Global Ecology and Conservation 13 (2017) e00370

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: http://www.elsevier.com/locate/gecco

Original Research Article

The importance of historical land use in the maintenance of early successional habitat for a threatened rattlesnake

Eric M. McCluskey [a, *], Stephen N. Matthews [b], Isaac Y. Ligocki [a], Matthew L. Holding [a], Gregory J. Lipps Jr. [c], Thomas E. Hetherington [a]

[a] Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, 300 Aronoff Laboratory, 318 West 12th Avenue, Columbus, OH 43210-1293, USA
[b] School of Environment and Natural Resources, The Ohio State University, 2021 Coffey Rd., Columbus, OH 43210, USA
[c] Ohio Biodiversity Conservation Partnership, The Ohio State University, Sisson Hall, 1920 Coffey Road, Columbus, OH 43210, USA

ARTICLE INFO

Article history:
Received 18 August 2017
Received in revised form 7 December 2017
Accepted 21 December 2017
Available online xxx

Keywords:
Eastern massasauga
Agriculture
Aerial photography
Maxent

ABSTRACT

Understanding how historic habitat changes have impacted species and searching the past for clues to better understand the current plight of threatened species can help inform and improve future conservation efforts. We coupled species distribution modeling with historical imagery analysis to assess how changes in land use/land cover have influenced the distribution of eastern massasauga rattlesnake (*Sistrurus catenatus*), a federally threatened species, and its habitat in northeastern Ohio over the past ~75 years. We also examined land use/land cover changes throughout southern Michigan for a broader perspective on the influence of historical processes on contemporary habitat. There was a pronounced shift in northeastern Ohio land cover from 1938 to 2011 with forest cover becoming the predominant land cover type as agricultural fields were abandoned and succession occurred. Most known eastern massasauga locations in the area were at some point used for agriculture and higher habitat suitability values were associated with agricultural fields that were eventually abandoned. We observed more stable habitat conditions across southern Michigan populations indicating agricultural abandonment was not as necessary for habitat creation in this part of their range. We present a new approach for linking historical landscapes to present day habitat suitability models; permitting inferences on how prior land use/land cover states have influenced the current distribution of species and their habitats. We demonstrate how agricultural abandonment was an important source of early successional habitat for a species that requires an open canopy, a finding applicable to a broad array of species with similar habitat requirements.

1. Introduction

Understanding how prior anthropogenic activities have influenced wildlife populations can benefit current conservation efforts in various ways. For example, historical information on exploited marine species has been used to explain abnormally low genetic diversity (Bonnell and Selander, 1974) and degraded ocean ecosystem functioning (Lotze and Worm, 2009).

* Corresponding author.
E-mail addresses: mccluskey.29@osu.edu (E.M. McCluskey), matthews.204@osu.edu (S.N. Matthews), ligocki.3@osu.edu (I.Y. Ligocki), holding.5@osu.edu (M.L. Holding), lipps.37@osu.edu (G.J. Lipps), hetherington.1@osu.edu (T.E. Hetherington).

https://doi.org/10.1016/j.gecco.2017.e00370

Historical information can also aid in the quantification of anthropogenic impacts on critical habitats that promote species persistence and movement through the landscape (Fahrig, 1997; Cushman, 2006).

Species distributions are governed principally by constraints imposed by climatic factors and the availability of suitable habitat alongside prevailing ecological drivers such as dispersal ability and species interactions (e.g. predation, competition) (Araújo and Luoto, 2007). In many locations, however, humans have influenced both the availability of suitable habitat, the broader matrix of habitat in which suitable habitat is embedded (e.g. fragmentation), and the composition of local ecological communities. Research on populations that have persisted in these modified landscapes can provide valuable information for future conservation planning if factors related to persistence (e.g. characteristics of refugia) are identified (Chazdon et al., 2009).

Enlisting a historical perspective can illuminate the underlying patterns and resulting impacts of fragmentation and habitat loss and provide important insights to help reverse trends of population declines associated with isolated populations in modified landscapes (Kuussaari et al., 2009). Reliable forms of historical data are scarce, which limits efforts to link past human activities with current species distributions. For example, long-term field studies can provide insights into the timing and location of human-caused population declines (Clutton-Brock and Sheldon, 2010) but few have existed for the duration of the past century during which human-mediated land modification has intensified.

Historical aerial photograph archives in the U.S. and elsewhere present a unique opportunity for assessing changes in land use and land cover over the past 75 years because they serve as discrete samples, each photograph captures the landscape features for a given location showing both patterns of vegetation and anthropogenic use. In the field of ecology, historical aerial photographs have been applied to study trends in land cover (Mast et al., 1997; Morgan et al., 2010), but applications to wildlife research are still sparse. Pringle et al. (2009) demonstrated the utility of historical aerial photographs for assessing long-term habitat trends by showing how encroaching vegetation has decreased available unshaded, rocky habitat for an Australian endangered species, broad-headed snake (*Hoplocephalus bungaroides*), from 1941 to 2006. We sought to merge the retrospective benefits of historical imagery with modern species distribution modeling (SDM) techniques to study wildlife habitat associations with historical land use.

A limited number of studies have incorporated an SDM framework into historical habitat-based analyses. Ficetola et al. (2010) used historical niche models in an invasion biology context to identify expansion routes of invasive American bullfrog (*Rana catesbeiana*) in Northern Italy, creating niche models using historical imagery then projecting them to later time periods. Brambilla et al. (2010) developed a habitat suitability map (HSM) for the red-backed shrike (*Lanius collurio*) based on current conditions to assess changes in habitat availability/suitability and then extrapolated into the future under different land use scenarios.

Our approach merged historical imagery analysis with SDM techniques in the context of assessing the role of prior landscapes in determining the distribution of present day habitat for a federally threatened species, eastern massasauga rattlesnake (*Sistrurus catenatus*). Constructing SDMs based on historical aerial photographs necessitates the use of broadly defined land cover classes as predictor variables that can be inferred from black and white imagery (Brambilla et al., 2010; Ficetola et al., 2010). Instead, we used contemporary GIS and remotely sensed variables associated with eastern massasauga habitat in our SDM process to produce a more refined HSM based on current conditions. We then used classified historical aerial photographs in conjunction with the HSM to examine how changes in land use and land cover have influenced the distribution of the eastern massasauga and its diminished habitat in northeastern Ohio. If prior landscape features do predict present day habitat, this information could be used in conjunction with present day landscape information to derive predictive land management and acquisition strategies. Finally, we assessed land cover changes in southern Michigan, the region with the most remaining eastern massasauga populations, to determine if the factors influencing the availability of snake habitat in Ohio are also present in the species' stronghold.

Eastern massasauga require open canopy habitats that include fens, wet prairies, and forested wetlands throughout their Great Lakes distribution (Szymanski, 1998). In northeastern Ohio, they are primarily found in early successional grassland habitats with poorly drained soils.

Conversion of these grassland and wetland habitats to agriculture is one of the primary causes for eastern massasauga population declines during the last century (Szymanski, 1998). An additional threat to snakes in northeastern Ohio and elsewhere in the species' range is habitat loss due to succession as grasslands are replaced by forest (Szymanski et al., 2015). Increases in forest cover associated with agricultural abandonment have been well documented across the eastern U.S. during the last half-century (Ramankutty and Foley, 1999; Ramankutty et al., 2010). The negative impact of diminishing early successional habitats on biodiversity in the Northeast has started to receive attention from the conservation community (DeGraaf and Yamasaki, 2003; Litvaitis, 2003).

Our objectives were to (1) shed light on how the historical dynamics of agriculture and forest succession have influenced the present-day distribution of a federally threatened snake and its habitat in northeastern Ohio and (2) determine if there are commonalities in the land use history of sites where this threatened species has persisted in other parts of its range. We did this by (a) object based classification of historical aerial photographs to quantify land cover changes over time; (b) generating SDMs for Ohio based on current environmental conditions to relate contemporary habitat suitability to historical land cover and (c) land cover change analysis in Michigan populations. We provide evidence that agriculture and the transition of grassland to forest will continue to impact landscapes inhabited by the remaining eastern massasauga populations, and demonstrate that quantifying historical transitions among habitat types can inform future management plans.