Ecological Modelling 272 (2014) 16–27

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Measuring and predicting abundance and dynamics of habitat for piping plovers on a large reservoir

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ARTICLE INFO

Article history:
Received 7 January 2013
Received in revised form 23 August 2013
Accepted 26 August 2013
Available online 19 October 2013

Keywords:
Breeding population
Density
Remote sensing
Reservoir
Shorebird
Waterbird

ABSTRACT

Measuring habitat and understanding habitat dynamics have become increasingly important for wildlife conservation. Using remotely-sensed data, we developed procedures to measure breeding habitat abundance for the federally listed piping plover (*Charadrius melodus*) at Lake Sakakawea, North Dakota, USA. We also developed a model to predict habitat abundance based on past and projected water levels, vegetation colonization rates, and topography. Previous studies define plover habitat as flat areas (<10% slope) with ≤30% obstruction of bare substrate. Compared to ground-based data, remotely-sensed habitat classifications (≤30/>30% bare-substrate obstruction) were 76% correct and omission and commission errors were equal. Due to water level fluctuations, habitat abundance varied markedly among years (1986–2009) ranging from 9 to 5195 ha. The proportion bare substrate declined with the number of years since a contour was inundated until 5 years ($\hat{\beta} = -0.65$, SE = 0.05), then it stabilized near zero, and the decline varied by shoreline segment (5, 50, and 95 percentile were $\hat{\beta} = -0.19$, SE = 0.05, $\hat{\beta} = -0.63$, SE = 0.05, and $\hat{\beta} = -0.91$, SE = 0.05, respectively). Years since inundated predicted habitat abundance well at shoreline segments ($R^2 = 0.77$), but it predicted better for the whole lake ($R^2 = 0.86$). The vastness and dynamics of plover habitat on Lake Sakakawea suggest that this is a key area for conservation of this species. Model-based habitat predictions can benefit resource conservation because they can (1) form the basis for a sampling stratification, (2) help allocate monitoring efforts among areas, and (3) help inform management through simulations or what-if scenarios.

Published by Elsevier B.V.

1. Introduction

Measuring habitat and understanding habitat dynamics have become increasingly important for wildlife conservation. Land use changes have affected the composition and availability of habitat for many species around the globe (Foley et al., 2005). Indeed, many management or conservation plans set habitat abundance targets in efforts to conserve or recover species (e.g. U.S. Fish and Wildlife Service [USFWS], 2003). However, habitat targets often are set without good information about abundance and dynamics of habitat and their linkages to population size. The need for large-landscape scale habitat information for conservation of wildlife suggests that collection of ground-based survey information alone is not feasible to address contemporary conservation questions (e.g., Harrison and Bruna, 1999; Osborne et al., 2001). Remote sensing of habitat through satellite imagery and high-resolution digital elevation models (DEM) has led to significant advances in techniques to measure habitat characteristics and to define and quantify habitat for wildlife species (Horning et al., 2010).

Large-scale or complete habitat estimates can be an important tool in the conservation of wildlife. Wildlife abundance estimates could be improved by including habitat data in population models, especially for species that are distributed unevenly across the landscape. In many cases habitats can be very dynamic and they affect animal distribution and recruitment, so understanding habitat dynamics can improve understandings of population dynamics and habitat-abundance targets (e.g., Cowardin et al., 1995; Strong and Trost, 1994). Clearly, retrospective measurements of habitat are important for management and conservation; however, the ability to accurately or consistently predict abundance of habitat is rare, but would be clearly useful for many aspects of research, conservation and management.

Habitat abundance can be dynamic in response to climate, conservation, or land use (Anteau, 2012; Bethke and Nudds, 1995; Drever, 2006; Johnson and Shaffer, 1987). If relationships between factors that influence habitat abundance can be understood then meaningful predictions of habitat can be made under various scenarios. Predicted habitat values could be input into habitat-based

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0304-3800/$ – see front matter. Published by Elsevier B.V.
http://dx.doi.org/10.1016/j.ecolmodel.2013.08.020

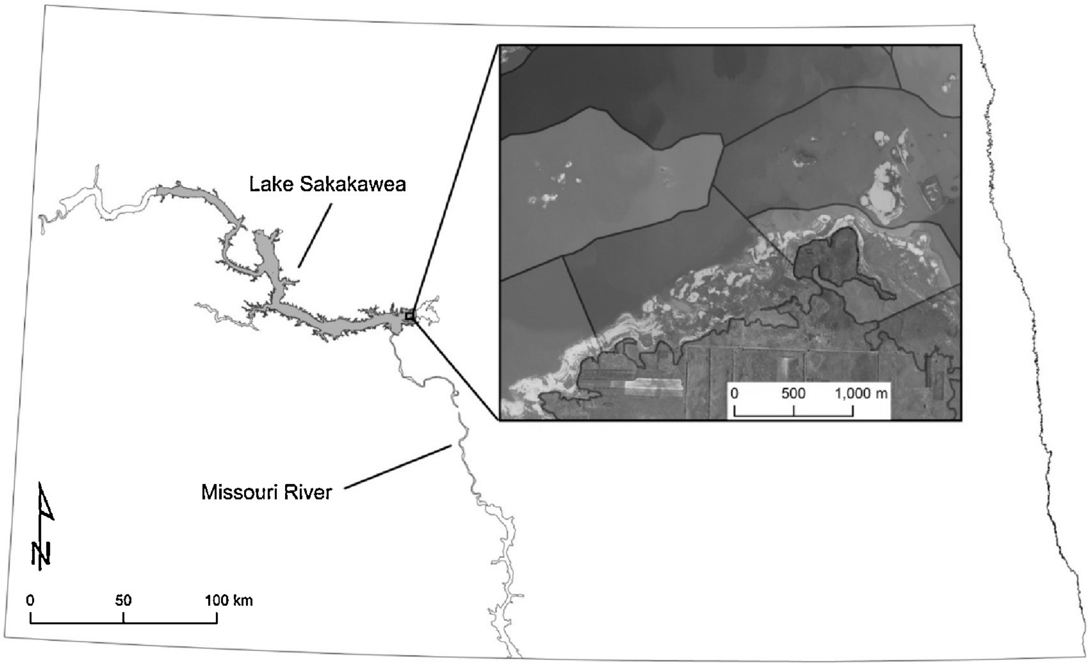

Fig. 1. Map of North Dakota depicting our study area (shaded in gray) at Lake Sakakawea and an example of our study area segmentation.

species abundance models, used as the basis for stratification of sampling, or to allocate of efforts among research areas. Clearly, having a prospective spatial-abundance distribution would be very useful for research and conservation of rare species that have uneven distributions across vast areas (Anteau et al., submitted-a). Moreover, habitat predictions under various what-if scenarios would be useful for informing adaptive management or structured decision making to conserve, manage, or maximize habitat abundance.

Piping plovers (*Charadrius melodus*; hereafter plovers) have been the subject of many ongoing monitoring programs and focused research studies since their federal listing in 1986 (e.g., Catlin, 2009; Elliott-Smith and Haig, 2004; Shaffer et al., 2013; Sherfy et al., 2008). Plovers typically nest on areas that are unvegetated, flat, and sandy with occasional scattered pebbles or gravel and nest sites typically follow an uneven distribution within the landscape used by plovers (Anteau et al., 2012b; Burger, 1987; Elliott-Smith and Haig, 2004; Prindiville Gaines and Ryan, 1988; Sherfy et al., 2008). Plover broods typically stay near their nest site and also select for unvegetated flat areas (Haffner et al., 2009; Harris et al., 2005; Knetter et al., 2002; Wiltermuth et al., submitted), and those habitat characteristics near the nest site also influence chick survival or fledging rates (Anteau et al., submitted-b).

Since the 1950s, with the construction of dams on large river systems in the Northern Great Plains, plovers began nesting on mainlands and islands of reservoirs (Elliott-Smith and Haig, 2004). Recently over 60% of Missouri River plovers and 29% of the Northern Great Plains population used reservoir habitats during the breeding season (cf., Anteau et al., 2012b). Indeed, over 40% of Missouri River plovers were observed on a single reservoir, Lake Sakakawea (hereafter SAK; Fig. 1; cf., Anteau et al., 2012b). While reservoirs receive heavy use by plovers in many years, they only receive light use in others (U.S. Fish and Wildlife Service, 2003).

Many reservoirs in the Northern Great Plains, SAK included, typically experience great inter-annual water-level fluctuations in response to management and wet/dry climate cycles which likely causes dynamics in habitat abundance. Periodically, extreme-wet years fill the reservoir, followed by a series of drier years where the water levels draw down (Fig. 2). While colonization of vegetation in relation to water-level fluctuations has been well studied in riparian systems, it has received little attention on reservoir shorelines (Nilsson and Berggren, 2000). Terrestrial vegetation on the shoreline of a reservoir likely is killed and eroded when water level increases. The pattern of sequential drawdown annually exposes new unvegetated habitat that likely persists for some time until it is colonized again by terrestrial vegetation (Nilsson and Keddy, 1988). Accordingly, we expect that the number of years since a given elevation contour has been inundated should predict the abundance of habitat for plovers in that contour. Additionally, in a narrow elevation band ($\sim\pm0.5$ m) around the water-surface there is potential for erosion of nutrients and fine soil particles through wave action (Sharpley, 1985). Accordingly, we predict that the duration that historic water level was sustained during the non-winter months should be a good indicator of elevation contours containing coarse-substrate-nesting habitat for plovers.

The management and conservation of the Northern Great Plains plover population calls for inventory and monitoring of habitat

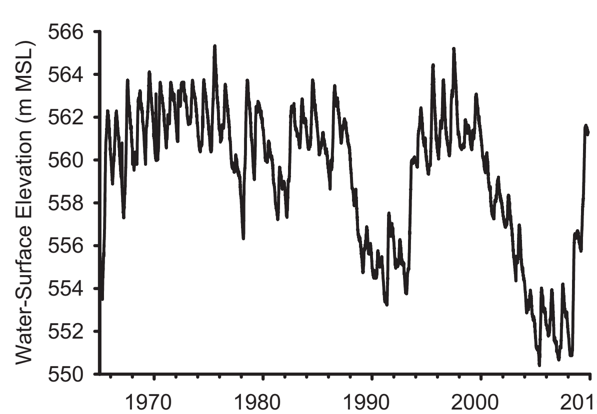

Fig. 2. Water-surface elevation (m MSL) of Lake Sakakawea from 1965 to 2009. Adapted from U.S. Army Corps of Engineers (2010).

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