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Artificial wetlands and surrounding habitats provide important foraging habitat for bats in agricultural landscapes in the Western Cape, South Africa

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ABSTRACT

Agriculture and related habitat modification have been identified as globally important drivers of species loss. Habitat modification resulting from agriculture can, however, have both positive and negative consequences for animal species. The ecological trade-offs involved in agricultural development have often not been explored sufficiently well to identify mutually beneficial solutions. Bats, for example, have been strongly impacted by agriculture intensification, mainly through the destruction of forests and natural wetlands. However, artificial wetlands created primarily for irrigation in agricultural landscapes may provide foraging habitats for bats and thus contribute to both the conservation of bat species and the regulation of insect pest species. We studied the influence of artificial wetlands on bat communities in agricultural landscapes in South Africa. We used mixed models to assess spatial variations in species richness, total bat activity, and species activity across 30 landscapes. Each study site was centred on a 'focal wetland' and surrounded by various habitat categories: open habitat, vineyards, orchards and trees. Our results show a crucial role of wetlands for all bat species as well as a significant influence of wetland size and water cover on bat activity. However, we observed no significant difference in species richness and only small differences in activity levels between the 'focal wetland' and the surrounding habitats. The present study contributes to the body of literature suggesting that farm dams may act as biodiversity hotspots when properly managed. More generally, our analysis suggests that an in-depth understanding of the trade-offs between agricultural production and ecosystem integrity is important for finding mutually beneficial outcomes.

1. Introduction

Conversion of natural vegetation for agriculture has been identified as one of the primary factors contributing to the decline of biodiversity in many parts of the world (Mickleburgh et al., 2002). The most obvious implications of a loss of natural vegetation for bats include reductions in roosting, breeding and foraging habitats and a reduction in food supply. Bats are important bioindicators and may provide insight into the integrity of natural ecosystems, including those altered by intensive agriculture (Jones et al., 2009). This is especially so because bats are thought to be adversely affected by some of the practices associated with agricultural intensification (Wickramasinghe et al., 2003), including increased pesticide use (Wickramasinghe et al., 2004, but see also Pocock and Jennings, 2008). Furthermore, in tandem with increasing concern over declining bat populations, there is an increasing awareness of the value of the ecosystem services provided by bats (Kunz et al., 2011). Over two thirds of bat species are insectivores and lactating female bats may consume up to 100% of their body mass of insects each night (Kunz et al., 2011). As a result, the beneficial influence of bats on leaf damage by arthropods is stronger even than that of birds in tropical forests (Kalka et al., 2008). Recently, Boyles et al. (2011) estimated that the economic value of pest control services provided by bats for agriculture was around $74/acre ($30/ha) per year in a cotton-dominated agricultural landscape in south-central Texas.

Bats may thus serve as valuable indicators of how certain agricultural practices, such as the development of artificial wetlands, may support ecosystem functioning. Most studies on habitat use by bats in agricultural landscapes have focused on the role of forest fragments (Estrada and Coates-Estrada, 2002; Ethier and Fahrig, 2011) or other forms of tree cover retained in agricultural

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landscapes (Harvey et al., 2006). In agricultural landscapes where fewer trees remain, research has focused on the role of linear features such as hedgerows and tree lines (Walsh and Harris, 1996) or scattered trees (Lumsden and Bennett, 2005). These studies often recommend maintaining more tree cover in agricultural landscapes. However, giving arable land over to trees is not always either possible or desirable (Burton et al., 2008). In other cases, crops have themselves been shown to provide foraging habitats for some bats, such as vineyards for pallid bats (*Antrozous pallidus*) (Rambaldini and Brigham, 2011), olive groves for Mediterranean horseshoe bats (*Rhinolophus euryale*) (Russo et al., 2002), cotton fields for Brazilian free-tailed bats (*Tadarida brasiliensis*) (Cleveland et al., 2006), and cacao and banana agroforestry systems for Costa Rican bat assemblages (Harvey and González Villalobos, 2007). In agricultural landscapes, natural water points (Ciechanowski, 2002) and riparian vegetation (Medina et al., 2007) are thought to be important for bats. Indeed, many bat species are known to use the edges of aquatic ecosystems as foraging habitats (Vaughan et al., 1997). However, natural wetlands have dramatically decreased in many parts of the world (e.g. An et al., 2007; Davis and Froend, 1999; Turner, 1997). As a result, there is a growing interest in the role of artificial wetlands, which are often common in human-modified landscapes, for biodiversity conservation (e.g. Gioria et al., 2010; Williams et al., 2004). The influence of these artificial wetlands on bat diversity provides an interesting example of how agricultural impacts may be partially mitigated by habitat manipulation.

Artificial wetlands have the potential to both provide foraging habitat for bats (Stahlschmidt et al., 2012) and increase connectivity between foraging habitats (Lookingbill et al., 2010), hence to increase bat activity in surrounding habitats. Several studies have assessed the relevance of artificial wetlands for bats (e.g. Lison and Calvo, 2011; Rebelo and Rainho, 2009; Downs and Racey, 2006), but few have studied bat activity concomitantly at artificial wetlands and in surrounding agricultural areas (e.g. Stahlschmidt et al., 2012) as an indication of the extent of the influence of these wetlands on the ecosystem.

We examined the influence of artificial wetlands and surrounding habitats on the activity of bats in the Cape Floristic Region, South Africa. This region has been heavily transformed through cultivation, urbanization and invasive species. Agriculture is the major agent of habitat transformation, with an average of 25.9% of land area converted for intensive agriculture (including commercial forestry plantations) and some habitat types have been converted by up to 80% (Rouget et al., 2003). Moreover, a further 15–32% of untransformed land is likely to be transformed during the next 10–20 years (Rouget et al., 2003) and much of it is likely to be used for the development of wind energy.

The aim of our study was to assess the impact of artificial wetlands, and the representation of different habitats in the surrounding agricultural area, on ecosystem integrity using bat diversity and abundance as indicators. We predicted that (1) bat diversity and activity would be highest at wetlands and in habitats with a complex vertical structure, and lowest over dry, open habitats; and (2) bat diversity and activity would increase with wetland size, both at the wetland and in the surrounding habitats.

2. Materials and methods

2.1. Study area

The study area was located in the western part of the Cape Floristic Region in South Africa (Fig. 1). The Cape Floristic Region constitutes one of the six world biodiversity hotspots (Myers et al., 2000). It is a Mediterranean vegetation type characterized by shrubby natural vegetation (mainly Fynbos and Renosterveld) and few native trees. However, this region has been heavily modified by human activities which have resulted in a heterogeneous region comprised of sandy plains intensively farmed on the west coast, inland undulating hills extensively farmed, and unfarmed, rugged sandstone mountain ranges that rise abruptly as high as 2000 m, separated by fertile valleys. The rainfall ranges from 200 mm annually along the western sandy plains to 3600 mm on some of the higher mountains. Natural wetlands occurring in this region include riparian wetlands, floodplain wetlands, pans and estuaries and are mainly distributed in the coastal plains. Their level varies between winter (rainy season) and summer when some wetlands become completely dry. Natural wetlands have been affected by agriculture, urbanization and erosion, with more than 50% of the extent of existing natural wetlands having been lost in our study area (Kotze et al., 1995). Artificial wetlands, also called farm dams or stock ponds, are very common in this entire area. There are more than 4000 farm ponds in the Western Cape, with a cumulative storage capacity in excess of 100×10^6 m^3 (Adams, 1993). Cape Town is the biggest city in the study area, with a total population of more than 3 million (Rouget et al., 2003). As a result, there is a gradient of urbanization from Cape Town in the Southwest of the Province (1400 inhabitants per km^2) to the North and East (3 inhabitants per km^2).

2.2. Site selection

We selected 30 study landscapes located in different parts of the Western Cape across the gradient of agricultural contexts, from intensive wheat fields on the sandy plains to mixed agriculture in the valleys and isolated farms in the mountain ranges. We selected pairs of landscapes located in 15 areas (Fig. 1) to facilitate the sampling of two landscapes during the same night and thus minimize the potential bias of weather on bat activity. The two landscapes were located in the same area but separated by around 5 km to minimize spatial correlation in the dataset. Each landscape was centred on a 'focal wetland'. These wetlands were selected to cover the entire range of wetland sizes found in the study area. As a result, the size of focal wetlands varied from 0.07 to 172 ha. The riparian vegetation of these wetlands was characterized by continuous grass cover and reeds with a limited number of trees. The decrease of water levels throughout summer created increasing areas of bare ground between the riparian vegetation and the water. Only 3 of the 30 wetlands selected were associated with cattle trampling, but always affecting a limited section of the riparian vegetation. In each of the 30 landscapes, we selected three sampling points: (1) the 'focal wetland' and (2 and 3) two patches with contrasting habitat structures in the vicinity of the wetland. Habitats included grassland, crops (wheat, alfalfa), vineyard (usually grown in 2 m-high well-structured rows), trees (mostly lines of pine trees or small tree stands), orchards or reeds.

2.3. Bat surveys

Insectivorous bat communities were surveyed at the 90 sampling points (i.e., 30 landscapes $\times$ 3 sampling points per landscape) between November 2010 and April 2011, the summer period in the southern hemisphere. Surveys were restricted to warm nights without wind or rain. At each sampling point we positioned one bat detector (Pettersson D240; Pettersson Elektronik, Uppsala, Sweden) protected in a plastic box placed on top of a pole at a height of about 1.75 m. Each detector was set up in time expansion mode and connected to a Roland Edirol R-09 digital recorder. The threshold influencing the recording range was set to a fixed sensitivity (trigger level set to the position 'high'), which corresponds to a recording radius of about 16 m (Sprong et al., 2012) for most bat