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Analysis

The effect of climate change on optimal wetlands and waterfowl management in Western Canada

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ABSTRACT

Warmer temperatures and a decrease in precipitation in the 21st century could severely deplete wetlands in the prairie pothole region of western Canada. In this study, we employ linear regression analysis to determine the casual effect of climate change on wetlands in this region, with temperature, precipitation and the standardized precipitation index (SPI) used to predict the effect of potential climate change on wetlands. We then use a waterfowl–wetlands bioeconomic model to solve for socially optimal levels of duck harvests and wetlands retention under current climate conditions and various climate change scenarios. The model maximizes benefits to hunters plus the amenity values of ducks to non hunters and the non-market ecosystem benefits of wetlands. Results indicate that climate change could decrease wetlands by between 7 and 47%, and that the optimal number of wetlands to retain could decrease by as much as 38% from the baseline climate.

1. Introduction

Climate change is expected to increase drought in the southern parts of the Canadian Prairie provinces of Alberta, Saskatchewan and Manitoba, also known as the prairie pothole region, because of increased temperatures and changes to patterns of precipitation (Johnson et al., 2005, p.864). Conditions in the 21st century are expected to be substantially drier than during the past century, perhaps closer to what they were in the mid 1800s when explorers found much of the region to be too dry to warrant cropping (The University of Calgary, 1997). Drier conditions will have a major impact on the prairie pothole region (PPR) — North America's 'duck factory.' A drier climate will reduce wetlands, which will have an adverse impact on agricultural ecosystems and the region's ability to produce waterfowl, as seen from the correlation between wetlands and breeding duck populations in Fig. 1. Drier conditions will simply mean that the region will not be able to support historically observed levels of migratory waterfowl.

The Intergovernmental Panel on Climate Change (IPCC) predicts that surface temperatures around the globe could rise by between 1.1 and 6.4 °C by 2100 (Solomon et al., 2007, p.13), while regional climate models predict that temperatures could rise by 1.8 °C to 4 °C in the prairie pothole region (Johnson et al., 2010). Future precipitation patterns are more difficult to predict. Johnson et al. (2005) point out that changes in average annual precipitation during the next 100 years may vary between a decrease of 20% and an increase of 20%, while other analysts predict changes between a decline of 5% and an increase of 10% (Solomon et al., 2007). Further, both Ojima and Lackett (2002) and Johnson et al. (2004) indicate that climate change will likely increase droughts and torrential rains.

Several studies have used multiple regression models to estimate the causal effect of climate change on wetlands. Using the Palmer Drought Index (PDI), Sorenson et al. (1998) estimate the effect of climate change on wetlands in the north central United States, while Larson (1995) employs temperature and precipitation data to estimate the effect of climate on wetlands in the U.S. and Canada. In this study, therefore, we use a multiple regression framework and data on drought, temperature and precipitation to estimate the impact of climate change on wetlands in Canada's prairie pothole region (Fig. 2).

In the current research, rather than using the PDI, we rely on the Standardized Precipitation Index (SPI), which is a popular drought index based solely on precipitation. Bethke and Nudds (1995) and Adams (1988) argue that the best indicator of wetlands in the

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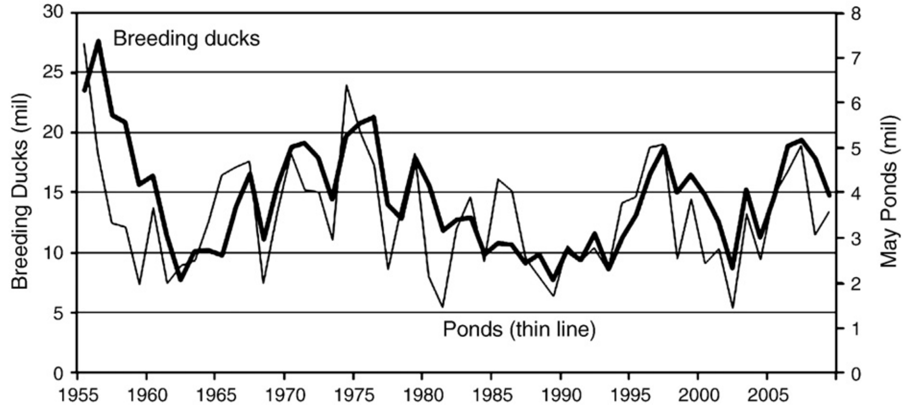

Fig. 1. Relationship between wetlands and waterfowl in Canada's Grain Belt, 1955–2009.

Canadian PPR is precipitation in the previous year. This correlation is verified in Fig. 3, where wetlands (as measured by pond numbers) and a one-year lag of precipitation are plotted for the PPR. Further, the drought that was caused when precipitation fell in 2001 to 40% of its historical average was followed in 2002 by the lowest number of wetlands in recent history. Given the observed effect of precipitation on wetlands in the PPR, the SPI variable likely captures the relationship well. For robustness, we also used data on temperatures and precipitation, and compare results using both models.

Another contribution of the current study is that, in addition to estimating the effect of climate change on wetlands, we use a bioeconomic model to find the optimal level of wetlands and duck harvests. The bioeconomic model is based on a model by van Kooten et al. (in press) that extends an earlier model of migratory waterfowl and wetlands due to Gardner Brown and Judd Hammack (Brown and Hammack 1974; Brown and Hammack, 1973; Brown et al., 1976). Brown and Hammack's waterfowl management model focused solely on the consumptive value of waterfowl. But, in addition to their (consumptive) use value to hunters, waterfowl also have non-use value while wetlands have a variety of use and non-use values outside of their role in producing waterfowl. For instance, wetlands filter agricultural and other pollutants, provide water for livestock and wildlife, contribute to visual and recreational amenities, and store greenhouse gases. Van Kooten et al. include amenity values of waterfowl and wetlands, but do not take climate into account.

The objectives in this study are to (1) estimate the causal effect of climate indicators on wetlands, (2) explore the impact that a changing climate might have on wetlands in Canada using results from linear regression models, and (3) estimate the impact of climate change on the optimal management of waterfowl and wetlands using a bioeconomic model.

The remainder of this paper is organized as follows. In Section 2, we provide a brief overview of relevant literature. The two regression equations are developed and estimated in Section 3, while the bioeconomic model is described and parameterized in Section 4. In Section 5, we first describe the climate scenarios and then employ the estimated regression equations to predict how wetlands might be expected to change under various climate scenarios. These projections are used in the logistics equation of the bioeconomic model to estimate socially optimal baseline (current climate) values of wetlands retention, duck populations and duck harvests, as well as optimal values that account for the effect of climate change on wetlands. We conclude in Section 6 by discussing the opportunities and challenges facing policymakers and directions for future research.

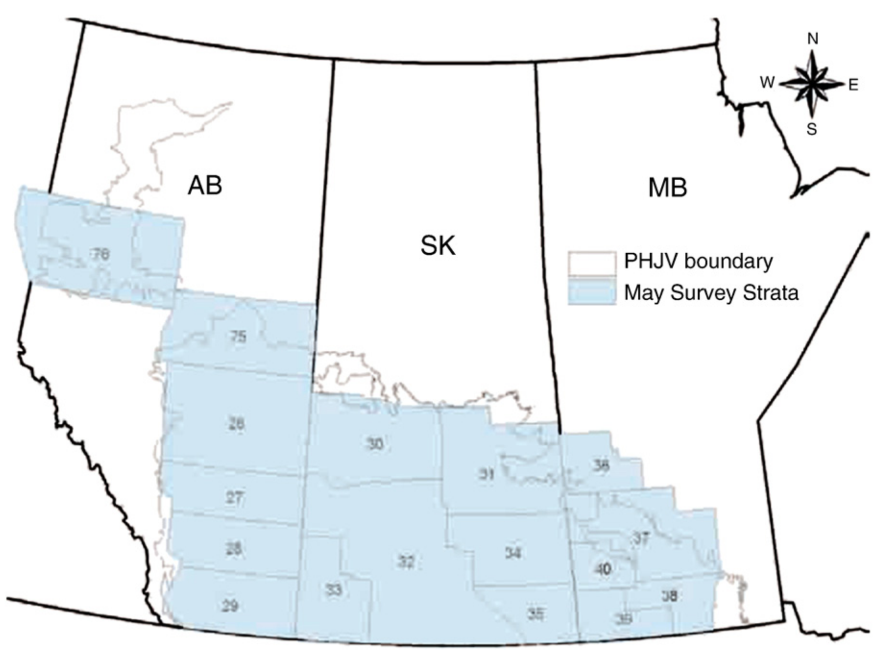

Fig. 2. The prairie pothole region of Canada.
Source: Prairie Habitat Joint Venture: Implementation Plan 2007–2012, obtained online at http://www.phjv.ca/pdf/PHJV%20Implementation%20Plan%20090506-lowres.pdf.