



# Intense ranchland management tips the balance of regional and local factors affecting wetland community structure



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## ABSTRACT

Greater understanding of land management effects on species richness and composition is needed to manage biodiversity-related ecosystem services in agricultural ecosystems. Here we studied responses of vascular plants, macroinvertebrates, and ectothermic vertebrates to local and regional factors in two ranchland management intensities (semi-natural and highly-managed). Samples were collected in 40 separate wetlands embedded in the two management intensities. Based on community assembly theory, we expected a shift from regional to local-based factors as predictors of communities where local conditions become more limiting. We also expected highly managed ranchlands to most strongly “filter” community membership to become more homogeneous. Both predictions were supported though results sometimes differed among taxa. Wetland communities embedded in highly managed pastures were more homogeneous and significantly different from those in semi-natural pastures. Overall, regional factors related to propagule dispersal were most important in semi-natural pastures, and local factors (especially nutrients) were most important in highly managed pastures. However, some community metrics were consistently affected most by local or regional factors regardless of land use intensity. For instance, vegetation richness and vertebrate composition were consistently influenced by local factors, whereas macroinvertebrate composition was consistently influenced by regional factors. Based on our results, biodiversity conservation will be most effective if management efforts focus on improving local habitat conditions in highly managed areas, and on preserving regional heterogeneity in more natural areas. Taxon-specific conservation strategies should account for taxon-specific sensitivities to local and regional processes.

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## 1. Introduction

Growing demands on agricultural lands for food, fibre, and fuel are predicted to rapidly increase in coming decades with continued population growth (Bommarco et al., 2013). Agricultural land occupies 5 billion hectare of the land surface on earth and increases annually by 13 million hectare (FAO, 2002). Given that growth, a “multifunctional agriculture” approach should be applied to manage agricultural lands in order to acknowledge agriculture’s influence on ecosystem services and environmental

integrity, including habitat for native species (Robertson and Swinton, 2005; Bommarco et al., 2013; NRC, 2003; Kleijn et al., 2011). Biodiversity is often considered to indicate ecosystem services; in agricultural ecosystems, biodiversity may indicate biological control, decomposition, pollination, arthropod habitat, disease regulation, and conservation value (Bommarco et al., 2013). Biodiversity is often considered essential to the delivery and stability of ecosystem services (Naeem et al., 2012). To effectively manage for biodiversity-related ecosystem services in agricultural ecosystems, an increased understanding is required for land management effects on richness and composition of multiple taxonomic groups (Bommarco et al., 2013; Robertson and Swinton, 2005; Turtureanu et al., 2014).

Categorical agricultural land use can be a major driver of biodiversity loss (e.g., McKinney, 2006). However, agricultural land-use intensity can vary substantially *within* a category, and understanding the effects of this intensity on biodiversity is key to clarifying

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the drivers of biodiversity loss and homogenization (Foley et al., 2005). Ecology has long focused on local, deterministic drivers of community structure, and has recently expanded to include the effects of regional, dispersal-based processes on community assembly (Leibold et al., 2004; Ricklefs, 1987). Modern theory now expects community assembly mechanisms to shift from dispersal- to niche-based processes where local habitat conditions are restrictive (Chase, 2007). Thus, species that exist in restrictive local conditions are a subset of the regional pool, adapted to withstand environmental extremes, whereas benign environmental conditions permit priority effects in community assembly, resulting in greater heterogeneity among communities (Chase, 2007).

The above expectations derive from theory and experimental tests in artificial systems (e.g., Chase, 2007; Weiher et al., 2011); land use in agricultural landscapes presents an opportunity to test these hypotheses at regional scales and in a context relevant to biodiversity conservation and land management (Foley et al., 2005). For example, agricultural practices alter soil structure, nutrient levels and vegetation, which affect local conditions in embedded aquatic ecosystems and also change factors acting at regional scales such as dispersal (Boughton et al., 2010; Dickson, 1986; Rabalais et al., 2002). These changes can reduce local species richness, but also permit invasion of non-native species (Limpens et al., 2003; Hobbs and Huenneke, 1992). Moreover, taxonomic groups may respond differently to management or disturbance, so knowledge of local and regional effects on multiple taxa is important (Lawton et al., 1998; Oertli et al., 2005). For example, converting forested lands to pasture reduces dispersal by amphibians (Rothermel and Semlitsch, 2002) but may affect other taxa differently (Turtureanu et al., 2014).

Here we report on a study of 40 wetland communities embedded in an agricultural landscape used for beef production with two long-term management intensities (semi-natural and highly-managed). The study examined how land-use intensity alters local and regional predictors of community composition. The two pasture categories are known to be distinct due to decades of management and research (Boughton et al., 2010; Swain et al., 2013), and we expected highly managed pastures to impose restrictive local conditions on regional biota. The wetlands and pastures are in the northern Everglades region of Florida, where wetlands comprise nearly 15% of land area, and like many other parts of the world, ranching is the dominant land use (Foley et al., 2005). Detailed records of long-term land use for the two pasture types offered a clear context relative to uncoordinated and diverse land uses among multiple land owners. We focused on three taxonomic groups (vascular plants, macroinvertebrates, and ectothermic vertebrates) in the wetlands, and evaluated them separately and in combination. These groups were chosen since they relate to both important ecosystem services in agricultural lands as well as inherent conservation value. For example, plant diversity may indicate delivery of arthropod habitat (Letourneau et al., 2011); macroinvertebrates may indicate delivery of biological control (Letourneau et al., 2009) and decomposition (Lavelle et al., 2006), and ectothermic vertebrates may indicate pest control and food chain support (Hocking and Babbitt, 2014).

The overall hypothesis was that community assembly shifts from regional to local-based processes between semi-natural and highly managed landscapes, causing more homogeneous composition in the highly managed landscape (*sensu* Chase, 2007). Two specific predictions must be supported for the overall hypothesis to be supported: (1) wetland communities embedded in intensively-managed pastures are less diverse and more homogeneous than those in less intensively managed pastures, and (2) local factors are important to community composition with greater land-use intensity. We measured communities using three metrics: species richness, composition, and compositional similarity, where

we defined a wetland community as the total of its vegetation, macroinvertebrate, and vertebrate assemblages (Fauth et al., 1996). We expected regional, dispersal-related factors to be associated with heterogeneity between wetland communities and local, niche-related factors to be associated with homogeneity between wetland communities. Accordingly, we expected wetland communities in semi-natural pastures to best correlate with a combination of regional (dispersal-based) and local (niche-based) factors. In contrast, we expected wetland communities in highly managed pastures to best correlate with local habitat factors. We also predicted that taxonomic groups would respond differently to pasture intensification. Finally, we expected composition and heterogeneity to be more sensitive than species richness to the effects of land use given that very different assemblages may sum to the same species richness.

## 2. Materials and methods

### 2.1. Study area and sampling design

We sampled seasonal, isolated wetlands at the MacArthur Agro-Ecology Research Center (MAERC), located in south-central Florida (27°09'N, 81°11'W). The MAERC is at Buck Island Ranch, a 4170 ha commercial cattle ranch with > 600 isolated, seasonal wetlands embedded in two pasture management regimes (Fig. 1). Highly managed pastures were fertilized with NPK (nitrogen, phosphorus, potassium) from the 1960s through 1986, with nitrogen only (~52 kg ha<sup>-1</sup>) since 1987, and were limed regularly (every 3–5 y) since the 1960s. Highly managed pastures were composed primarily of introduced forage grass (*Paspalum notatum* Flueggé) and extensively ditched, and had cattle-stocking densities nearly twice that of semi-natural pastures (0.52 vs. 0.28 cow-calf pairs ha<sup>-1</sup>; Boughton et al., 2010). In contrast, semi-natural pastures were never fertilized and had a mixture of *P. notatum* and native grasses (e.g., *Andropogon* spp. L., *Axonopus* spp. P. Beauv., and *Panicum* spp. Torr.), and were less extensively ditched. We selected forty wetlands (twenty per pasture type) of similar size (0.25–0.75 ha) and shape (circular) to minimize confounding effects of wetland size, hydroperiod, and edge effects. We maximized inter-wetland distances to reduce spatial autocorrelation between replicates (Fig. 1). Wetlands were assigned to blocks, where each block consisted of eight wetlands (four highly managed and four semi-natural) and accounted for potential variation due to sampling time, location and hydroperiod (in this landscape, spatial location influences hydroperiod with minimal changes in elevation).

### 2.2. Biotic sampling

We sampled wetland vegetation at the end of the growing season during October–November 2006, when biomass peaked. We collected species presence/absence data in 1 m<sup>2</sup> circular quadrats at 15 random points (selected using ArcView 9.0, ESRI, Redlands, CA, USA) stratified by five zones in each wetland: center, northeast, northwest, southeast, and southwest. One sample point was randomly selected in each stratum and marked with a steel post for additional sampling (below). Plant species were identified using Godfrey and Wooten (1979a,b). Voucher specimens were deposited in University of Central Florida and MAERC herbariums.

We sampled aquatic macroinvertebrates in September 2006 at five stratified random points (steel posts, above). This sampling time was selected because all wetlands had contained water for at least two weeks and was in the middle of the growing season, ensuring that populations of invertebrates and vertebrates had sufficient time to emerge and mature for identification (where relevant). At each point, we conducted two, 1 m-long sweeps at

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