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Maximizing ecosystem services from conservation biological control: The role of habitat management

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Abstract

The intentional provision of flowering plants and plant communities in managed landscapes to enhance natural enemies is termed habitat management and is a relatively new but growing aspect of conservation biological control. The focus of most habitat management research has been on understanding the role of these plant-provided resources on natural enemy biology, ecology, and their ability to enhance suppression of pest populations. Far less attention has been paid to additional ecosystem services that habitat management practices could provide in managed landscapes. We first evaluate whether habitat management is well positioned to advance in these areas. Our analysis of past habitat management studies indicates that four plant species have been tested in the majority of field evaluations, while plants native to the test area and perennial plants are particularly underrepresented. We suggest that synergies among biodiversity conservation, ecological restoration, human cultural values, tourism, biological control and other ecosystem services have largely been overlooked in past habitat management research and we illustrate how these potential ecosystem services could be evaluated and enhanced. We then review two case studies in which broader ecosystem services were explicitly addressed in plant selection criteria. One case study demonstrates that native plants useful in restoration of rare ecosystems can increase natural enemy abundance as much as widely recommended non-natives. The second addresses additional ecosystem services provided by habitat management in New Zealand vineyards. We conclude that addressing 'stacked' ecosystem services with multiple ecosystem service goals can decrease agriculture's dependence on 'substitution' methods such as the current reliance on oil-based agro-chemical inputs.

Keywords: Native plants; Ecological restoration; Biodiversity conservation; Biological control; Ecosystem services

1. Introduction

Modern agricultural landscapes have been shaped by production systems aimed at maximizing yield and profitability. While these landscapes generally fulfill this goal admirably, there are increasing calls for agriculture to broaden the range of ecosystem services it provides to society (Robertson and Swinton, 2005; Swinton et al., 2006). Ecosystem (or nature's) services are defined as all of the "conditions and processes" by which ecosystems "sustain and fulfill human life" (Daily, 1997). Examples of these services from both managed and natural systems include production of harvested products, provision of clean air and water, regulation of climate, maintenance of biodiversity, biological control of pests, diseases and weeds, and cultural or aesthetic values (Costanza et al., 1997). As part of a conservation biological control approach, habitat management seeks to maximize one specific ecosystem service, i.e., pest regulation, by enhancing natural enemy impact through manipulating plant-based resources in the landscape (Bugg and Pickett, 1998). Typically, this is accomplished by selecting plants that provide a limiting resource such as pollen, nectar, alternative hosts, or shelter and establishing these plants or plant communities within the managed system (Landis et al., 2000). In contrast with other types of pest management, habitat management appears to be uniquely positioned to provide directly or to synthesize

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the provision of many additional ecosystem services that society values. These include aesthetics, conservation of biodiversity, wastewater treatment, and weed suppression while enhancing invertebrate biological control. The latter can be achieved through the provision of shelter, nectar, alternative prey/hosts and/or pollen for natural enemies, which can be easily deployed by individual growers.

Past research on habitat management for biological control has primarily focused on maximizing the pest reduction service it can provide. This emphasis is clearly evident in the selection criteria used to choose plants for habitat management research. These include: attractiveness to natural enemies (Bugg et al., 1989; Maingay et al., 1991; Patt et al., 1997), prolific production of pollen and/or nectar (Zhao et al., 1992), accessibility of floral resources (Baggen et al., 1999; Wäckers et al., 1996), flowering phenology (Freeman-Long et al., 1998; Rebek et al., 2005; Stephens et al., 1998; Winkler, 2005), availability of seed (Hickman and Wratten, 1996), use of plants already present in, or adapted to, agricultural areas (Altieri and Whitcomb, 1979; Foster and Ruesink, 1984; Idris and Grafius, 1995; Nentwig, 1998; Nentwig et al., 1998; Nicholls et al., 2000), previous success (Ambrosino et al., 2006; Frank and Shrewsbury, 2004; Lavandero et al., 2005; Stephens et al., 1998), and selectivity in favor of the natural enemy rather than its own (fourth trophic level) natural enemies, or the pest itself (Araj et al., 2006). However, for habitat-management approaches to enhance other ecosystem services, researchers need to consider additional criteria in selecting plants for their studies as well as new partnerships in both the research and implementation phases of their work.

The goal of this paper is to document the ecosystem services beyond pest suppression that might be enhanced via habitat management, and to illustrate potential advantages of research aimed at achieving multiple goals. We begin by examining past field studies of habitat management and asking whether the discipline is currently well positioned to synergize broader ecosystem services. We then review the range of additional ecosystem services that could accrue from habitat management practices but have not been well studied, specifically, biodiversity conservation, ecological restoration, and human cultural values. Finally, we examine case studies where the provision of ecosystem services is explicitly woven into the research agenda and how this can lead to increased multi-functionality of habitat management practices.

2. Plant selection for multifunction habitat management

2.1. How diverse is the toolbox?

Achieving multiple ecosystem services from habitat management is an attractive goal and plants that provide resources for natural enemies may well provide such additional benefits. We therefore begin by examining past field studies of habitat management to assess if the plants tested to date already provide a broad cross-section of plant diversity from which to harvest such ecosystem services. We anticipate that surveying a large number of plant species would provide the best chance for observing unique benefits, and candidate plants should represent a broad range of functional groups including trees, shrubs, vines, grasses, legumes, and forbs. Additionally, it may be important to screen species with differing life histories ranging from annual to long-lived perennials. While both native and exotic species should be represented, plants native to the region of study may best enhance biodiversity and related ecosystem services. Finally, the cultural services that such plants could provide should also be considered.

To assess the number and diversity of plants that have been studied for habitat management, we examined field studies published in peer-reviewed literature in which plants were purposefully established to provide nectar and pollen to natural enemies. To identify such studies, we performed a search on ISI Web of Science in the "Title/keywords/abstract" frame using the following search terms: *flower** and *conservation biological control*, *flower** and *natural enemy*, and *habitat management* and *conservation biological control* (actual search terms in italics). We also considered any references cited within papers found in these searches and selected only studies reporting original data and excluded strictly laboratory or observational studies.

We found 34 studies that met our criteria dating from 1989 (Table 1). While several studies performed prior to 1989 documented natural enemies visiting flowering crops or weeds already present in or near an agricultural area (Altieri and Whitcomb, 1979; Bugg et al., 1987; Leius, 1967), none involved the purposeful establishment of plants to enhance natural enemy effectiveness. The number of published studies per year ranged from 0–9 and has increased since 1989, indicating a growing interest in habitat management (Fig. 1, Gurr et al., 2004). Of the studies identified, 19/34 (0.56) examined only plants that were not native to the area of study, while 14/34 (0.41) examined both native and exotic plants, and 1/34 (0.03) only native plants. Similarly, annual and perennial plants have not been considered equally in habitat management: 14/34 (0.41) of studies considered only annual plants, 17/34 (0.5) included both annual and perennial plants and only 3/34 (0.09) considered perennial plants alone. In total, only 165 species of plants appear to have been field tested for their utility in habitat management (Table 2). Even this modest number is heavily influenced by just six studies that each considered more than 20 plant species (Braman et al., 2002; Chaney, 1998; Denys and Tscharntke, 2002; Fiedler and Landis, 2007a; Freeman-Long et al., 1998; Rogers and Potter, 2004). Species tested to date represent 35 plant families but only 4 families have had more than 10 species tested (Apiaceae, Asteraceae, Fabaceae, Lamiaceae). In addition, species tested consist almost entirely of forbs, with only 8 tree, 8 shrub, and 2 vine species, respectively (Table 2).