Biological Conservation 165 (2013) 198–202

Contents lists available at SciVerse ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Short communication

Mice on the move: Wheat rows as a means to increase permeability in agricultural landscapes

Giulia Sozio [a,*], Alessio Mortelliti [a,b], Luigi Boitani [a]

[a] Department of Biology & Biotechnology "Charles Darwin", University of Rome "La Sapienza", Viale dell'Università 32, 00185 Rome, Italy
[b] Fenner School of Environment and Society, Australian Research Council Centre for Environmental Decisions, National Environmental Research Program, The Australian National University, Canberra, ACT 0200, Australia

ARTICLE INFO

Article history:
Received 27 October 2012
Received in revised form 8 May 2013
Accepted 26 May 2013
Available online 29 June 2013

Keywords:
Agricultural matrix
Dispersal
Fragmented landscape
Perceptual range
Plantation rows

ABSTRACT

A crucial factor in determining the persistence of animal populations in fragmented landscapes is the individual's ability to move through a hostile man-made environment (the agricultural matrix). Previous studies suggested appropriate orientation of manioc plantation rows as a possible means to facilitate animal movements and to increase landscape functional connectivity.

The goal of our work was to broaden our understanding of plantation rows as a means to increase permeability in cereal-crop-dominated landscapes. In particular, we focused on (a) analyzing animals' ability to localize and move towards habitat fragments in different matrix types (i.e. their perceptual ranges) and (b) testing whether the orientation of wheat rows acted as dispersal route during three stages of the wheat plant maturation.

We carried out release experiments in an agricultural landscape of central Italy on three species of rodents: two forest specialists (*Apodemus flavicollis* and *Myodes glareolus*) and a habitat generalist (*Apodemus sylvaticus*). We released individuals in three matrix types (a bare field, a grass field and a wheat field at three maturation stages) and followed their movements. We found that (a) perceptual ranges were species- and matrix-specific, (b) individuals followed plantation rows when moving through the matrix at any stage of wheat growth, including recently planted wheat, (c) in the grass field individuals did not follow any preferential direction. These results provide strong empirical evidence that wheat plantation rows should be planted orientated between habitat patches and should be considered as a complementary conservation strategy to increase connectivity in agricultural landscapes.

1. Introduction

In fragmented landscapes many populations of forest-species are confined in extinction-prone residual forest fragments more or less connected by dispersing individuals. A crucial factor in determining the persistence of these populations is the individual's ability to move through a sub-optimal and often hostile man-made environment (the agricultural matrix). A high dispersal ability, for example, may allow a species to re-colonize fragments or maintain high immigration rates in structurally isolated patches. The dispersal ability of a species depends, among other factors, on its orientation skills, such as its perceptual range (Prevedello and Vieira, 2010) which is defined as the maximum distance at which an animal can perceive the surrounding landscape elements, i.e. a woodland patch (Zollner and Lima, 1997). A higher perceptual range can increase the ability of an individual to detect a habitat fragment and to move directly towards it, reducing time spent in the hostile matrix, where the survival probability is lower (Zollner and Lima, 2005). The perceptual range is not only a species-specific characteristic, it is also highly dependent on the environmental context (Prevedello et al., 2010). The type of matrix or the environmental conditions during dispersal have a strong influence on animals' ability to perceive habitat fragments. Perceptual range is higher in the presence of wind (e.g. for species orienting with smell), or in the presence of moonlight and in a matrix that does not obstruct the view (e.g. for visually oriented species) (Zollner and Lima, 1997; Prevedello et al., 2011).

Although conservation actions are predominantly targeted towards increasing habitat structural connectivity, matrix management is important because (1) even strictly forest species cross the agricultural matrix (e.g. Mortelliti et al., 2013), (2) habitat oriented conservation actions are expensive, therefore matrix management may often be the only feasible conservation action. From this perspective, a long-standing question in conservation ecology is: what makes a matrix more permeable to animal movements?

To date, many studies have demonstrated that animal species have different ways to orient and guide their movements in known

---

[*] Corresponding author. Tel.: +39 06 49694218.
E-mail address: giulia.sozio@uniroma1.it (G. Sozio).

0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.05.022

or unfamiliar areas, such as magnetoreception (Wiltschko and Wiltschko, 2005) or use of visual landmarks (Lipp et al., 2004). As demonstrated by Prevedello and Vieira (2010) forest marsupials tended to follow manioc plantation rows during their movements through the matrix, suggesting appropriate orientation of cultivation rows as a possible means to increase functional connectivity between habitat fragments.

The study by Prevedello and Vieira (2010) was carried out in manioc (*Manihot esculenta*) plantations on relatively large marsupial species. While manioc is an important crop in tropical habitats (3.4×10^6 ha globally; FAO, 2012), cereal cultivations (e.g. wheat *Triticum* sp.) are the most important crop in more temperate or dry environments (2.2×10^8 ha of wheat plantations globally in 2010; FAO, 2012).

The goal of our work was to broaden our understanding of plantation rows as navigation cues in agricultural landscapes. We focused on testing whether the orientation of wheat rows acts as a dispersal route during three stages of the wheat plant maturation. Such aspect is not trivial: while manioc has long pre-harvesting periods (up to 1 year and over), on the opposite wheat is normally harvested 110–130 days after sowing. The longer animals use plantation rows as navigation routes, the more likely their use will coincide with dispersal events.

We chose as model species two forest rodents (*Apodemus flavicollis* and *Myodes glareolus*) and a habitat generalist (*Apodemus sylvaticus*), which are characterized by different degrees of dispersal ability (Marsh and Harris, 2000; Mortelliti et al., 2009).

Our experimental design followed three conceptual phases:

(1). Determination of the perceptual range of model species in different matrix types.
(2). Test on the influence of wheat plantation rows on animal movement (hypothesis: animals will follow plantation lines as navigation cues).
(3). Control test in a grass field (hypothesis: due to obstructed view combined with lack of orientation pattern in grass vegetation, animals will not follow any preferential direction).

2. Materials and methods

2.1. Study area

The study was carried out in central Italy (see KML file) from March to June 2012 in an agricultural landscape with residual mixed oak (*Quercus* sp.) forest fragments (residual wood cover <10%; agricultural fields cover >80%) (see Figs. A1 and A2 for some pictures of the study area). The majority of fields are conventionally managed and cultivated with cereals, especially wheat. A small proportion of fields are periodically left uncultivated. Spring wheat is sown in February–March and harvested in July, when it reaches its maximum height (about 120 cm).

Experiments were carried out in a bare field, a grass field and a wheat field at three maturation stages (20 cm, 60 cm and 120 cm in height). All the studied fields were characterized by completely flat terrain. Wheat plants were cultivated along rows spaced approximately 20 cm. Within the same line, plants were closer (1.5–2 cm) but distant enough not to create a barrier for small rodents, which could easily pass through lines in any direction (as testified by the multiple crossings observed during a pilot experiment, Sozio pers. obs.). In the grass field the distribution of herbaceous plants did not follow any regular pattern.

2.2. Experimental protocol and data collection

Our experiments consisted in releasing individuals (*A. flavicollis*, *A. sylvaticus*, *M. glareolus*) in the fields in order to observe their movements through the matrix. We assumed that when released in an hostile open matrix, individuals would go toward the wood as soon as possible, with their movements and orientation revealing their ability to perceive it (Zollner and Lima, 1997). We considered this assumption valid also for the habitat generalist *A. sylvaticus*, which is known to prefer woodland habitat due to predation risk in open environment (Tattersal et al., 2001; Amori et al., 2008).

We first released individuals in the bare field (March) at progressive distances from the target habitat patch (20 m, 40 m and 100 m; Table 1) and in a wheat field at three maturation stages (respectively in March, May and June; see Fig. A3 for an example). At the earlier maturation stage we released individuals at 40 m of distance from the wood; since none of the species perceived the wood at this distance (see Results paragraph), in the following (more obstructed) maturation stages we reduced distances to 20 m in order to detect a possibly lower perceptual range. In the case of *A. flavicollis*, in the intermediate wheat field we were able to extend the experiment at the distance of 10 m (Table 1). We also released individuals in the grass field (May; 60 cm in height) at 20 m of distance from the wood. For *A. flavicollis* we extended the experiment at the distance of 10 m (Table 1).

In order to vary the direction of the wheat plantation rows relative to the edge of the wood and the position of the target woods relative to the release points, we used two different sides of the fields adjacent to different habitat patches.

We used Sherman and Longworth traps to capture individuals. In order to avoid homing behavior (Zollner and Lima, 1997), animals were captured in forest fragments distant more than 13 km from the release landscape. The landscape where species were captured was similar to that of release in terms of agricultural matrix composition, type and cover of residual forest fragments. Only healthy looking adult and sub-adult (following Gurnell and Flowerdew, 2006) individuals were used for the experiment. Field determination of the two *Apodemus* species was confirmed through molecular analysis.

Individuals were kept in cages and fed for a maximum of 72 h before being released; each individual was released only once. We used a release mechanism and procedure designed to reduce the observer-induced disturbance on animals' behavior (see Online Appendix for details). Immediately before being released, animals were marked with fluorescent powders of different colors (pigments F002, F008, F016, F019 Abralux Colori Beghè srl, Italy; Figs. A4 and A5). Experiments were carried out during night time with moonlight (moon phase between 70% and 100%) in order to maximize perceptual ability of the individuals, avoiding windy and cloudy nights in order to reduce confounding factors (Prevedello et al., 2011). Individuals released in the same night were spaced along the edge of the wood at least 50 m from the others in order to reduce possible intersection of their trajectories.

Few hours after the release we tracked animal routes by illuminating powder fallen from each individual with ultra-violet light (Fig. A6), in accordance with standard procedures (Zollner and Lima, 1997). We followed tracks until no additional powder was detected or until the reaching of the wood. Individual paths were recorded through GPS devices.

2.3. Data analysis

Unlike other authors (e.g. Prevedello et al., 2011), who often analyze only the first few meters of each path to determine the initial orientation of individuals, we chose to analyze entire paths in order to understand if, when released at certain fixed distances, individuals were likely to reach the wood or not. Therefore we subdivided each individual route in segments (at least 1 m long) and then we calculated weighted mean vectors of each route, with