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Applying indicators of disturbance from plant ecology to vertebrates: The hemeroby of bird species

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ABSTRACT

In plant ecology, hemeroby is a widely used indicator reflecting the anthropogenic disturbance level of a habitat. It is scaled on a range of point scores, higher scores of hemeroby meaning higher level of disturbance. In this study two indicators of sensitivity to disturbance based on the habitat preferences of bird species were used: HS (mean hemeroby score), calculated on the habitat types where each species occurs, and HH (mean hemerobiotic habitat diversity), indicating the level of a species generalism with respect to the range of disturbance levels characterizing the habitat where it occurs. Although already known in plant ecology, HS, so far, has never been applied to a group of vertebrates, while HH is a newly proposed index based on Shannon diversity. Both indexes are based on species position and range, along a gradient of disturbance, from pristine to completely man-made habitats. Drawing from a recently published atlas of bird species, it was possible to calculate the ecological preferences for a large number of habitat types in 75 common breeding bird species found in Latium (Central Italy). For each habitat, the average level of disturbance (based on hemeroby) within a 5-point scale was assessed. From the occurrences of birds in each habitat, HS (averaged disturbance calculated on the habitat types where each species occurs) and HH (the level of a species generalism with respect to the range of disturbance levels characterizing the habitats where it occurs) were calculated. The distribution of bird species number along the gradient showed a pattern of intermediate disturbance. Two different trends were found when analyzing the relationship between HS and HH: (i) a hump-shaped curve peaking at intermediate levels of HS, suggesting that generalism (HH) is maximum at intermediate levels of disturbance, and (ii) a second linear relationship pointing to a decrease of HH with increasing HS for a sub-set of synanthropic species (i.e., species linked to man-made habitats). The latter developed a further arm on the right of the hump-shaped curve: synanthropic species occurred only at higher levels of disturbance, and showed an increasing specialization with increasing levels of disturbance. Such a distribution was confirmed by analysing other data sets obtained from a real case study: the fraction of species with low values of HS sharply decreased from forest to urban habitats, while the fraction with high values increased; species with mid values of HS showed a maximum in crop-lands. HS and HH indexes are promising tools both in theoretical study and in practice, e.g. in management and monitoring of vertebrate communities.

1. Introduction

Animal species have a specific disturbance sensitivity in relation to their natural history, ecology and other context-specific conditions and circumstances (Sousa, 1984). Recent advances in the application of species-specific ecological traits have provided a new approach for studying the response to disturbances since some of those traits may be considered strong predictors of disturbance sensitivity (Mouillot et al., 2013). In particular, habitat specialization has been considered an important species trait (Julliard et al., 2006; Katayama et al., 2014) and specialized species may show a different response to disturbances occurring in a site when compared to ecological generalists (Wiens, 1989; Reifa et al., 2013). The level of habitat specialization (or, its opposite, generalism) may explain the species coexistence and diversity in a community, as suggested by the intermediate disturbance hypothesis (Connell, 1978; Huston, 1994; Crandall et al., 2003; Barnagaud et al., 2011). According to this model, the effect of disturbance on a community depends on its regime, i.e. its intensity or frequency (Sousa,

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1984). Communities where disturbances have low intensity or frequency tend to be relatively stable and dominated by more competitive species while communities where disturbances have high intensity or frequency tend to be instable and dominated by species that are less competitive but more adapted to dynamic environments. In conditions of intermediate levels of disturbance, communities should be structured with a mix of less and more competitive species in stable ecosystems together with specialist of more dynamic habitats (Wilson, 1994; McCabe and Gotelli, 2000).

Birds represent the richest class of terrestrial vertebrates, which includes a large number of species inhabiting different habitat types (Wiens, 1989). Bird species range from strictly specialized (linked to only one or few habitat types) to broad generalist, i.e. species that use a very high number of habitat types (Wiens, 1989). Moreover, bird species show different levels of adaptation and response to natural and anthropogenic disturbances (Brawn et al., 2001). According to White (1979), Pickett and White (1984) and Sousa (1984), a disturbance is a physical, chemical or biological event, with a different frequency degree, causing an alteration or damage to one or more individuals and directly or indirectly creating an opportunity for other individuals. Therefore, among birds, we may define both disturbance-tolerant or disturbance-enhanced species and disturbance-sensitive ones (Brawn et al., 2001). An extreme is represented by a few species that show a marked preference for human-made ecosystems (such species are named ‘synathropic’: Marzluff et al., 2001).

The sensitivity level of bird species to disturbance may be indirectly expressed by the relationship between species and vegetation types: from species restricted to pristine habitats (i.e., less disturbed in terms of intensity or frequency) to synanthropic species, which prefer heavily human-transformed habitats (i.e., with a high level of intensity or frequency of disturbance). Although the nature of this relationship between species, habitat and disturbance is widely recognized (e.g., Hildén, 1965; Cody, 1985; Carignan and Villard, 2002; Gregory et al., 2005; Devictor et al., 2008a), to our knowledge what is still apparently lacking is an explicit their quantification for birds and other animals. The situation is different in plant ecology, where a long tradition has established a close link between disturbance levels and species distribution, and a quantification of tolerance to disturbance has been realized drawing on the concept of hemeroby (Van der Maarel, 1975; Steinhardt et al., 1999; Hill et al., 2002; Walz and Stein, 2014).

Hemeroby is defined as the sum of disturbance effects on the current ecological components (Steinhardt et al., 1999), and can easily be determined when assessing the species composition of any habitat type (Fanelli et al., 2005). It was originally developed in the context of the rural-urban gradient, from natural to completely human-made habitats (McDonnel and Pickett, 1990; Kowarik, 1988; Walz and Stein, 2014). Hemeroby is the inverse of naturalness (Angermeier, 2000; Winter, 2012). More particularly, naturalness measures the distance from a pristine natural situation (Angermeier, 2000), whereas hemeroby measures the degree of disturbance. A few habitats are naturally disturbed (screes, flooded river banks, vegetation subjected to natural fires, naturally grazed vegetation) and therefore are highly natural but with some degree of disturbance (Schleupner and Schneider, 2013). Hemeroby is frequently employed in the assessment of disturbance in different types of vegetation, in particular in Central Europe (Lindacher, 1995; Grabherr et al., 1998; Steinhardt et al., 1999; Acosta et al., 2002; Hill et al., 2002; Testi et al., 2009; Schleupner and Schneider, 2013; Mayrhofer et al., 2015), and large databases of hemeroby scores for plants exist, for example in Italy (Fanelli et al., 2005; Fanelli and Battisti, 2014). However, to our knowledge this concept has rarely been tested in animals (e.g., Dennis et al., 2004; Schleupner and Link, 2008).

At least in Europe, large spatially related data sets are available (e.g., atlases and breeding bird surveys at a regional/national scale starting from Sharrock, 1976 and Lack, 1986). They represent an important and useful tool in obtaining data both on species distribution and their local ecology (e.g., Devictor et al., 2008b; Devictor and Robert, 2009; Belmaker et al., 2012). Atlases constitute a source of many types of species-related information, among which habitat, altitude, season and sites of individual occurrence. Such tools are very useful in obtaining information about the context-specific habitat preferences of a large set of species for a specific geographical study area. Thanks to atlases and other studies, habitat use in a large array of different species is now well known. Therefore, it is possible to locate each species along a coarse-grained habitat specialism–generalism gradient and along a gradient of species response to anthropogenic disturbance (Canterbury et al., 2000; Crooks et al., 2004; Julliard et al., 2006).

In this paper, drawing on a large data-set of breeding bird species collected in a region of Central Italy, the approaches of bird and plant ecology were merged in such a way that the information on suitable habitat types for birds contained in an atlas was linked to the related hemeroby of their habitats. In other words, we were able to assess the level of disturbance to which each bird species is adapted from the level of disturbance of the vegetation type where such a species occurs. Common birds species were characterized according to two parameters: the mean hemeroby score (HS), obtained from their occurrence in different habitat types, and the level of their generalism/specialization obtained from hemerobiotic habitat diversity (HH). With the help of these two indexes, each species can be located along two gradients, a gradient of disturbance (from low hemeroby to high hemeroby, expressed as HS) and a gradient of generalism towards the disturbance, i.e. from species which are highly generalist when subjected to a disturbance to specialized ones (expressed as HH). Furthermore, we discuss the implications of resulted patterns of species in a HS/HH comparison in the light of more general theory of intermediate disturbance hypothesis (Connell, 1978). Finally we applied such indices to a case study.

2. Methods

2.1. Study area

In this study, a large data-set of breeding bird species found in the Latium region (central Italy) was reviewed. This geographic region covers an area of c. 17,000 km^2 with a population of about 5,100,000 people and a mean population density of 297 inhabitants per km^2. The study area extends from the Apennines to the Tyrrhenian Sea and is characterized by a high level of habitat diversity, with mountains (26%), hills (54%), and alluvial lowlands (20%; Regione Lazio, 2000, 2004).

2.2. Protocol

A total of 186 species breed in Latium, central Italy (Brunelli et al., 2011). Among them, only the common ones were considered (with more than 100 independent records totally obtained and with more than 20 square units where they occur; n = 75 “common” species). We did not include rare species, because their ecology may be strongly affected by casual factors and bias in observer efficiency, a known weakness in atlas studies (see Sutherland, 2006). Taxonomic nomenclature followed Clements (2000).

For each common species, we checked the habitat types reported in the atlas. These habitat types correspond to a set of coarse-grained vegetation types. Since bird atlases use land use maps as layers to built the species maps, in these reviews the