Pendleton and Mendelsohn (1998) examined the effects of a doubling of greenhouse gas emissions on Rainbow Trout *Oncorhynchus mykiss*, other trout, and panfish in the northeastern United States. They combined an ecological model that predicted changes to catch rates for different species with an economic model from fishers' behaviors to establish changes to net benefits. Their estimates of welfare change ranged from a net loss of US$8.4 million to a net benefit of $37.3 million based on fiscal year (FY) 2015 dollars for a doubling of CO_2 and depended heavily on which climate circulation model was employed (i.e., Goddard Institute of Space Science and Oregon State University). Within the region, Maine and New Hampshire were predicted to benefit from climate change, though the outcomes for New York and Vermont were less certain.

Ahn et al. (2000) investigated the effects of climate change scenarios on coldwater fish in the southern Appalachian Mountains of North Carolina through changes to habitat (area available for fishing) and abundance of fish. Through a variety of scenarios with different assumptions about habitat and abundance, Ahn and his colleagues (2000) estimated large potential economic welfare losses ranging from US$95 to $911 million per year in FY2015 dollars for licensed North Carolina fishers.

Jones et al. (2013) examined how changes to fish habitat in streams throughout the coterminous United States might impact the economic value of recreational fishers. Using an existing

Box 1: Potential for Climate Change to Impact Fishers through Fish

Little information exists that establishes links between climate change impacts to fishers from fish. Therefore, we assessed the potential for climate change to impact fishers through this fish-mediated pathway by summarizing literature that connects fish to fishers. Though it is commonly assumed that there is a strong relationship between fish and fishers, evidence for this relationship is less clear. In fact, there is increasing evidence suggesting that catch rates decline at a much slower rate than fish stock abundance (e.g., Post et al. 2002; Ward et al. 2013). There is a growing belief that this hyperstability of catch for inland fisheries results from effort sorting; where a population of fishers with different skill levels mobilize their effort differently, with more skilled fishers remaining at water bodies with depressed fish stocks (see Ward et al. 2013). If true, effort sorting implies that changes to fish abundance will impact recreational fishers' catch rates and behaviors, albeit in potentially nonintuitive ways (e.g., skilled fishers will be overrepresented at sites with low fish abundance).

The amount and location of fishing effort can also be influenced by fish. Evidence that catch-related fishing quality influences fishing participation decisions is mixed (see Dabrowska et al. 2014 for some support and Loomis and Fix 1998 for little support). However, there is evidence that catch-related fishing quality is related to effort. For example, Abbott and Fenichel (2013) demonstrated strong links between total effort and catch rates for Chinook Salmon *Oncorhynchus tshawytscha* and Lake Trout *Salvelinus namaycush* on Lake Superior and Lake Michigan. This importance of catch and fishers' behaviors are supported by others (e.g., Johnson and Carpenter 1994; Post et al. 2008), including a large set of literature focusing on fishing site choices (Hunt 2005). However, these studies also reveal that non-catch-related factors (travel costs, environmental quality, facility quality, congestion, and regulations) combined with heterogeneous preferences among fishers for catch- and non-catch-related factors influence fishers' behaviors (Hunt 2005; Fenichel et al. 2013a). Thus, climate change impacts on fishers through fish are moderated by resource and social conditions including the type of fisher.

Climate change can also influence fishers through fish by altering decisions about voluntary harvest decisions. Inland fisheries in North America have a strong tradition of voluntary catch-and-release fishing, where decisions to release fish are influenced by situational (catch) and personal (fisher) factors (Arlinghaus et al. 2007). Consequently, catch-related factors such as the target species, catch rates for target and substitute species, and size of fish influence fishers' decisions to retain caught fish (Hunt et al. 2002; Cooke and Suski 2005). Therefore, as fish stock abundance and fish communities change, the behaviors of fishers will change.

model of fishing effort, transfers of benefits from different types of fishing trips, different discount rates, and climate change scenarios, the authors estimated that climate change could negatively impact recreational fishers by between US$101 million and $7.1 billion in FY2015 dollars over the period 2009–2100.

We assessed changes to target fish species by inland recreational fishers in Canada and the United States from existing data sources and reports based on large-scale survey data from recreational fishers (DFO 1990, 2010; USDOI et al. 1993, 2011). We used these data sources to summarize the target species of resident inland fishers by state, province, and territory since 1990. Target species were based on estimated targeted effort in the United States and from estimates of catch reported in Canada. United States data were collected in species aggregates with the most targeted species being either a warmwater (black bass, panfish [excluding crappie], and catfish), a coolwater (Walleye *Sander vitreus*), or a coldwater (trout and salmon) guild.

Given the coarse resolution of target species from the reports and our interest to explore the role of climate change at influencing these patterns, we grouped species by their thermal preference with coldwater (10°C–18°C), coolwater, (19°C–25°C), and warmwater (≥26°C) guilds (Coker et al. 2001). In the early 1990s, fishers in western, mountainous, and northeastern states and all Atlantic provinces mostly targeted coldwater species (Figure 3). Fishers from the remaining Canadian provinces and territories, along with Minnesota and the Dakotas, mostly targeted coolwater species. However, between 1991 and 2011, the thermal guild of the primary target species was estimated to have changed in seven U.S. states. Six of these seven changes (Connecticut, New Hampshire, New Jersey, New York, Vermont, and Washington) were from a cold- to warmwater species. These changes are consistent with documented and suspected impacts of climate change on the distribution of fish species (Lynch et al., this issue). In fact, if we assume that seven changes in target species occurred by chance, there would only be a 6.3% chance that at least six of the seven changes in target species would be from colder to warmer water guilds. Therefore, it is plausible that these changes arose instead because fishers are responding to environmental signals associated with greater prevalence of species from warmer thermal guilds. Of course, we cannot definitively say that climate change caused these changes as other factors, such as state/province specific management actions and policies as well as overexploitation could have influenced fish communities and fishers' behaviors.

PATHWAY 2: NON-FISH (ENVIRONMENTAL CONDITION) MEDIATED IMPACTS ON RECREATIONAL FISHERS

Fisheries scientists often focus on climate change impacts on fishers mediated through fish. However, as illustrated by pathway 2 in Figure 2, changing environmental conditions can directly impact fishers through changes to the quality and/or availability of recreational fishing experiences (Hunt 2005). In fact, de Freitas (1990) suggested that thermal (e.g., temperature, humidity), physical (e.g., precipitation, wind), and esthetic (e.g., clear skies) conditions of climate and weather affect the behaviors of tourists and recreationists. Though researchers have developed indices from these conditions to identify potential climate change impacts to tourists (Scott et al. 2015), such indices have not been applied to recreational fishers.

Fishers from northern latitudes appear to respond positively to warmer thermal conditions measured crudely through change to air temperatures (e.g., Hunt and Dyck 2011) partly because ice fishing is far less popular relative to open water fishing (USDOI et al. 2011). However, climate change is likely to reduce participation

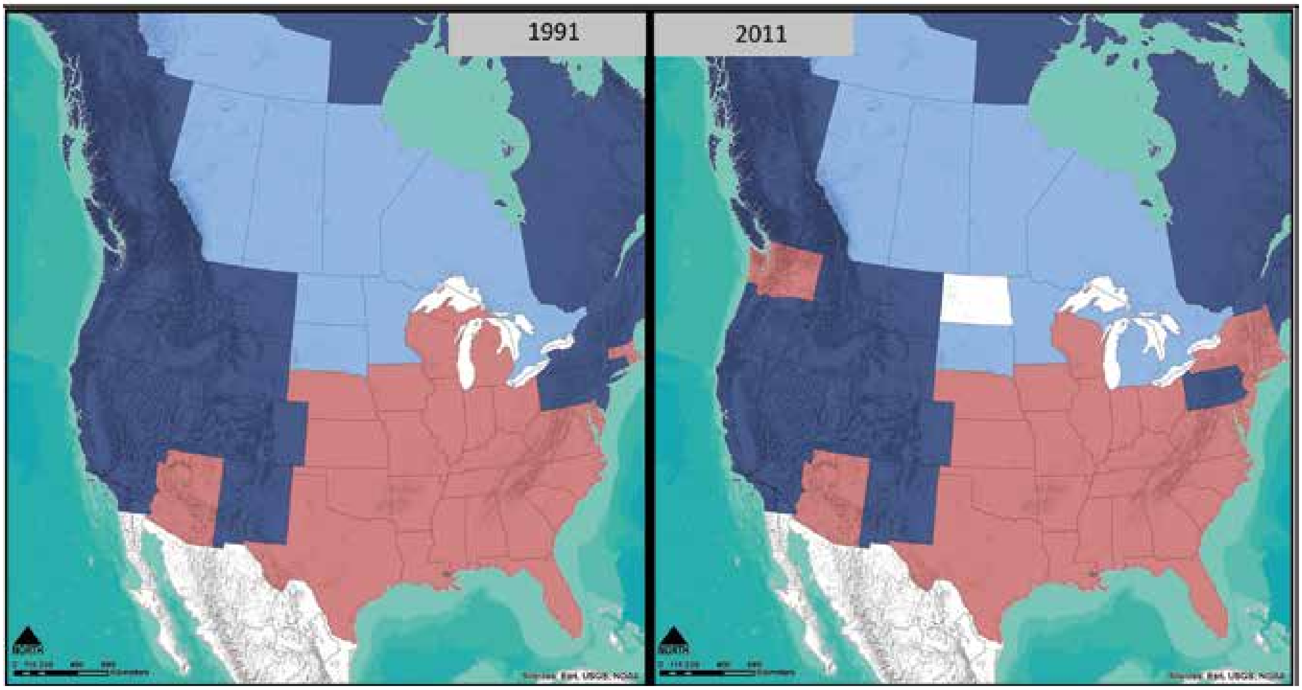

Figure 3. Thermal guild of most targeted species by inland recreational fishers in Canada and the United States. (Dark blue, light blue, and pink shading refer to cold (10-18°C), cool (19-25°C), and warm (≥26°C) water species guilds; 2011 North Dakota data were unavailable; for Canadian data primary target defined as species with greatest reported catch).

in ice fishing through reduced ice formation (i.e., season, timing, depth) across Northern Hemisphere lakes (Benson et al. 2012). These changes in ice phenology already have led to the cancellation of an ice fishing championship in Ontario (Scott et al. 2015) and are projected by 2100 to reduce the ice fishing season in northeastern Ontario by between 6% and 15% (Hunt and Kolman 2012). Even if fishers concentrate their existing ice fishing effort into this smaller season length, the increased congestion at these fishing sites is expected to negatively impact fishing quality and the well-being of fishers (see Hunt 2005 for a review).

Mendelsohn and Markowski (1999) attempted to predict the impacts of changing thermal conditions from climate change on a variety of activities including recreational fishing for the United States. The authors developed models to predict the number of days that individuals participated in each activity using demographic and January and July temperatures as explanatory variables. The authors predicted positive impacts, and by 2060 climate change impacts on recreational fishing (including inland and marine) were estimated to be US$3.1 and $8.7 billion (FY2015 dollars) from temperature increases of 1.5°C and 2.5°C, respectively. These large estimates arose because of longer open water fishing seasons and more desirable temperatures for fishing and not from any consideration of pathway 1 impacts. Though consistent with other beliefs (Morris and Walls 2009), the conclusions are limited by only considering thermal conditions from this one pathway and assuming homogeneous effects from temperature on all fishers. Yet, they highlight important trade-offs and forces and suggest that climate change–driven effects may move in opposite directions.

Physical conditions of weather also impact fishers. In northern latitudes, trip timing for recreational fishers is negatively impacted by precipitation and, for trips to large-sized lakes, strong wind speeds (Hunt and Dyck 2011). Climate change is expected to increase the frequency of these extreme weather events (heavy precipitation and strong wind events), likely resulting in changes to the timing and/or amount of fishing activity. Anecdotal evidence suggests that these extreme events are already more common. For example, between 2008 and 2012, weather and wind damage aside from hurricanes represented the third most common factor inducing insurance claims among members of the Boat Owners Association of the United States (Fusco 2013). In 2005, these damage claims ranked fifth (Fusco 2013), suggesting that these events are occurring more often and that climate change can impact fishers through increased costs for insuring fishing-related equipment against these events.

Increased climate variability can also impact fishers through increased occurrences of drought and flood. For example, decreased fishing activity was observed at Lake Mead on the Arizona–Nevada border through closure of several boat launches and marinas because water levels decreased 40 m from 1999 to 2010 in part due to drought (Holdren and Turner 2010). Lower water levels can represent a limiting factor for boat-based recreational activities. For example, over a quarter of marina operators on the Canadian side of the Laurentian Great Lakes closed slips for boats and over one-half had conducted dredging activities to combat low water levels at some point since owning a marina (Bergmann-Baker et al. 1995). Though fishers can adapt to changes in low water levels in marinas and boat launching facilities by choosing other sites, these fishers will likely incur well-being losses (e.g., increased travel costs).

Esthetics such as forested settings and water quality influence recreational fishers' choices of fishing sites (Hunt 2005). Climate change is likely to impact these setting and water quality attributes through changing patterns of natural disturbance and changes to land use activities (Mendelsohn and Dinar 2009; IPCC 2014). Consequently, climate change can impact fishers' behaviors and well-being through this esthetic factor.

PATHWAY 3: ENVIRONMENTAL POLICY–MEDIATED IMPACTS OF CLIMATE CHANGE ON RECREATIONAL FISHERS

The third climate-related pathway that could affect inland recreational fisheries is through environmental policy that is designed to mitigate or adapt to impacts from climate change (see pathway 3 in Figure 2). We are unaware of any studies that have explicitly investigated this pathway. Given the lack of information about this pathway on recreational fishers, we speculate about two potential cases whereby environmental policies may impact inland recreational fishers and fisheries.

Mitigation efforts to reduce greenhouse gas emissions are already underway. In fact, almost 40 countries and a number of states and provinces such as California, British Columbia, and Quebec are actively engaged in emission trading or carbon tax policies (Kossoy et al. 2015). These and other efforts to reduce dependence on fossil fuels make energy more expensive (IPCC 2014). The higher cost of transport will affect fishers' choices of the location and number of fishing trips (e.g., Morey et al. 1993; Hunt 2005). For example, a 10 cent (CDN) increase per liter of fuel was predicted to reduce trip taking by between 4% and 7% among fishers in northern Ontario, Canada (Hunt and Dyck 2011).

Higher transportation costs will likely reduce fishing effort in remote locations while fishing effort near heavily populated regions could increase. This change would lead to increased exploitation impacts on fisheries near urban centers, thus placing an increased burden on fisheries managers to maintain or to increase fishing opportunities near cities, many of which are already supported through stocking efforts. Likewise, the increased costs for fuel could result in fishers reducing their travels by boat or shifting modes from gas-powered outboard motors to shore-based or paddle-based fishing trips, resulting in fishing effort concentrated near locations where fishers access a water body (e.g., boat launch).

Another possible impact of climate change policy on fishers occurs when policy impacts environmental conditions that in turn flow through pathway 1 from Figure 2. We include this pathway here because its genesis is from external environmental policy change that is rarely considered when discussing climate change impacts on inland fisheries.

Climate models predict more punctuated precipitation events across most of North America and increased precipitation has occurred in North America's temperate latitudes since the 1950s (IPCC 2014). However, demands for water will likely increase because of human population growth, reduced snowmelt, and possibly increasing needs for food production. In arid regions, riverine systems are expected to be negatively affected by decreased stream flow and increased water removal (USCCSP 2008). Reservoir and dam managers will need to respond to this list of demands for water in response to climate change. Cases like the Klamath River where conflicts emerged between allocating water for agriculture and stream flow for endangered fish species (Jaeger 2004) could become more common. We suggest that it is probable that maintaining water flow for recreational fisheries is low on the list of concerns when paired with residential, commercial, and agricultural demands for water. Consequently, water allocation decisions can compromise water quality (e.g., temperature) and levels necessary to support fish. These influences on fish habitat will work back to fishers through the first pathway.

CONCLUSION

Climate change is likely to impact inland recreational fishers through three primary pathways (Figure 2). There is a lack of published data and information that describe the potential strength of influence of each pathway on fishers. Where such publications exist, there is no documentation of impacts and instead the information is extracted from models based on associations that only considered one possible pathway. It is also not clear that the three pathways will necessarily lead to shifts in fishing behavior and well-being in the same direction (e.g., longer summers on their own might lead to increases in effort, whereas warm waters could make fishing itself less desirable through impacts on fishes). Furthermore, past research results are presented at very coarse scales (e.g., the United States), and well-being assessments have lacked appreciation for climate impacts arising from climate variability and increased prevalence of extreme weather events. Therefore, the overall impact of climate change on the well-being of inland recreational fishers is uncertain (Box 2) and is likely heterogeneous given the variability in recreational fisher populations. Though specific groups will be negatively impacted (e.g., ice fishers and fishers who target coldwater species at current southern range limits), research findings are too limited to develop lists of "winners" and "losers" in terms of well-being. Such lists can only be assembled once researchers develop a more comprehensive understanding of how each pathway individually and jointly impacts the behaviors and well-being of fishers (see Box 3).

The potential for climate change to impact fishers through the three pathways is poorly understood. Even for the most studied pathway of fish impacts on fishers, the relationships are likely less straightforward and weaker than is typically assumed when viewing fishers as a predator within a predator–prey system (see Box 1). Additional research is also needed to understand better the complex network of direct and indirect feedbacks between fishes and fishers (see Box 3).

Climate change has and will continue to impact fishers as well as fish. Part of what makes addressing climate change challenging is the fact that climate change and climate change adaptation and mitigation are likely to alter the social and economic landscape in which people, including recreational fishers, live. The managers of recreational fisheries already need to account for societal shifts in attitudes and preferences. Climate change and the broader societal response to climate change (e.g., water, energy, and transportation policy) are likely to create new challenges on the social dimensions of fisheries research. Though these social dynamics may be seen as external pressures from the standpoint of some fishery managers, savvy managers will anticipate these changes, particularly when evaluating the benefits and costs of attempting to preserve a stressed fishery or to replace it with a new "climate change–adapted" system.

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Box 2: Smallmouth Bass and Profitability of Ontario Tourism Operators Catering to Recreational Fishers

Climate change–induced expansion of Smallmouth Bass *Micropterus dolomieu* population distributions may affect the revenues generated by fishing-oriented nature-based tourism operators in northeastern Ontario, Canada (see Hunt and Kolman 2012 for details). Throughout North America, many individuals offer accommodation to recreational fishers in the form of fishing lodges and camps. In some instances, individuals offer guests a unique experience whereby fishers travel by float plane to access lodges and camps on remote lakes. For northern Ontario, the 770 lodges and camps that were accessible only by float plane and were operating in 2000 served a single market (Hunt and Kolman 2012). Consequently, the prices that these individuals charged recreational fishers include the market value of the characteristics that encompass a fishing package (e.g., fishing quality and lodge amenities).

Revenues were estimated from a proxy of the market price that tourism operators charged for a weeklong fishing trip at tourism establishments that were primarily accessed by floatplane. A (hedonic) model was developed to explain variations in these market prices by site and setting characteristics at these establishments and associated water bodies from across northern Ontario. Catch-related fishing quality characteristics were measured by operator-reported catch rates and expected size for the primary species that guests targeted such as Walleye *Sander vitreus* along with the presence of Smallmouth Bass. Combined with projections of changes to Walleye abundance from climate change scenarios (Chu and Fischer 2012), a potential modest decrease of revenues (~8.5%) was estimated for establishments situated on lakes with Smallmouth Bass (Hunt and Kolman 2012). Though this decrease was driven by the presence of Smallmouth Bass and not changes to Walleye catch rates, the exact reason why Smallmouth Bass presence was negatively associated with revenues remained unexplained. Nevertheless, the result implies that introductions of bass might result in losses to revenues generated by the nature-based tourism industry in northern Ontario. Therefore, as the range of Smallmouth Bass in Ontario increases northward (Alofs et al. 2014) and management agencies respond by removing seasonal restrictions on harvest of nonnative species (Paukert et al., this issue), climate change can exacerbate this negative impact on nature-based tourism operators in Ontario. Of course, the overall impact of range expansion on the well-being of Ontario fishers is uncertain partly because fishers and tourist operators will respond to these changes in Smallmouth Bass abundance in ways that will impact different drivers, resulting in further changes and responses (see Figure 4).

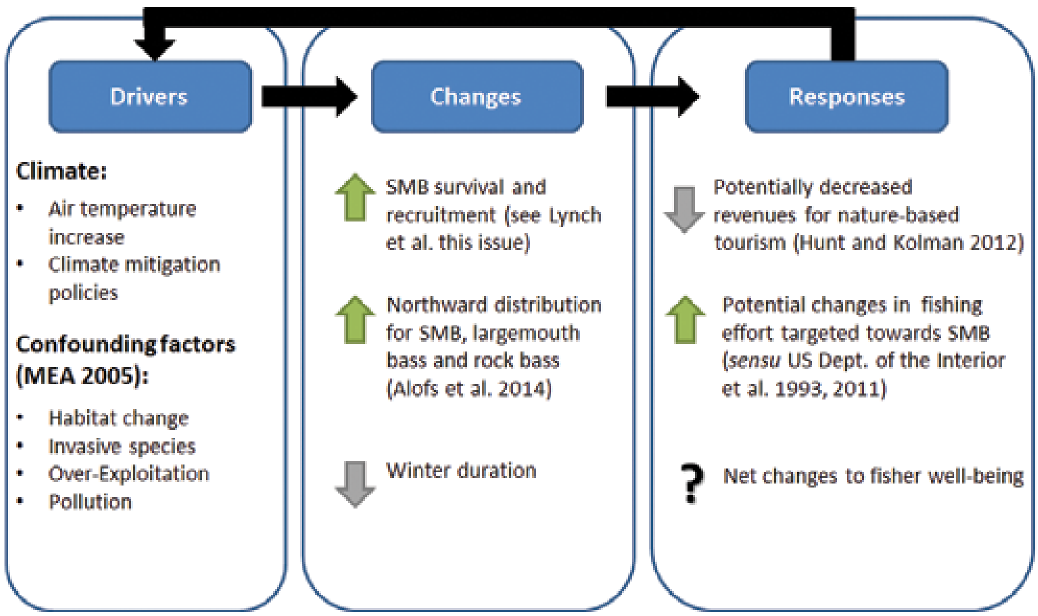

Figure 4. Possible climate change impacts to fishers from northward range expansion of nonnative Smallmouth Bass (SMB) in Ontario's lakes facilitated by climate change. (Changes to SMB from Lynch et al. this issue, green arrows indicated an increased or earlier seasonal response, gray arrows indicated a decrease or later seasonal response, while the question mark represents an unsure response).

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Box 3: Suggestions for Future Research and Management of Climate Change Impacts on Recreational Fishers

- **Integrating considerations of all three pathways into management:** Fisheries managers should be mindful of the potential of all three pathways to impact inland fishers from climate change across space and time. It is important for fishers and fisheries managers to work with others who develop environmental policy to try and ensure that fisheries concerns are adequately considered and to give ample warning for fishers to adapt to changing social and resource conditions that arise from such policy.
- **Developing long-term monitoring data about fishers:** These data should focus on more than effort and instead provide opportunities to understand the diversity of preferences and fishing behaviors and the wide array of well-being benefits that accrue to fishers. The monitoring should also provide data about lapsed and potential fishers (i.e., people who do not fish but might under different conditions) that would help researchers to understand and predict how climate change and other environmental stressors could impact fishing participation (Abbott and Fenichel 2013; Fenichel et al. 2013a). For example, one can use repeated cross-sectional or panel surveys of fishers to measure changes in behaviors such as location, timing, and intensity of effort and changes to satisfaction with recreational fishing opportunities.
- **Extending efforts focused on integrative and interdisciplinary models:** These models are needed to help understand the consequences of climate change and other drivers (stressors) on fishers' behaviors and well-being. Such model predictions should be validated through active experimentation or at least from associations with long term monitoring data. For example, by modeling both the ecological and social systems, researchers can assess the consequences of climate change scenarios jointly on aquatic ecosystems and fishers.
- **Exploring new methods, impacts, and study areas:** Thermal, physical, and esthetic conditions of weather and climate influence the behaviors of tourists and recreationists (de Freitas 1990; de Freitas et al. 2008). Research is needed to assess the reliability of these conclusions in the context of recreational fishing. Research is also needed to move beyond average impacts to account for increased climate variability including extreme weather events and to focus on southern U.S. recreational fishers who are likely to be most negatively impacted through changing climate.
- **Evaluating the strength of responses between fish abundance and fishing behaviors (effort):** This research is critical to understand the relative strength of the three pathways. This understanding is also important to assess how fishers' behaviors might serve to moderate the impacts of climate change on fishes. For example, if fishers respond strongly to change in fish stock abundance, fishers could adapt by reducing fishing effort on species that become less abundant and shifting time allocation to other activities.
- **Communicating climate science effectively to audiences:** The impacts of climate change on fishers should be communicated in ways that resonate with the audience. For example, DeWeber and Wagner (2015) communicate the extirpation of Brook Trout *Salvelinus fontinalis* in the northeastern United States through messages of how much further residents will need to travel to pursue their trips. Such communications can serve to highlight the importance of climate change to fishing and other human activities.

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