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Food availability and flight routes for migratory birds: a GIS approach

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ABSTRACT

Bird migration is a wide studied phenomenon but still many factors that influence migratory flows remain unknown or poorly understood. Food availability en route is particularly important for many species and can affect their migration success, pattern and timing but this relationship have not been addressed at wide scale due to the lack of spatial models of food availability on the terrain.The aim of this work is to fill this gap with a GIS-database approach that links together spatial and non-spatial information in order to map and measure food availability in the different periods of the year in the SE Alps, an important node of European migratory routes. We created a unique database that contains information on the presence and periods of fructification of 52 wild plants carrying berries and a series of original cartographic themes. With this approach we were able to identify various flyways and compare them with known stopover sites, ringing stations and food availability using a mix of techniques of statistical geostatistical and interpretation of ecological data.

Keywords: food availability, forest types, wild berries, 3d visibility, bird migration, kernel, GRASS GIS, QGIS, R-statistics, Open source

BACKGROUND

Bird migration is one of the most extraordinary natural phenomena that has always fascinated humans and stimulated researchers curiosity. Even if migration is increasingly studied, many factors that influence migratory flows and routes still remain unknown or poorly understood (Bairlein, 2003, 2008). Different works studied migration paths and birds features taking into account various parameters (Chevallier et al., 2010; Vilkov, 2013; Bauer et al., 2010). The relation between migration paths and trophic availability en route is particularly difficult to study, since it is not so easy to model food availability on the terrain (Drent et al., 2006; Ma et al., 2005; Moore and Woodrey, 1999; Gyimóthy et al., 2011). Finding food during the migration route is extremely important for many migratory species and can affect their migration success, pattern and timing (Drent et al., 2006; Newton, 2006; Vilkov, 2013).

In recent years some trials have been performed to study this complicated issue. Wade and Hickey (2008) used a combination of satellite imagery processing that were statistically compared with data collected in the field, mapped according to locations of birds'preferred food in an aquatic environment, with the aim to prioritize research and conservation efforts in these areas. Mudrzynski and Norment (2013) studied the influence of habitat structure and fruit availability on use of a northeastern stopover site by fall songbirds, with the aim to understand if the successional stages of forest affect birds food's availability.

In Europe, birds migrate in autumn from central or northern Europe towards southern African wintering areas (post-nuptial migration) while in spring, the species come back towards reproduction and nesting areas (pre-nuptial migration) (Berthold, 2001). During this periodic mass movements between Europe and Africa many species of birds must face a long journey encountering threats and obstacles represented by geographic barriers like the Alps, the Mediterranean Sea and Sahara Desert. During spring migration many individuals, driven by reproductive instinct, pass through the Alps following a shorter route than circumventing the same mountain chain. However, this choice requests more energy since the birds must fly at higher elevations to overtake the mountains. For many birds spring and autumn migration routes can be different and during the travel toward wintering areas they can actually circumvent the Alpine chain. Nevertheless, many birds pass through the Alps also during autumn migration and researchers are trying to understand the reasons (Bruderer and Jenni, 1988). Trophic availability in the Alpine area seems to play a fundamental role in this migratory route (Bruderer and Jenni, 1990). Alpine valleys are relatively more natural than the surrounding European plains, that are interested by extensive agriculture and urbanization. The seasonal availability of fruits and berries is one of the main resources for those passerines that become mainly frugivorous during migration, but the information about this food source is not available at large scale.

AIM OF THE WORK

The aim of this work is to fill this gap with a GIS-database approach that links together spatial and non-spatial information in order to map and measure food availability in the different periods of the year in the SE Alps, an important node of European migratory routes. We propose a new method to link non-spatial data about plant phenology with spatial open maps of vegetation and 3D visibility analysis as a starting point to deepen the knowledge of the bonds between migration and environment. The literature examination shows that the topic is extremely hot but very few studies have explored a complex approach like the one we followed in this work (Berthold, 2001; Bauer et al., 2010; Bairlein, 2008; Chevallier et al., 2010). We used open source tools for all the research process, from data analysis to editing (GRASS GIS (GRASS Development Team, 2008), QGIS (Quantum GIS Development Team, 2011), R (R Development Core Team, 2005), LaTeX, LibreOffice) and open data available from open geo-portals ([1], [2], [3] Jarvis et al. (2008)).

The main goals of this study are:

- Assessment of the suitability of habitat for stopover and transit migration based on the availability of trophic edible fruits in the late summer and autumn obtained creating coverage and richness maps for species that produce berries;
- Analysis of the most suitable habitat that support migration and in particular:

  Identification of potential routes through three-dimensional GIS analysis: evaluation of the visibility of the routes in the topography;

Evaluation of the shortest path and with less variation in altitude along the main migration routes identified by previous studies;

- Spatial analysis of food rich area with known stopover sites and the above identified routes.

MATERIALS AND METHODS

The study area, south-eastern Alps, is interested by different migration routes of many bird species, since 1997 several ringing stations have been recording the bird passage in the frame of "Progetto Alpi" carried out by "ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale and MUSE Museo delle Scienze di Trento" (Pedrini et al., 2008).

A list of 52 vegetation species that are commonly eaten by migratory birds was produced with the aid of vegetation specialists and compared with the the standard dominance classification proposed by Blanquet of these species in forest type catalogue (Odasso, 2002). Braun Blanquet scale is a recognized international standard for floristic and vegetation inventories Van Der Maarel (1975). A list of the periods of fruiting and permanence of the berries on the plants was obtained from the literature and expert advises. We linked this information with the Forest type maps and checked it against a vector map of the plant species in Trentino (kindly provided by Filippo Prosser Museo Civico di Rovereto) with more than 52000 geo-referenced points collected in the field from 1993 to 2008.

RESULTS AND DISCUSSION

For 41 species of plants cover percent was available in each of the forest types of Trentino, for the remaining species was tested and validated a geo-statistical method to model cover using point data from field sampling based on Gaussian KernelXie and Yan (2008). This method was used to calculate the cover of the 11 species that were not present in the forest type catalog, because the results for the 41 test species had a Kappa of 80 % when compared to Forest types catalog (considered the ground truth). We aggregated the results in the following raster maps: monthly percent cover of fruiting plants, monthly specific richness and total specific richness.

Besides the nutritional needs, migration is affected by other factors such as weather conditions, the place of origin and destination as well as the visibility, especially in the alpine environment. With the aid of GRASS GIS modules we tested whether there are routes along which birds can see at greater distances, and if there are visible stopover places. The hypothesis is that the migratory birds tend to choose those paths implying a lower energy expenditure, thus preferably moving along the direction in which they see fewer obstacles, specifically very high mountains, and maintaining a relatively low flight altitude.

With this approach we were able to identify various flyways and compare them with known stopover sites, ringing stations and food availability.

The results obtained on the assessment of the temporal and spatial trophic availability are useful not only for the migrants but also for other species, as well as a starting point for further studies and to support decision-making processes in environmental planning. An innovative aspect of the presented results is the synthesis of all knowledge available in the area through mixed techniques of statistical geostatistical and interpretation of ecological data. This has created a unique database

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that contains information on the presence and periods of fruitification of 52 species and a series of original cartographic themes.

CONCLUSIONS

The methodology allows the repeatability of the method for other species, and in particular shows a good correspondence between the percentages of coverage expected and those obtained from the processing of the floristic point sampling which has allowed us to harmonize various type of data.

Maps downloaded from:

1. Regione Veneto

   https://www.regione.veneto.it/web/agricoltura-e-foreste/banche-dati-cartografiche

2. Provincia di Brescia
   http://sit.provincia.brescia.it/tipi_forestali

3. Provincia di Trento
   http://www.territorio.provincia.tn.it/portal/portale_geocartografico_trentino/254

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