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Pattern of richness, abundance and diversity of four interior bird species in a hilly landscape in Central Italy: a contribution to assess their sensitivity to habitat fragmentation.

Roberto Bianconi (*), Corrado Battisti (**) & Marzio Zapparoli (*)

(*) Dipartimento di Protezione delle Piante, Università della Tuscia, Via San Camillo de Lellis, 01100 Viterbo, Italy
(**) Servizio Ambiente, Ufficio Conservazione Natura, Provincia di Roma, Via Tiburtina 691, 00159 Roma, Italy, E-mail: cbattisti@inwind.it
(**) Corresponding Author

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Abstract

The patterns of richness and abundance of four forest interior bird species (*Picus viridis, Picoides major, Sitta europaea*, *Garrulus glandarius*), known as sensitive to habitat fragmentation, have been investigated in 12 fragment and 3 large forest sites in a mosaic landscape of Central Italy using the line transect method. Fragment area and their isolation affected in different ways the patterns of richness and abundance of the studied species, except for *Picus viridis*. Tree mean diameter in the fragments does not seem to explain the general patterns of the interior species in the study area, even though the uneven aged forest stand management of the fragment might, at least locally, sustain the presence of the species. Probably, the populations of the selected species may show a "patchy structure" in the study area and forest fragments could be functionally acting as stepping stones for local dynamics of individuals at landscape scale. These preliminary results seem to confirm partially previously published data on these forest interior species (poor disperser, area-, isolation- and habitat quality-sensitive). Studied species (particularly, *Sitta europaea* and *Garrulus glandarius*) may be proposed as "target/indicator" of fragmentation process, at least in the hilly fragmented landscape mosaics of Central Italy. Although, abundance of individual target species could be affected by stochasticity if referred to small sample of forest fragment, total abundance of these species may be a useful dependent variable able to give rapid quantitative information for landscape planning strategies at local scale (*e.g.* selection of nature reserves, Gap analysis, ecological network planning).

Introduction

Anthropogenic habitat fragmentation is among the main threats to biological diversity and is considered a factor responsible for the extinction of many animal and plant species (Ambuel & Temple, 1983; Fahrig, 1997; Bennett, 1999; Soulé & Orians, 2001). It acts in a complex way altering processes at all ecological levels and at different spatial and temporal scales (Noss, 1992).

At the community level, following habitat fragmentation, the species with restricted habitat requirements tend to decrease first, and to become extinct eventually, whilst generalist species, linked to the edge environment, increase (edge species; Bellamy *et al.*, 1996). The effect of habitat fragmentation has been recorded for amphibians (*e.g.*, Caughley & Gall, 1985; Laan & Verboom, 1990), reptiles (*e.g.*, Kitchener & How, 1982; Caughley & Gall, 1985), birds (*e.g.*, Galli *et al.*, 1976; Kitchener *et al.*, 1982; Ambuel & Temple, 1983; Opdam *et al.*, 1984; Blake & Karr, 1987; McCollin, 1993), mammals (*e.g.*, Kitchener *et al.*, 1980; Suckling, 1982; Bennett, 1987; Laurance, 1990; Bright, 1993), as well as in some arthropoda (*e.g.*, Shreeve & Mason, 1980; Thomas *et al.*, 2000).

At the species/population level the sensitivity to habitat fragmentation and to perimeter/area ratio has been recorded especially in interior species (Wilcove *et al.*, 1986) as well as in stenoecious, sedentary and poor disperser species or those with naturally low population densities (*e.g.*, Kareiva & Wennergren, 1995).

Among these sensitive species some could be chosen as indicators or surrogates of biodiversity and play a role in the elaboration of planning for nature conservation strategies (see Henle *et al.*, 2004). Such species, defined as "target" (Soulé, 1991), may reflect the status of a complex ecological system and provide information on the effects of fragmentation in different geographical contexts and for specific ecosystem type (Soulé & Orians, 2001). However, such species should be chosen to represent as much as possible a large number of ecologically related species (role of indicator). Moreover, in this sense they should be relatively widespread in the study area and easily evaluated for their abundance and local distribution patterns (Pearson, 1995).

In European forest ecosystems, some land bird species belonging to Piciformes or Passeriformes are very sensitive to habitat fragmentation. Although in different ways, mature wood species such as Green Woodpecker (*Picus viridis*), Great Spotted Woodpecker (*Picoides major*), Nuthatch (*Sitta europaea*), Jay (*Garrulus glandarius*) are considered as interior species as well as habitat specialist, poor dispersers, isolation- and fragmentation- sensitive, and sensitive to the vegetational structure (Moore & Hooper, 1975; Cieslak, 1985; Opdam *et al.*, 1985; Møller, 1987; Wiens, 1994; Hinsley *et al.*, 1995; Bellamy *et al.*, 1996; Landmann, 1998; Massa *et al.*, 1998; Matthysen, 1998; Nour *et al.*, 1999). Such characteristics, along with a relatively wide distribution make these species possible indicators of environmental transformations. In N-Italy, these species have been recorded as lowland forest indicators and focal species for planning (Massa *et al.*, 2000; for the concept of "focal species", see Lambeck, 1997). Woodpeckers have also been proposed as indicators for assessing forest avian diversity at the landscape scale (Mikusinski *et al.*, 2001).

In Central Italy, the sensitivity of these species to area and isolation of the habitats, as well as physiognomy and vegetation structure has been pointed out by Bernoni *et al.* (1989), Guerrieri *et al.* (1992), Massa *et al.* (1998), Battisti (2001). However, data on the relative role played by these factors on this single species in the hilly landscapes of Central Italy are lacking.

The aim of this preliminary study was to investigate the main factors influencing the distribution and population abundance patterns of four forest bird species (*Picus viridis, Picoides major, Sitta europaea, Garrulus glandarius)* in a agricultural-wooded landscape with a high degree of habitat fragmentation in Central Italy. The results are discussed in terms of sensitivity of these species to fragmentation/landscape components (area, isolation, habitat quality).

Study area and methods

The study area is located in Umbria (the municipalities of San Gemini, Quadrelli, Castel Todino and Montecastrilli in the provincial district of Terni; Central Italy) between 250-600 m above sea level.

From a geobotanic point of view, Umbria belongs to the middle-European floristic region with "islands" of Mediterranean flora in the more internal sectors of the region (the transition zone between Temperate and Mediterranean bioclimates) producing a patchiness at regional scale (Orsomando & Catorci, 1999; Orsomando *et al.*, 1999; see Giovagnotti, 1991 for a geological description).

Two main forest ecosystems are present in the area (Orsomando & Catorci, 1999). The first is named *Rubio-Quercetum cerridis* (Pignatti, 1968), dominated by *Quercus cerris*, and is the result of a prolonged coppicing, fire and grazing on acidophilus forest formations. Such formation is typical of landscapes composed of low hills with sandy - clayey and sandy soils with conglomerates (Orsomando & Catorci, 1999; Orsomando *et al.*, 2000).

The second forest type is termed *Orno-Quercetum ilicis* (Pignatti, 1968) and is tipically composed of wide hilly woods, characterized by the presence of *Quercus ilex* associated with broad leaved species such as *Fraxinus ornus* and *Ostrya carpinifolia*. These woods are the most widespread element in the landscape of Southwestern Umbria (Central Italy; Orsomando *et al.*, 2000).

In this area, the kind of wood land management is the coppice, although uneven aged forest stand fragments (high forest with large and mature trees) are present. The progressive increase of agricultural activities in the last centuries resulted in a strong reduction of forest area. Currently, landscape mosaics with residual forest fragments are present, especially in hilly areas. An exception are some areas located at higher altitudes and with a steeper slopes where a continuous forest cover is still present with a non-anthropic-derived patchiness (Orsomando *et al.*, 1998).

Sampling was carried out at 15 sites. Twelve sites are represented by small forest fragments (area range, 1-43 ha), and 3 are the large blocks of forest in the area (the "core areas"; area range, 204-928 ha; see Tab. I for the place names and forest structure of the sites). Forest fragments 1, 3, 6 and 12, were coppiced, whilst, fragments 4 and 5 had the typical structure of a high forest and are included in areas proposed as Special Areas of Conservation (CE 92/43/CE Directive "Habitat").

The overall forest area at landscape scale is smaller than 30% on the total of the study area: consequently, effects linked to fragmentation may act on bird communities and species (see Andrén, 1994).

The four investigated bird species (*Picus viridis, Picoides major, Sitta europaea, Garrulus glandarius*) have been selected from the forest breeding species of the region (Magrini & Gambaro, 1997), on the basis of their sensitivity to the habitat fragmentation and to physiognomic and structural characteristics of the vegetation (*e.g.*, Bernoni *et al.*, 1989; Landmann, 1998). Ease of sampling and wide distribution at the regional scale (Boano *et al.*, 1995; Magrini & Gambaro, 1997; Tellini Florenzano *et al.*, 1997) also influenced the choice of the species.

To analyse the presence/absence and abundance patterns of the above-mentioned species, a modified line transect method has been used (Merikallio, 1946; Jarvinen & Vaisannen, 1973). All individuals were recorded by direct observation or hearing of their voice/song inside the fragment/core areas. The line transect length was directly related to the fragment size and ranged between 70 and 650 m. Each transect start at the edge and is oriented along a longitudinal axis of the fragment (see Villard *et al.*, 1995, for an application in fragmented landscapes). In some cases, only the most representative line transect has been followed due to their poor accessibility (fragments 12 and 3) or to the extension of the area (core areas). Each line transect was surveyed three times from February 3 to April 22, 2002 (I period: 3 Feb. – 17 Feb.; II period: 17 March – 29 March; III period: 7 April – 24 April) for a total time of about 38 hours. The anticipated monitoring period were selected to coincide with the early seasonal territorial displays of Piciformes (Cramp, 1985; Cramp & Perrins, 1993; Cramp & Perrins, 1994).

Some information would support the adequacy of the line transect method in fragmented landscapes compared to others: Mapping method (Pough, 1947) is too consuming time over a landscape scale and for a large number of fragments (as highlighted it is often advisable to increase the number of sites sampled rather than to census a few sites intensively in fragmentation studies; see Haila & Hanski, 1984); point counts (*e.g.*, E.F.P.; Blondel, 1975) do not permit to acquire a significant number of data (*i.e.*, number of points) in small fragments. Line transect method was utilised in analogous studies in fragmented landscapes (*e.g.*, Villard *et al.*, 1995).

The following dependent variables were recorded on each study area: number of species (S_t); abundance of each individual species (PM: *Picoides major;* PV: *Picus viridis;* SE: *Sitta europaea;* GG: *Garrulus glandarius*, in individuals/km; maximum values on three transect; see above); total abundance (TOTABB: the sum of abundance values for each species, in ind./km); Shannon diversity index (Shannon & Weaver, 1963) has been applied on the interior bird communities composed by the four species investigated.

The vegetation structure has been measured using a simplified version of the Range Findle Circle Method (James & Shugart, 1970): At one-hundred meter intervals along the line transects the diameter of all plants with a diameter at breast height (1.40 m) > 7.5 cm was recorded in an approximately 0.04-ha wide area (Tab. I).

For each fragment and core area, the size area (AREA, in ha; from Italian Military Geographic Maps, scale 1: 25.000) and average diameter of the trees (DIAM, in cm) have been considered as intra-fragment independent variables. The following inter-fragment variables were taken (from 1:25000 maps) ("between-site variables"; see McCollin, 1993): Distance from the nearest forest site with surface area greater or equal to 10 ha (DIST10HA, in m: see Bellamy *et al.*, 1996), distance from the nearest core area (DISTCORE, in m).

Interior species richness have been explicited spatially in a cartesian space by area/isolation patterns.

Correlation among dependent and independent variables were calculated (simple nonparametric with Spearman test; Pearson test with log-transformed variables) followed by stepwise multiple regression (dependent variables: TOTABB: PM, PV, GG, SE; independent variables: AREA, DIAM, DIST10HA, DISTCORE). Independent variables were analysed, using untransformed and log-transformed data (assigning 0,1 at 0 values) by SPSS for Windows (SPSS inc., 1989-1996; standard version; 1997).

Results

The highest number of target species ($S_t = 3$) was recorded in the core areas I and III and in the forest fragments 5 (high forest) and 12 (Tab. II). No target species were found in the forest fragments 1-4 and 6-8 (size area < 3,5 ha in extent). S_t is strongly correlated with AREA ($r_s = 0.698$; $P = 0.004$) and inversely correlated with DIST10HA ($r_s = -0.627$; $P = 0.012$; Spearman rank correlation test).

The highest total abundance value (13,7 ind/km) has been recorded in core area III. High values of total abundance have also been recorded in core areas I and II and in forest fragments 5 (high forest) and 12 (> 5 ind./km).

The values of Shannon diversity index are in Tab. II.

Area/isolation patterns of interior species richness are reported in Figs. 2a and 2b. These patterns show in explicit way increasing values towards the high-right side of the diagrams (larger and less isolated sites).

Abundance values of the individual species (PM, PV,

Tab. I. Forest structure of the sampling sites.
Site names refer to Italian Military Geographic Institute map (n. 138 IV NO). FT: vegetation type (R,—*Rubio-Quercetum cerridis*; O, *Orno-Quercetum ilicis*); n: number of sample areas (0,04 ha wide); N: total number of sampled trees; DIAM: mean diameter of sampled trees (standard deviation between brackets); d/0.04: mean number of plants with diameter >7.5 cm in 0.04 ha.

Site	Place name	FT	n	N	DIAM (sd)	d/0.04
Fragment 1	La Rotte	R	1	54	10.65 (5.25)	54
Fragment 2	Le Capanne	R	2	70	16.79 (9.48)	35
Fragment 3	C.^{se} S. Cristoforo	R	2	75	15.52 (8.15)	37.5
Fragment 4	Casarnese	R	2	58	18.72 (8.06)	29
Fragment 5	Podere Vetturina	R	4	134	17.39 (8.56)	33.5
Fragment 6	Podere Bacocco	R	3	46	15.1 (8.50)	15.3
Fragment 7	C.^{se} S. Martino	R	2	102	15.33 (6.35)	51
Fragment 8	Poderi di Colle Capretto	R	2	164	13.48 (4.81)	82
Fragment 9	Podere Casella	R	2	108	16.45 (8.32)	54
Fragment 10	Podere Vignarelle	R	2	58	13.58 (7.09)	29
Fragment 11	Colle Scoppio	R	2	53	17.55 (10.05)	26.5
Fragment 12	La Cerreta	R	3	72	15.34 (6.09)	24
Core area I	Cesi	O	6	404	11.36 (3.86)	67.3
Core area II	Capitone	O	5	235	13.66 (4.46)	47
Core area III	Foce	O	3	138	15.01 (7.87)	46

Fig. 1. Location of the study area.

SE, GG) do not strictly meet the necessary assumptions to perform correlation tests (more than half of the values are equal: Fowler & Cohen, 1992). Bearing in mind this caveat, the log-transformed variable correlations (Pearson test) showed that: Between Piciformes only abundance of PM (log-transformed) was inversely correlated with Log DIST10HA (r = -0.589; P = 0.021); Abundance of SE was directly correlated with Log AREA (r = 0.741; P = 0.002) and inversely with Log DISTCORE (r = -0.617; P = 0.014); Abundance of GG was inversely correlated with Log DIST10HA (r = -0.714; P = 0.003) and with Log DISTCORE (r = -0.584; P = 0.014). No significant correlation was found between individual interior species and the Log DIAM.

Log TOTABB was directly correlated to Log AREA (r = 0.731; P = 0.002; Fig. 3) and inversely correlated to Log DIST10HA (r = -0.672; P = 0.006) and Log DISTCORE (r = -0.559; P = 0.030). No significant correlation was found with the Log DIAM.

Multiple regression analysis with log-transformed data showed that two predictors (Log AREA; Log DIST10HA) accounted for about 68 % of the variation in the variable Log TOTABB and that this finding is statistically significant (Log AREA: t = 2.972; P = 0.012; Log DIST10HA: t = - 2.390; P = 0.034). The observed significance level associated with Log DIAM (P = 0.432) and Log DISTCORE (P = 0.330) are too large for entry (P>0.05): The best regression equation contains two predictors. Log-transformed data fitted better than non-transformed ones (where only 37 % of the variation is explained by the model) and significant multiple regression are presented in Tab. III.

As with non-transformed data, high correlation among independent variables were observed (Log DISTCORE and Log AREA: r = - 0.887; P < 0.01), consequently, the obtained regression data should be considered only indicative.

Multiple regression with log-transformed data of individual species shows that: A single predictor (Log DIST10HA) accounted for about 35 % of the variance in the variable PM (t = - 2.631; P = 0.021), no predictor entered the analysis for PV, a single predictor (Log AREA) accounted for about 55 % of the variance in the criterion variable SE (ANOVA; F 1,13 = 15.853; P = .002; t = 3.982;

Tab. II. Fragments and core areas investigated.
AREA: fragment/core area size (in ha); (*): Surface of core areas only relative to study area; DIST10HA: distance from the nearest forest area with surface >= 10 ha (in m); DISTCORE: distance from the nearest core area (in m); (**): for core areas distance was considered = 0. L_t: transect length (in m); S_t: number of target species recorded; TOTABB: total abundance of the sampled target species (mean values, individuals/km); PM, PV, SE, GG (see methods for abbreviations): abundance values of the individual species (mean values, individuals/km); H: Shannon diversity index applied on interior bird communities (Fragments 1-4 and 6-8: index not calculable).

Site	AREA	DIST10HA	DISTCORE	L_t	S_t	TOTABB	PM	PV	SE	GG	H
Fragment 1	1. 44	422. 5	500	70	0	0	0	0	0	0	-
Fragment 2	9. 69	975. 0	1113	230	0	0	0	0	0	0	-
Fragment 3	9. 97	975. 0	2213	240	0	0	0	0	0	0	-
Fragment 4	7. 75	510. 0	2865	220	0	0	0	0	0	0	-
Fragment 5	9. 09	847. 5	3205	400	3	6. 62	1. 65	0. 82	4. 15	0	0.9
Fragment 6	2. 81	727. 5	4410	270	0	0	0	0	0	0	-
Fragment 7	1. 25	1115	5303	145	0	0	0	0	0	0	-
Fragment 8	3. 43	1602. 5	5338	200	0	0	0	0	0	0	-
Fragment 9	3. 53	887. 5	4843	240	1	1. 38	1. 38	0	0	0	0
Fragment 10	13. 50	75. 0	2223	235	1	1. 40	0	0	0	1. 4	0
Fragment 11	9. 00	52. 5	3145	220	1	4. 54	4. 54	0	0	0	0
Fragment 12	43. 44	75. 0	1865	345	3	13. 47	4. 81	0	6. 75	1. 91	0.99
Core area I	928. 12 (*)	597. 5	0 (**)	650	2	5. 63	0	3. 58	2. 05	0	0.66
Core area II	204. 00 (*)	115. 0	0 (**)	540	3	9. 23	0. 61	0	3. 07	5. 55	0.85
Core area III	578. 12 (*)	115. 0	0 (**)	340	3	13. 70	4. 88	0	2. 94	5. 88	1.06

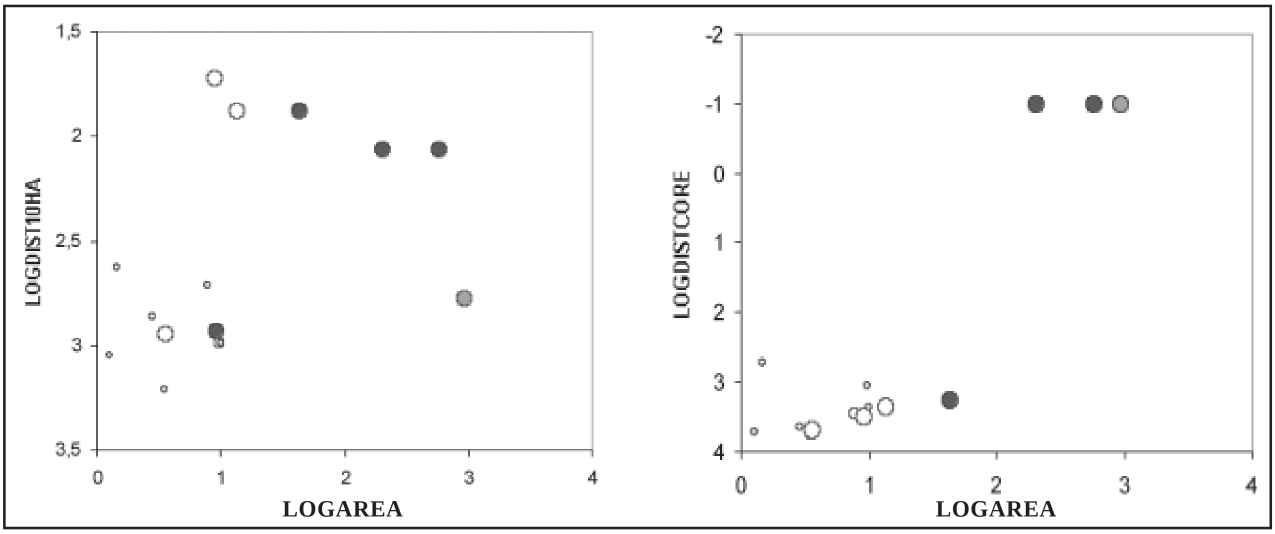

Fig. 2. Area – isolation pattern of interior bird richness studied. a (left): DIST10HA; b (right): DISTCORE. Black circle: 3 interior species; grey: 2; white (large): 1; white (small): 0.

P = .002), two predictors (Log DIST10HA and Log DISTCORE) account for about 65 % of the variance in the variable GG (Log DIST10HA: t = - 3.290; P = .006; Log DISTCORE: t = - 2.238; P = .045).

Discussion

In the study area, the independent variables area (*in primis*) and isolation of the fragments significantly affected richness and total abundance of interior bird species studied and the abundance of some individual species with consequences on their distribution and abundance patterns at landscape scale (Figs. 2 and 3). This confirms previous studies: *e.g.*, Freemark & Merriam (1986) found that the number of forest interior in species in temperate forests could be explained by fragment area.

The vegetation structure factor used in this study (diameter of trees at breast height: DIAM) did not appear to account for the total abundance of the selected species. Moreover, in this sample of fragments, the range variation of the area and isolation variables is higher than the variation in habitat quality (*e.g.*, DIAM). So, it is not surprising that area and isolation were significant variables, whereas habitat quality not. Furthermore, the small number of investigated fragments did not allow us to draw significant conclusions for the individual species. However, the results seemed to stress the sensitivity to the size and degree of isolation of the forest fragments for some of interior species investigated.

Core areas and fragments were different with regard to vegetation type (see study area and Tab. I). Different vegetation types may act on habitat structure, an important variable influencing the presence/abundance of these species (Cramp, 1985; Cramp & Perrins, 1993; Cramp & Perrins, 1994). The range of variation of mean diameter in *Quercus ilex* wood in core areas was comprised in the wider range of the *Q. cerris* vegetation in fragments, analogously to tree density values (Tab. I). Moreover, deciduous and mixed woods represent an habitat type more suitable for some species (Meschini & Frugis, 1993). In this study we observed an higher richness and abundance of the species in larger and less isolated sites, including core areas, characterised by vegetation type less suitable with regard to *Q. cerris* woods. Results obtained highlight the higher role of spatial variables considered in respect to the structural and vegetation ones in defining distribution and abundance of these species. Nevertheless, further studies could investigate also these aspects.

At individual species level, *Picus viridis* did not appear sensitive to investigated fragment/landscape variables. In the study area, the abundance of this localised

Tab. III. Stepwise multiple regression equations describing the relationship between log-transformed dependent variables (TOTABB: Total abundance of target species; Log SE, GG, PM: Abundance of individual species; for abbreviations, see methods). Only models with significant regression coefficients (P <.05) are given. Standard error of coefficients in brackets.

Model	R^2	Adjusted R^2	ANOVA
Log TOTABB = 1.311 +0.566 Log AREA -0.794 Log DIST10HA	0.684	0.632	$F_{3, 12}$ = 13.016 P = 0.001
(.987) (.190) (.332)			
Log SE = -1.244 + 0.636 Log AREA	0.549	0.515	$F_{1, 13}$ = 15.853 P = 0.002
(.230) (.245)			
Log GG = 1.859 -0.807 Log DIST10HA -0.151 Log DISTCORE	0.654	0.596	$F_{2, 12}$ = 11.326 P = 0.002
(.612) (.245) (.067)			
Log PM = 1.723 -0.844 Log DIST10HA	0.347	0.297	$F_{1, 13}$ = 6.922 P = 0.021
(.843) (.321)			

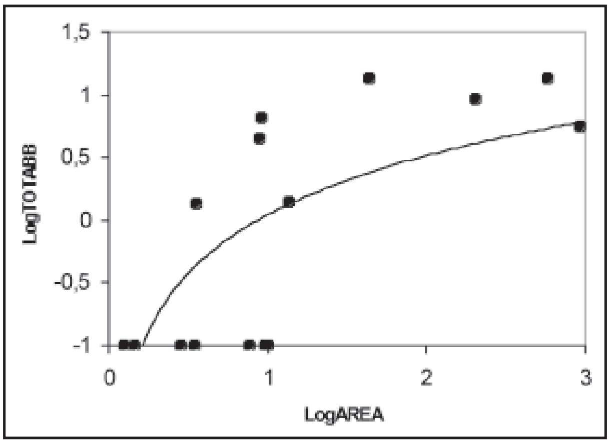

Fig. 3. Area – total abundance of interior bird species diagram (log-transformed variables: respectively, LogAREA and LogTOTABB; r = 0.731; P = 0.002; Pearson test).

species did not appear significantly correlated to area and isolation and, probably, other factors at landscape scale as well as distribution at regional scale not considered here could influence the observed spatial distribution patterns (see Hinsley *et al.*, 1995).

Picus viridis is known as a specialist of mature woods (Opdam *et al.*, 1985, McCollin, 1993, Bellamy *et al.*, 1996) and a lowland forest indicator species (Massa *et al.*, 1998). Bearing in mind the preference of this species for ecotones and agroecosystems as well as forest habitats (Cramp, 1985), factors such as type of landscape matrix and presence, scattering and spatial arrangement of the agroforest ecomosaics, may be more relevant.

Picoides major show, in this study, an isolation-sensitivity. Bernoni *et al.* (1989) and Guerrieri *et al.* (1992) included the degree of isolation of the forest fragments (other than size area) among the factors affecting the distribution of this species in the landscapes of Central Italy. Opdam *et al.* (1985) have shown also an area-sensitivity for *Picoides major* in N-Europe (see also, *e.g.*, van Dorp and Opdam, 1987).

In highly fragmented landscape mosaics, the populations of Piciformes may show a “patchy” structure rather than metapopulation one (see, *e.g.*, Thomas *et al.*, 2000). These fragments, which may be occasionally occupied by erratic individuals or a small number of pairs, may have a function as stepping stones (*sensu* Bennett, 1999) in the local dynamics at landscape scale (*e.g.*, *Picoides major* is adapted to frequent fragmented woodland and can routinely be recorded in small fragments).

Regard to *Sitta europaea* these results seem to confirm previously published data on their high sensitivity to some fragmentation components. *Sitta europaea* was known as an interior species with low dispersal power (in particular, juvenile dispersal), sensitive to the isolation of the reproductive habitats and to habitat fragmentation (Moore & Hooper, 1975; Cieslak, 1985; Opdam *et al.*, 1985; McCollin, 1993; Bellamy *et al.*; 1996; Landmann, 1998; Massa *et al.*, 1998; Matthysen, 1998). Our data confirm the area (*in primis*)- and isolation-sensitivity of this species in context studied.

Vegetation structure is known to be another habitat factor that affect the local spatial distribution of *Sitta europaea* (see Landmann, 1998). However, in our study it does not seem to explain the pattern of the species in the study area (likewise to the total abundance: see above), even though the uneven aged forest stand management of the fragments might, at least locally, sustain the presence of the species (see high forest fragment 5; Tab. II).

Garrulus glandarius, was indicated as an area-sensitive and forest interior species (Møller, 1987; McCollin, 1993; Hinsley *et al.*, 1995; Bellamy *et al.*, 1996; Massa *et al.*, 1998, Massa *et al.*, 2000). Our results show that isolation from other fragments/core areas could be an additional factors influencing the distribution pattern of this species.

Garrulus glandarius and *Sitta europaea* are mostly sensitive to fragmentation factors such as fragment size and isolation, in different ways, and show high abundance values especially in the not fragmented core areas I, II and III, more larger and less isolated. Their presence in the forest fragments may be casually related to local factors (*e.g.*, structure and physiognomy of the vegetation in the fragment 5 for *Sitta europaea*). Such species may show consistent populations in non-fragmented forest areas, and marginal subpopulations (*e.g.*, *Sitta europaea*), few couples and/or erratic individuals (*e.g.*, *Garrulus glandarius*) could inhabit in the highly fragmented areas.

The sensitivity to forest fragmentation of *Garrulus glandarius* and *Sitta europaea* (both widespread in the hilly landscapes of Central Italy: Boano *et al.*, 1995; Magrini & Gambaro, 1997; Tellini Florenzano *et al.*, 1997) and the easy identification in the field potentially allows the rapid assessment of their spatial distribution and abundance patterns and makes these species possible useful target/indicators in landscape planning strategies (Soulé, 1991; Pearson, 1995; Massa *et al.*, 2000).

Using a small sample of forest fragments, the total abundance of the selected species (or, in alternative, the total abundance of only *Sitta europaea* and *Garrulus glandarius*) may be a useful dependent variable able to give preliminary qualitative and quantitative information which may be more useful than considering the individual species separately (less data available for statistical analyses), although the contribution as indicator of some species should be better defined (*e.g., Picus viridis*: previous data on sensitivity to some fragmentation factors not confirmed in our study).

Size of wood area (fragment or core) appears the better predictor of total abundance of the selected interior species. Larger fragments are more suitable for these interior species than smaller ones, confirming previous data (see literature cited above): These data suggest that 10 ha (see patterns in Fig. 2 and diagram of Fig. 3) could be a fragment size threshold that contribute to predict the presence/absence and abundance of interior species, according to others authors (*e.g.*, Cieslak, 1985). Sites larger than 100 ha show a cumulative trend in total abundance (Fig. 3; see Moore & Hooper, 1975). Nevertheless, for species structured as “patchy-population” and for “eyesight navigator” species (see Smith, 1989) also small woods could have a functional role as stepping stones and may facilitate dispersion at landscape scale (see, *e.g.*, Spellerberg & Sawyer, 1999).

The role of analysed spatial variables (AREA, *in primis*; DIST10HA and DISTCORE, secondarily) in predicting the richness of interior species studied was highlighted also by area/isolation patterns (Fig. 2).

Further researches with a larger sample of forest fragments and at a longer temporal scale are required in order to define the fragmentation effects on individual species and to reduce and identify possible spatial and temporal stochastic effects in limited contexts of study (Haila, 1985). Nevertheless, although preliminary, these data may contribute to the selection of fragmentation-sensitive interior/target species as indicator that provide concise and quick indications in landscape planning strategies (nature reserve plans and selection; Gap analysis, Scott & Jennings, 1997; ecological networks at local scale; *e.g.* Battisti, 2003).

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References

Ambuel, B. & Temple, S.A. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forest. Ecology 64: 1057-1068.

Andrén, H. 1994. Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. Oikos 71: 355-366.

Battisti, C. 2001. Comunità ornitiche e frammentazione ambientale: dati dalle Riserve naturali “Nomentum” e “Macchia di Gattaceca e del Barco” (Roma, Italia centrale). Rivista Italiana di Ornitologia 71: 115-123.

Battisti, C. 2003. Habitat fragmentation, fauna and ecological network planning: Toward a theoretical conceptual framework. Italian Journal of Zoology 70: 241-247.

Bellamy, P.E., Hinsley, S.A. & Newton, I. 1996. Factors influencing bird species numbers in small woods in south-east England. Journal of Applied Ecology 33: 249-262.

Bennett, A.F. 1987. Conservation of mammals within a fragmented forest environment: the contributions of insular biogeography and autoecology. In: D.A. Saunders, G.W. Arnald, A.A. Burbidge & A.J.M. Hopkins (eds.). Nature conservation: the role of remnants of native vegetation. Surrey Beatty & Sonns: Chipping Norton, New South Wales, pp. 41-52.

Bennett, A. F. 1999. Linkages in the landscape. IUCN, Gland, Switzerland.

Bernoni, M., Ianniello, L. & Plini, P. 1989. Contributo alla conoscenza del popolamento ornitico in ambienti degradati e/o antropizzati del Lazio. Rivista Italiana di Ornitologia 59: 223-228.

Blake, J.G. & Karr, J.R. 1987. Breeding birds of isolated woodlots: area and habitat relationship. Ecology 68: 1724-1734.

Blondel, J. 1975. L’analyse des peuplements d’oiseaux, element d’un diagnostic ecologicque. La methode des Echantillonages Frequentiels Progressifs (E.F.P.). La Terre et la Vie 29: 533-589.

Boano, A., Brunelli, M., Bulgarini, F., Montemaggiori, A., Sarrocco, S. & Visentin, M. (eds.) 1995. Atlante degli uccelli nidificanti nel Lazio. Alula 2: 1-224.

Bright, P.W. 1993. Habitat fragmentation - problems and predictions for British mammals. Mammal Review 23: 101-114.

Caughley, J. & Gall, B. 1985. Relevance of zoogeographical transition to conservation of fauna: amphibians and reptiles in the southwestern slopes of New South Wales. Australian Zoologist 21: 513-529.

Cieslak, M. 1985. Influence of forest size and other factors on breeding bird species number. Ekologia Polska 33: 103-121.

Cramp, S. (ed.) 1985. The Birds of the Western Palearctic. Vol. IV: Terns to Woodpeckers. Oxford University Press. Oxford, 970 pp.

Cramp, S. & Perrins, C.M. (eds.) 1993. The Birds of the Western Palearctic. Vol. VII: Flycatchers to Shrikes. Oxford University Press. Oxford, 584 pp.

Cramp, S. & Perrins, C.M. (eds.) 1994. The Birds of the Western Palearctic. Vol. VIII: Crows to Finches. Oxford University Press. Oxford, 906 pp.

Fahrig, L. 1997. Relative effects of habitat loss and fragmentation on population extinction. Journal of Wildlife Management 61: 603-610.

Fowler, J. & Cohen, L. 1992. Statistics for Ornithologists. British Trust for Ornithology, London, 2nd edition, 150 pp.

Freemark, K.E. & Merriam, H.G. 1986. Importance of Area and Habitat Heterogeneity to Bird Assemblages in Temperate Forest Fragments. Biological Conservation 36: 115-141.

Galli, A.E., Leck, C.F. & Forman, R.T.T. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93: 356-364.

Giovagnotti, C. 1991. Bibliografia geologica dell’Umbria. Protagon editrice. Perugia.

Guerrieri, G., Biondi, M. & Pietrelli, L. 1992. Struttura della vegetazione e comunità ornitiche in ecosistemi residui dell’Italia centrale. Rivista Italiana di Ornitologia 62: 121-135.

Haila, Y. 1985. Birds as a tool in reserve planning. Ornis Fennica 62: 96-100.

Haila Y. & Hanski I.K. 1984. Methodology for studyng the effect of habitat fragmentation in land bird. Ann. Zool. Fennici 21: 393-397.

Henle, K., Davies, K.F., Kleyer, M., Margules, C. & Settele, J. 2004. Predictors of species sensitivity to fragmentation. Biodiversity and Conservation 13: 207-251.

Hinsley, S.A., Bellamy, P.E., Newton, I. & Sparks, T.H. 1995. Habitat and landscape factors influencing the presence of individual breeding bird species in woodland fragments. Journal of Avian Biology 26: 94-104.

James, F.C. & Shugart, H.H. 1970. A quantitative method of habitat description. Audubon Field Notes 24: 727-736.

Jarvinen, O. & Vaisanen, R.A. 1973. Finnish line transect censuses. Ornis Fennica 53: 115-118.

Kareiva, P. & Wennergren, U. 1995. Connecting landscape patterns to ecosystem and population processes. Nature 373: 299-302.

Kitchener, D.J., Chapman, A., Muir, B.G. & Palmer, M. 1980. The conservation value for mammals of reserves in the Western Australian wheatbelt. Biological Conservation 18: 179-207.

Kitchener, D.J. & How, R.A. 1982. Lizard species in small mainland habitat isolates and islands of south-western Western Australia. Australian Wildlife Research 9: 357-363.

Kitchener, D.J., Dell, J., Muir, B.G. & Palmer, M. 1982. Birds in Western Australian wheatbelt reserves-implications for conservation. Biological Conservation 22: 127-163.

Laan, R. & Verboom, B. 1990. Effects of pool size and isolation on amphibian communities. Biological Conservation 54: 251-262.

Lambeck, R.J. 1997. Focal species: a multi-species umbrella for nature conservation. Conservation Biology 11: 849-856.

Landmann, A. 1998. Tree-climbing birds in small urban greenspaces: habitat relationship and between year dynamics of patch utilization. Biologia e Conservazione della Fauna 102: 229.

Laurance, W.F. 1990. Comparative responses of five arboreal marsupials to tropical forest fragmentation. Journal of Mammalogy 71: 641-653.

Magrini, M. & Gambaro, C. 1997. Atlante ornitologico dell'Umbria. Tipolitografia Petruzzi, Città di Castello.

Massa, R., Bani, L., Bottoni, L. & Fornasari L. 1998. An evaluation of lowland riserve effectiveness for forest bird conservation. Biologia e Conservazione della Fauna 102: 270-277.

Massa, R., Baietto, M., Bani, L. & Bottoni, L. 2000. Uso di specie focali quali indicatori per la individuazione di reti ecologiche. Informatore Botanico Italiano 32 Suppl. 1: 26-30.

Matthysen, E. 1998. Population dynamics of Nuthatches in forest fragments: the impacts of dispersal losses. Biologia e Conservazione della Fauna 102: 232.

McCollin, D. 1993. Avian distribution patterns in a fragmented wooded landscape (North Humberside, UK): the role of between-patch and within-patch structure. Global ecology and Biogeography Letters 3: 48-62.

Merikallio, E. 1946. Uber Regionale Verbreitung und Anzahl der Landvögel in Süd-und Mittelfinnland, Besouders in deren östlichen Teilen, im Lichte von quantitativen Untersuchungen. Ann. Zool. Soc. "Vanamo" 12 (1): 1-143, 12 (2): 1-120.

Meschini, E. & Frugis, S. 1993. Atlante degli uccelli nidificanti in Italia. Suppl. Ricerche di Biologia della Selvaggina 20.

Mikusinski, G., Gromadzki, M. & Chylarechi, P. 2001. Woodpeckers as indicators of forest bird diversity. Conservation Biology 15: 208-217.

Møller, A.P. 1987. Breeding birds in habitat patches: random distribution of species and individuals? Journal of Biogeography 14: 225-236.

Moore, N.W. & Hooper, M.D. 1975. On the number of bird species in British woods. Biological Conservation 8: 239-250.

Noss, R.F. 1992. Issues of Scale in Conservation Biology. In: Fiedler P.L. & Jain S.K. (eds.). Conservation Biology. Chapman and Hall, New York and London.

Nour, N., Van Damme, R. & Matthysen, E. 1999. Forest birds in forest fragments: are fragmentation effects independent of season? Bird Study 46: 279-288.

Opdam, P., van Dorp, D. & ter Braak, C.J.F. 1984. The effect of isolation on the number of woodland birds in small woods in the Netherlands. Journal of Biogeography 11: 473-478.

Opdam, P., Rijsdijk, G. & Hustings, F. 1985. Bird Communities in Small Woods in an Agricultural Landscape: Effects of Area and Isolation. Biological Conservation 34: 333-352.

Orsomando, E., Catorci, A., Beranzoli, N., Ferranti, G., Ciarapica, A., Segatori, R. & Grohmann, F. 1998. Carta geobotanica con principali classi di utilizzazione del suolo. Scala 1: 100.000. Regione dell'Umbria, Università di Camerino, 16 pp. + 2 map.

Orsomando, E. & Catorci, A. 1999. Carta della vegetazione naturale potenziale dell'Umbria. Scala 1: 200.000. Regione dell'Umbria, Università di Camerino, 31 pp. + 1 map.

Orsomando, E., Catorci, A., Pitzalis, M. & Raponi, M. 1999. Carta fitoclimatica dell'Umbria. Scala 1: 200.000. Regione dell'Umbria, Università di Camerino, Università di Perugia, 58 pp. + 1 map.

Orsomando, E., Catorci, A., Martinelli, M. & Raponi, M. 2000. Carta delle unità ambientali-paesaggistiche dell'Umbria. Scala 1: 100.000. Regione dell'Umbria, Università di Camerino, Università de São Paulo 79 pp. + 2 map.

Pearson, L.D. 1995. Selecting indicator taxa for the quantitative assessment of biodiversity. In: J.L. Harper & D.L. Hawksworth (eds.). Biodiversity-Measurement and estimation. Chapman & Hall, London, pp. 75-80.

Pignatti, S. 1968. Die inflation der höheren pflanzensoziologischen Einheiten, Ber. Internat. Symp. Vegetationskunde 1964: 85-97.

Pough, R.H. 1947. How to take a breeding census. Audubon Mag., 49: 290-297.

Pulliam, H.R. 1988. Sources, sinks, and population regulation. Am. Nat., 132: 652-661.

Scott, J.M. & Jennings, M.D. 1997. A Description of the National Gap Analysis Program. http:// *www.gap.uidaho.edu/About/Overview/GapDescription/default.htm*.

Shannon, C.E. & Weaver, W. 1963. Mathematical theory of communication. University of Illinois Press, Urbana, Ill.

Shreeve, T.G. & Mason, C.F. 1980. The number of butterfly species in woodlands. Oecologia 45: 414-418.

Smith, A.T. 1989. Deterministic processes in mammalian colonization. Abstract V International Theriological Congress, Roma, 22-29/8/1989: 239.

Soulé, M.E. 1991. Theory and strategies. In: W.E. Hudson (Editor). Landscape linkages and biodiversity. Island press, pp. 91-104.

Soulé, M.E. & Orians, G.H. 2001. Conservation Biology. Research priority for the next decade. Island Press.

Spellerberg, I.F. & Sawyer, J.W.D. 1999. An introduction to applied biogeography. Cambridge Univ. Press, Cambridge.

SPSS Inc. 1989-1996. SPSS for Windows. Standard version. Release 7.5.2. May 16, 1997.

Suckling, G.C. 1982. Value of preserved habitat for mammal conservation in plantations. Australian Forestry 45: 19-27.

Tellini Florenzano, G., Arcamone, E., Baccetti, N., Meschini, E. & Sposimo, P. (eds.) 1997. Atlante degli uccelli nidificanti e svernanti in Toscana (1982-1992). Quaderni del Museo Provinciale di Storia naturale di Livorno, Monografie 1, 414 pp.

Thomas, C.D., Baguette, M. & Lewis, O.T. 2000. Butterfly movement and conservation in patchy landscapes. In: L. Morris Gosling, W.J. Sutherland (eds.). Behaviour and Conservation. Conservation Biology Series 2. Cambridge Univ. Press, Cambridge, pp. 85-104.

van Dorp, D. & Opdam, P. F. M. 1987. Effects of patch size, isolation and regional abundance on forest bird communities. Landscape Ecology 1: 59-73.

Villard, M.-A., Merriam, G. & Maurer, B.A. 1995. Dynamics in subdivided populations of neotropical migratory birds in a fragmented temperate forest. Ecology 76: 27-40.

Wiens, J.A. 1994. Habitat fragmentation: island *vs* landscape perspectives on bird conservation. Ibis 137: S97-S104.

Wilcove, D.S., McLellan, C.H. & Dobson, A.P. 1986. Habitat fragmentation in the temperate zones. In: Soulé M.E. (ed.). Conservation Biology. Sinauer Associates Inc. Sunderland, Massachussets, pp. 237-256.