



Review

Enhancing agricultural landscapes to increase crop pest reduction by vertebrates



Catherine Lindell^{a,b,c,*}, Rachael A. Eaton^{a,c,1}, Philip H. Howard^d, Steven M. Roels^{a,c}, M.E. Shave^{a,c}

^a Integrative Biology Department, Michigan State University, 288 Farm Lane, East Lansing, MI, 48824, USA

^b Center for Global Change and Earth Observations, Michigan State University, 1405 S. Harrison Rd., East Lansing, MI, 48823, USA

^c Ecology, Evolutionary Biology, and Behavior Program, Michigan State University, 293 Farm Lane, East Lansing, MI, 48824, USA

^d Community Sustainability Department, Michigan State University, 480 Wilson Rd., East Lansing, MI, 48824, USA

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ABSTRACT

A key challenge of the coming decades is increasing agricultural productivity while maintaining environments that optimize ecosystem service provisioning. Crop pests are a constant challenge for farmers. Recent investigations demonstrate that vertebrates consume numerous crop pests and that this consumption often reduces crop damage, a key ecosystem service. Pest-consuming vertebrates can be attracted to agricultural areas through several strategies that we refer to as landscape enhancements: 1) providing critical structures and materials like nest boxes and roosts, 2) managing habitat/landscape complexity, 3) reintroducing native species, and 4) reducing invasive species' impacts on target species. In addition to the potential for lower crop damage, attracting pest-consuming vertebrate to agricultural areas could: reduce use of pesticides, aid in the conservation of declining species, provide cultural ecosystem services like wildlife watching, and respond to consumer preferences regarding food production. Some of these benefits provide potential economic advantages to food producers. Our search of past research indicated that relatively few systematic studies have investigated vertebrate effects on crop pests and even fewer have studied how enhancements may increase trophic effects resulting in lower crop damage. Birds are the most studied vertebrate with regard to effects on crop pests, arthropods are the most studied pest group, and a plurality of studies have taken place in coffee and cacao. We lack information about key ecological and social questions related to enhancements including the contexts in which vertebrate predators are most likely to be attracted to enhancements and reduce crop pests, the potential economic benefits of enhancements, and how to marshal the human resources to install, maintain, and monitor enhancements. Addressing these questions will increase understanding of the interactions of vertebrate predators and their prey, the ways in which these interactions provide ecosystem services, and the roles of humans in protecting and encouraging these interactions.

1. Introduction

Food production activities cover one fourth of Earth's land surface (Millennium Ecosystem Assessment, 2005). With a growing human population, increasing agricultural productivity will be key to human well-being in the coming years (Godfray et al., 2010). Simultaneously, maintaining and improving environmental integrity and the ecosystem services vital to agricultural production will be comparable challenges (Robertson and Swinton, 2005; Meehan and Gratton, 2016).

Crop pests are a long-standing and costly challenge for farmers (e.g. Funayama, 2004). For example, management of the diamondback moth, *Plutella xylostella*, a major pest of cabbage, cauliflower, and

canola, costs farmers worldwide four to five billion dollars annually (Zalucki et al., 2012). Fruit producers in five U.S. states estimated the annual cost of pest birds in five fruit crops at nearly \$200 million (Anderson et al., 2013). Yield losses to rodents and birds in several high-value crops in California were estimated at 5% or greater (Gebhardt et al., 2011).

Conversely, other species in agricultural landscapes consume pest species, resulting in the ecosystem service of pest regulation and reduced crop plant damage (e.g. Maas et al., 2013).

The wrinkle-lipped bat, *Tadarida plicata*, in Thailand, for example, provides services worth 1.2 million USD annually through its consumption of the rice-damaging white-backed planthopper, *Sogatella*

* Corresponding author at: Integrative Biology Department, Michigan State University, 288 Farm Lane, East Lansing, MI, 48824, USA.

E-mail address: lindell@msu.edu (C. Lindell).

¹ Present address: BioSciences Department, Rice University, W100 George R. Brown Hall, 6100 Main St., Houston, Texas, 77251, U.S.A.

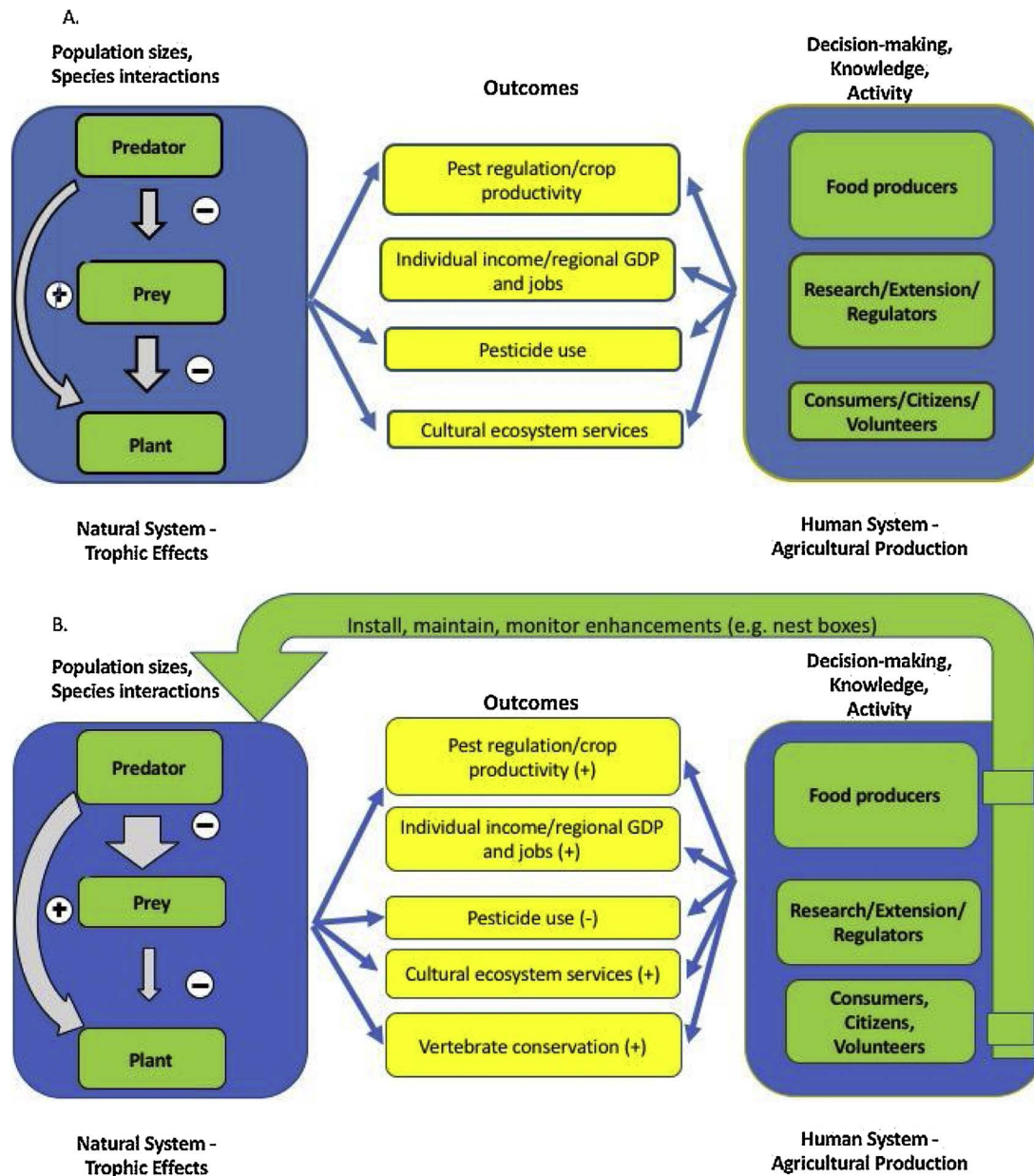


Fig. 1. Agricultural landscapes comprise both natural components (left sides of panels), wherein predators reduce crop pests and influence other outcomes (in yellow), and human components (right sides of panels) where individuals and groups make decisions and take actions that influence many of the same outcomes. Natural predators will reduce crop pests to some extent in agricultural landscapes (panel A) Gray arrows represent effects of a predator species on crop pest species and crops, leading to the ecosystem service of pest regulation. If humans improve landscapes for vertebrate predators through enhancements such as nest boxes (green arrow in panel B), they can influence predator-initiated trophic effects, potentially resulting in greater pest regulation, with associated outcomes on individual income, regional GDP, pesticide use, cultural ecosystem services, and vertebrate conservation. The pluses and minuses in the yellow boxes in panel B refer to the expected increases or decreases in this particular outcome when enhancements are used, as compared to when no enhancements are in place (panel A). This figure is a simplification that ignores phenomena such as intraguild predation and competitive interactions within trophic levels.

furcifera (Wanger et al., 2014). In the last ten years, a burgeoning amount of research has investigated such vertebrate contributions to crop pest regulation, indicating the potential benefits of enhancing our agricultural landscapes to increase their attractiveness to vertebrates which may, in turn, increase beneficial trophic effects, ecosystem services, and other components of the food production system (Fig. 1).

In this review, we discuss 1) why we should invest resources to conserve and attract pest-consuming vertebrates to agricultural landscapes, 2) ways to enhance ecosystem service delivery by vertebrate predators in agricultural landscapes, and 3) questions and challenges for future research in this area. To aid in the discussion of point 3, we conducted a literature search to determine patterns and gaps in research on wild vertebrates as predators on crop pests.

We use the term “enhance” to mean engaging in practices that

increase human benefits from an ecosystem service (Millennium Ecosystem Assessment 2005, p. 7). We define enhancements as structures or materials whose primary purpose is to increase important resources for, and/or reduce constraints on, habitat and landscape occupancy by pest-consuming vertebrates. Enhancements include nest boxes, artificial roosts, perches, and food resources. We use the term “enhancement” in this paper to refer to these structures and materials. We can also enhance landscapes to improve pest reduction through managing habitat/landscape complexity, reintroducing native species, and reducing invasive species’ impacts on target species. We will briefly discuss these activities, as well as structural and material enhancements.

Sections 2 and 3 below provide rationales to enhance landscapes to attract vertebrates and strategies for doing so in landscapes that have

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