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Analysis of Lake Huron recreational fisheries data using models dealing with excessive zeros

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ABSTRACT

Excessive zeros in recreational catch data can cause problems for fish stock assessment and management. We evaluated a range of count regression models for analyzing the recreational catch data of walleye, Chinook salmon, and lake trout in Lake Huron. We also used modern predictive measures of effects to interpret the statistical results and extract year effects from the complex models. We found that models that account for both excessive zeros and overdispersion in recreational data, i.e., the zero-inflated negative binomial (ZINB) and hurdle negative binomial models, performed much better than those that cope with only one or none of the two common count data problems. Using the results from the best ZINB models, we identified important factors affecting catch rate of the three aforementioned species, and constructed standardized CPUE indices for each species.

1. Introduction

Timely monitoring, and assessing changes in the ecosystem and fisheries of the Great Lakes have important social, economic, and ecological values. This is exemplified by the drastic decline in prey fish abundance and Chinook salmon (*Oncorhynchus tshawytscha*) fisheries in Lake Huron during the early and middle 2000s (Bence and Mohr, 2008; He et al., 2008; Riley et al., 2008). The decline in Chinook salmon fishery has cost Michigan major loss in Lake Huron fishing and other economic activities since 2004 (Dettmers et al., 2012).

Recreational fisheries in Michigan's Great Lakes waters are monitored through creel (on-site angler) surveys and charter-boat reporting systems (Su and Clapp, 2013). These monitoring programs provide total catch and fishing effort data that are essential for stock assessment and fisheries management. They also generate catch rate (catch-per-unit-of-effort, CPUE) data that are often used as an index of fish abundance.

Catch rates can be a distorted measure of trends in fish abundance, however, because they are affected by both fish abundance and factors that are unrelated to fish abundance, such as fishing site, season, target species sought by anglers, and changes in fishing techniques. Therefore, catch rates must be standardized to remove the effects of factors confounding fish abundance before they can be used as a reliable index of abundance (Maunder and Punt, 2004).

Catch-rate standardization refers to the process of isolating or removing effects of factors unrelated to trends in fish abundance. A historical method for standardizing catch and effort data involves selecting a "standard gear" and comparing the relative fishing power among all gears (Beverton and Holt, 1957). However, this method cannot account for the effects of those factors other than fishing gear. Modern approaches for standardizing catch and effort data utilize statistical models, such as generalized linear models (GLMs), to account for multiple factors that may confound the abundance trends in catch and effort data (Maunder and Punt, 2004; Quinn and Deriso, 1999). These models are built to relate catch or catch rates to a variable representing year effects and other explanatory variables that may cause variation in catch rates but are not related to abundance changes. The year effects can then be extracted from the fitted model and used as an index of abundance.

In Great Lakes waters, recreational catch data are characterized by an excessive number of zeros and small catch values. Many standard statistical models used for analyzing commercial or research-vessel catch data (Bishop et al., 2004; Deroba and Bence, 2009; Ye and Dennis, 2009) cannot deal with excessive zeros in the data (Lewin et al., 2010; Minami et al., 2007; O'Neill and Faddy, 2003; Ortiz and Arocha, 2004). Hence, using these models to fit recreational catch data may lead to biased parameter estimates, erroneous uncertainty estimates (e.g., standard errors or confidence intervals), and incorrect assessment (Webley et al., 2011). For

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such data, one should consider models that can handle excessive zeros.

Two commonly used modeling techniques that can account for excessive zeros in count data are hurdle models (Mullahy, 1986) and zero-inflated models (Lambert, 1992). A hurdle model is a two-part model that handles zero and positive counts separately (Mullahy, 1986). A zero-inflated model is a mixture model of a standard count distribution (e.g., Poisson or negative binomial) and a degenerate distribution at zero (Lambert, 1992). In fisheries and ecological literature, these models have been used to analyze abundance of rare species (Martin et al., 2005; Welsh et al., 1996), bluefin tuna (*Thunnus thynnus*) trap catches (Lemos and Gomes, 2004), shark bycatch data (Minami et al., 2007), and species–environment relationships (Lewin et al., 2010). With a few exceptions (e.g., O'Neill and Faddy, 2003), models that can handle an excessive number of zeros have rarely been used to analyze recreational fisheries data.

In this paper, we applied two standard count regression models (Poisson and negative binomial), two hurdle, and two zero-inflated count regression models to recreational fisheries data collected from creel surveys in Michigan waters of Lake Huron. Our objectives are to: (1) find the probability distributions that best describe these recreational catch data; (2) identify factors affecting recreational catch rates; and (3) standardize recreational fisheries catch rates. We used the Akaike information criterion (AIC) for model selection. We also used modern predictive measures of effects, such as predictive margins and differences (Gelman and Hill, 2007), to interpret the statistical results and to extract year effects from the complex hurdle and zero-inflated models.

We applied the aforementioned statistical models to catch and effort data for three recreational fish species in Lake Huron: Chinook salmon, lake trout (*Salvelinus namaycush*), and walleye (*Sander vitreus*). Chinook salmon was the main target species in Lake Huron before 2004 (Bence and Mohr, 2008), but due to drastic changes in Lake Huron's food web, Chinook salmon fisheries have declined substantially since 2004. Meanwhile, abundance and harvest rates of walleye and lake trout have increased. Walleye has become the major recreational species in Lake Huron. Thus, developing standardized catch rates for these three important recreational species and understanding major factors influencing the observed catch rates have important management implications.

2. Data and methods

2.1. Data

We used angler or boat trip data obtained from creel surveys conducted from 1987 to 2011 by the Michigan Department of Natural Resources (MDNR), Fisheries Division (Adlerstein et al., 2008; Su and Clapp, 2013). The data include fishing trip, species, and catch information obtained from interviews of anglers or angler parties who had finished their fishing trips (i.e., access or completed trips).

To demonstrate our methods, we focused our analysis on Chinook salmon and lake trout data from statistical district MH-2 and

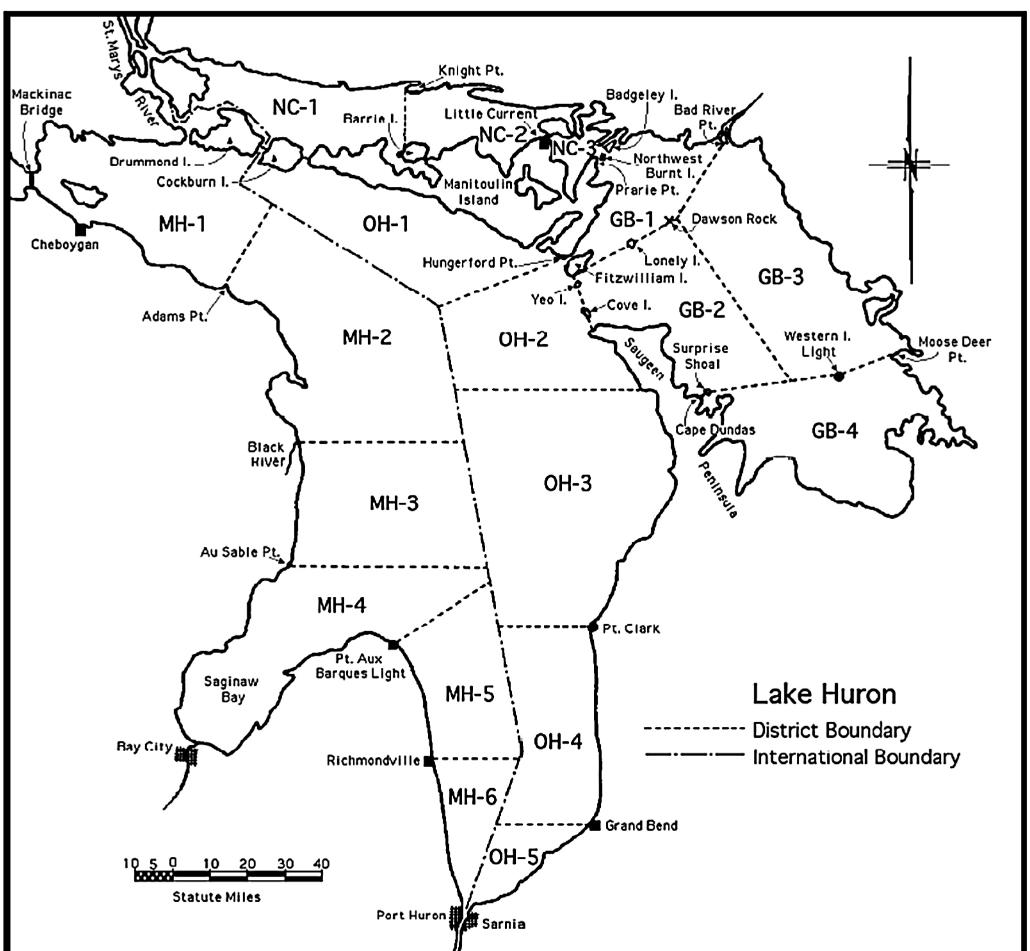

Fig. 1. Map of Lake Huron. MH-1 to MH-6 indicate statistical districts used for fisheries management purposes in Michigan.