LAND-MOLLUSC FOREST COMMUNITIES ALONG AN ALTITUDINAL TRANSECT IN NORTHERN ITALY

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ABSTRACT

While central and northern European land-mollusc forest communities have received considerable research effort, southern Europe has enjoyed much less attention. Despite the extent of Italian forests in terms of altitude and latitude, there has been only one previous quantitative study of their molluscan faunas. This paper describes the molluscan communities of six forest habitats in northern Italy along an altitudinal transect. Species richness had its highest values at low elevations, especially in maritime woodland and in riverine poplar woodland. Species abundance decreased from lowland to montane habitats, possibly as a consequence of a transition from eutrophic to oligotrophic habitats and from calcareous to acidic soils. Compared with the central and northern European forests, the Italian forests were poorer as far as species richness is concerned, but showed greater diversity among locations as the Jaccard presence/absence similarity index among habitats is equal or lower than 0.5. Considering abundances, all molluscan communities were significantly different in pairwise comparisons, with the single exception of the montane mixed-deciduous and beech forests. The low faunal similarity among sites and the high percentage of species found in only one habitat support the need for a network of diverse protected areas to preserve land-mollusc biodiversity.

INTRODUCTION

Forests are the richest habitat for land molluscs in Europe (Kerney & Cameron, 1979). European forest land-mollusc faunas have received much attention in recent decades and a number of quantitative works are available for central and northern Europe, e.g. by Cameron (1973, 1982), Cameron & Greenwood (1991) and Cameron, Pokryszko & Long (2006) for the United Kingdom, by Wäreborn (1969) for Sweden, by Valovirta (1968) for Finland, by Körning (1966) and Bless (1977) for Germany, by Dziczkowski (1972), Cameron & Pokryszko (2004), Sulikowska-Drozd & Horsák (2007) and Cameron, Pokryszko & Horsák (2010) for Poland and by Cameron et al. (2011) for Romania. While there are quantitative studies of other habitats in southern Europe (e.g. Cameron, Mylonas & Vardiniyannis 2000; Cameron et al., 2003), forest faunas have been considered mainly in works focusing on faunistics and biogeography (e.g. Boato, Bodon & Giusti, 1982; Giusti, Castagnolo & Manganelli, 1985). Only Bishop (1980) has studied pre-alpine and alpine forests in northwestern Italy.

Moreover—and this is a general pattern in studies on the European continental malaco fauna—there have been very few studies dealing with altitudinal transects, notwithstanding the increasing interest in this type of study in light of the effects of climate change (see Fischer, Blaschke & Bässler, 2011, for a review). Aubry et al. (2005) explored the variation of molluscan species richness along a transect ranging from 100 to 3100 m in southeastern France, including grassland, shrubland and woodland, while Muller et al. (2009) described the altitudinal distribution of molluscs in the forests of the Bavarian Forest National Park, on the border between Germany and the Czech Republic. Sulikowska-Drozd & Horsák (2007) correlated molluscan community composition with altitude, among other environmental variables, in the East Carpathians, Poland.

This study describes the communities of land molluscs in six forest habitats along an altitudinal transect in the Emilia-Romagna region in northern Italy: a maritime pine and oak woodland in Romagna, a poplar and willow woodland in the Pianura Padana, a poplar woodland along the Reno river at the foot of the Apennines, an oak woodland on the hills above the Reno river, a mixed deciduous forest from 650 to 900 m a.s.l. and a beech forest at the watershed with Toscana. These sites, and especially those at low altitude, are all affected by anthropogenic pressures. Our objectives were to evaluate (1) species richness and abundance, (2) the patterns of species rarity and dominance and (3) the differences in composition of the communities among the sites.

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MATERIAL AND METHODS

Study area

The study was conducted in four Natura 2000 sites of the Emilia-Romagna region along an altitudinal transect (Fig. 1): SCI-SPA IT4070010 ‘Pineta di Classe’, SCI-SPA IT4050024 ‘Biotopi e ripristini ambientali di Bentivoglio, San Pietro in Casale, Malalbergo e Baricella’, SCI-SPA IT4050029 ‘Boschi di San Luca e Destra Reno’ and SCI 4050020 ‘Laghi di Suviana e Brasimone’. In the following text, the sites will be referred to respectively as ‘Pineta di Classe’, ‘Ripristini di Bentivoglio’, ‘Destra Reno’ and ‘Lago Brasimone’, for brevity.

Pineta di Classe is a coastal woodland of 0.11 km². It is mostly covered by pine and oak woodland (Pinus pinea, P. pinaster and Quercus ilex). The soil is sandy and calcareous. Ripristini di Bentivoglio is a lowland site (maximum 17 m a.s.l.), originally covered by marshes until the 18th century, then reclaimed and used for rice fields until the mid-20th century. Here woodlands are mostly composed of poplar and willow (Populus alba and Salix alba), and sampling was concentrated in these areas. The soil is calcareous. Destra Reno is a diverse site on the hills south of Bologna, with two main habitats: a poplar woodland along the right side of the Reno River, and an oak woodland (Knautio-Quercetum pubescentis and Ostryo-Aceretum opulifolii) on the hills above. The river woodland lies between 50 and 70 m a.s.l., while the oak woodland lies between 80 and 370 m a.s.l. The soil is calcareous. Lago Brasimone is a site in the Apennines, near the watershed with Toscana. It has the greatest elevation range, from 600 to 1,250 m a.s.l. The site is covered by two main habitats: mixed deciduous forest with oak (Quercus cerris, Q. pubescens), hornbeam (Ostrya carpinifolia, Carpinus betulus) and chestnut (Castanea sativa) between 650 and 900 m a.s.l. and by extensive almost pure beech forests (Fagus sylvatica) above. The soils are mostly acidic.

Relative distances among sites are of the order of tens of kilometres. Pineta di Classe is 75 km from Ripristini di Bentivoglio, which is 30 km from Destra Reno, which is 35 km from Lago Brasimone. Within the last two sites, the different habitats investigated are contiguous. Distance among sampling stations within sites are in the order of 1 or a few kilometres. Whenever possible, locations have been cited in order from lowland sites to montane sites. Table 1 summarizes the details of each site and the sampling stations within them. Further details are given in Supplementary Material, Appendix 1.

Sampling and sorting techniques

Sampling was carried out from April to early June 2012. In each habitat, areas of c. 1 km² were randomly chosen. Each 1 km² area is designated as a ‘station’, to avoid confusion with the concept of a Natura 2000 ‘site’ where the samples were collected. At each station, three quadrats of 10 × 10 m were selected randomly and each was searched by a single operator for 30 min. In addition, five samples of 2 l of leaf litter and soil were collected outside the visual search quadrats. These samples were air dried and sieved down to a 0.5-mm mesh. All visual searches were carried out during daylight. This might have a reduced efficacy for slugs (Wäreborn, 1969), which are more active at night, but it is not expected significantly to affect the results for snails (Ward-Booth & Dussart, 2001).

Data analysis

Analysis was based on data obtained by merging living and dead individuals and all replicates for each station. Overall, this study is based on 20,099 individuals, collected at 50 stations along the transect. To evaluate sampling saturation, sample-based species accumulation curves were constructed. Then, the Chao 1 estimator (Chao, 1984; Colwell & Coddington, 1994) was computed after 500 randomizations, to estimate the potential number of species present in each habitat. Both analyses were performed with the software EstimateS v. 8.2.0 (Colwell, 2009). Comparison of species richness among habitats was performed by individual-based rarefaction by standardization to the smallest sample size (beech forest at Lago Brasimone) using the PRIMER-E v. 6 package (Clarke & Gorley, 2006), as suggested by Gotelli & Colwell (2001).

Multivariate analysis was performed by clustering samples with the Jaccard index on presence-absence data. Then, nonlinear Multi-Dimensional Scaling (nMDS) was performed on
abundance data after standardization and square-root transformation and using the Bray-Curtis similarity coefficient. Statistical tests were performed by one-way ANOSIM (Clarke & Green, 1988). All multivariate analyses were carried out with the PRIMER-E package (Clarke & Gorley, 2006). The species-samples abundance matrix on which analyses were conducted is given in the Supplementary Material, Appendix 2. Heterogeneity among stations within sites and habitats was examined using Whittaker’s I (Koleff, Gaston & Lennon, 2003).

Identification and taxonomy

Nomenclature follows the Fauna Europaea project (Fauna Europaea, 2012). Details on taxonomic and faunal issues can be found in Albano et al. (2013). Authorities for the taxa treated here are given in Supplementary Material, Appendix 2. Identified material is deposited at the Museo di Zoologia dell’Università di Bologna (MZUB).

RESULTS

Sampling saturation

Estimates of species richness are reported in Table 1, derived from accumulation curves and Chao1 estimator curves for the different habitats (Supplementary Material, Appendix 3). Saturation was substantially achieved at the lowest elevations (below 100 m): Pineta di Classe (30 species estimated vs 29 observed), Ripristerini di Bentivoglio (21 species estimated and observed) and the riverine forest of Destra Reno (36 vs 35 species). The mixed-deciduous forest and the beech forest at Lago Brasimone were also almost saturated (19 vs 18 species, and 15 vs 13 respectively). On the contrary, saturation was not achieved in the oak forest on the hills of Destra Reno (37 vs 28 species, a difference of 32.1%).

Habitat richness and abundance

Total observed species richness (S), species richness standardized to the smallest sample size (Srar) and estimated species richness (SChao1) are shown in Table 1. While S varied remarkably among habitats, Srar showed a much more even trend. Mean observed species richness (α) among stations within sites (Table 1) varied much more, but with maximum (Ripristerini di Bentivoglio) and minimum (Lago Brasimone) values in the same locations. Considering as the predictor variable the altitude of each station, both S and Srar showed a slight decrease from lowland to montane sites, but only the former proved significant in a generalized linear model (y = −0.009x + 14.905, P < 0.05, Poisson distribution).

As confirmed by Whittaker’s I (Table 1), the greater variation in mean S of stations among sites than among site totals indicates different levels of heterogeneity within sites, with those at the highest altitudes showing the greatest differences among stations. The richest site (Ripristerini di Bentivoglio) was also the most uniform among stations. Species abundance at each habitat, in terms of number of individuals per station (N), is reported in Table 1. The range is far greater than for species richness; Ripristerini di Bentivoglio has around 20 times as many individuals per habitat as the Beech forest at Lago Brasimone.

Species frequency and abundance

The rarity of species was analysed both by analysing species represented by few individuals and in terms of species found only in few stations (Table 1). The lowland habitats at Pineta di Classe and Ripristerini di Bentivoglio were characterized by a large number of species represented by many individuals with very few singletons (species represented by a single individual in
each habitat) and doubletons (species represented by two individuals in each habitat). Ripristini di Bentivoglio in particular had no singletons or doubletons. In Destra Reno these figures were 4 (11%) singletons and 6 (17%) doubletons in the riverine poplar forest and 6 (21%) singletons and 2 doubletons (7%) in the oak woodland on the hills. Similarly in Lago Brasimone there were 3 (17%) singletons and 4 (22%) doubletons in the mixed deciduous forest and 3 (23%) singletons and 1 (8%) doubletons in the beech forest. These differences clearly relate to overall abundance in each habitat.

The spatial rarity of the species was analysed in terms of uniques (species found at a single station only) and duplicates (species found at two stations only) (Fig. 2). Uniques were very few in lowland habitats, but were up to ~40% in Destra Reno and Lago Brasimone. Duplicates were more common in lowland sites (20–30%) but usually less (below 20%) in Destra Reno and Lago Brasimone.

![Graph showing the percentage of species in different habitats](image)

**Figure 2.** Uniques (grey) and duplicates (black) in each habitat. Site abbreviations: CLA, Pineta di Classe; BEN, Ripristini di Bentivoglio; DRE-R, Destra Reno, poplar woodland along river; DRE-H, Destra Reno, oak woodland on hills; BRA-M, Lago Brasimone, mixed-deciduous forest; BRA-B, Lago Brasimone, beech forest.

### Table 2. In the first three rows, the three most dominant species (D1, D2, D3) are listed with the number of individuals and their dominance.

<table>
<thead>
<tr>
<th>CLA</th>
<th>BEN</th>
<th>DRE-R</th>
<th>DRE-H</th>
<th>BRA-M</th>
<th>BRA-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Pomatias elegans</td>
<td>4,817 (52.4%)</td>
<td>Helix lucorum</td>
<td>1,726 (31.6%)</td>
<td>Pomatias elegans</td>
</tr>
<tr>
<td>D2</td>
<td>Punctum pygmaeum</td>
<td>1,438 (15.6%)</td>
<td>Pomatias elegans</td>
<td>1,199 (21.9%)</td>
<td>Carychium</td>
</tr>
<tr>
<td>D3</td>
<td>Bulgarica denticulata</td>
<td>900 (9.8%)</td>
<td>Truncatellina cf. callicratis</td>
<td>822 (15.0%)</td>
<td>Punctum pygmaeum</td>
</tr>
<tr>
<td>NR</td>
<td>20 (69%)</td>
<td>11 (52%)</td>
<td>20 (57%)</td>
<td>20 (71%)</td>
<td>12 (67%)</td>
</tr>
</tbody>
</table>

In the last row (NR) there is the number and percentage of rare species represented by less than 1% of total abundance. For site abbreviations, see Table 1.

### Table 3. Species found in only one habitat.

<table>
<thead>
<tr>
<th>CLA</th>
<th>BEN</th>
<th>DRE-R</th>
<th>DRE-H</th>
<th>BRA-M</th>
<th>BRA-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Columella edentula</td>
<td>–</td>
<td>Macrogastra attenuata</td>
<td>Platyla stussineri</td>
<td>Argna biplicata</td>
<td>Aegopinella pura</td>
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<td>Lauria cylindracea</td>
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<td></td>
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<td></td>
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<tr>
<td>Bulgarica denticulata</td>
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<tr>
<td>Cochlicella acuta</td>
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<tr>
<td>Trochoidea trochoides</td>
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</table>

For site abbreviations, see Table 1.
may be particularly strong in oligotrophic areas (Cameron & Pokryszko, 2004). While it is clear that further studies in these rather poor habitats should increase sampling intensity, the local heterogeneity probably reflects real differences among stations; we provisionally take the observed trends as reflecting real changes rather than as sampling artefacts.

Variation of species richness and abundance along the transect

As far as the mean number of species per station (α) is concerned, the locations could be divided into two groups: high diversity locations at low altitude (from 0 to 70 m a.s.l.) and low diversity locations at higher altitude (from 80 to 1,200 m a.s.l.). A trend of slight but progressive impoverishment towards the highest altitudes is also supported by the linear models. Species abundance also decreased from lowland to montane sites. Both declines could be correlated with transition from eutrophic and calcareous sites to oligotrophic and acidic sites. In similar nutrient gradients, species richness was observed to decrease with decreasing nutrients both at the regional scale (e.g. Pokryszko & Cameron, 2005 for North Europe) and the local scale (Waldén, 1981; Cameron & Pokryszko, 2004). We did not see the marked mid-altitudinal peak, which is the general pattern in altitudinal studies (Rahbek, 1995) and which was found also in molluscan diversity by Anbry et al. (2005). Our pattern was closer to the decrease with altitude observed by Müller et al. (2009) (but whose transect ended at 650 m a.s.l.). However, our sampling design was focused on habitats and not specifically on elevation intervals. Detection of any mid-domain effect would need more samples in a transect in which, for example, soil and rock types varied less than here.

Patterns of species rarity and dominance

While the observed rarity of some species may reflect sampling problems, there are some clear differences among abundant and locally dominant species. Where Pomatias elegans is present, it tends to dominate the molluscan community and to be ubiquitous at the site. The major exception was observed in the beech forest of Lago Brasimone, where the most acidic soils are encountered, constituting a major obstacle to the presence of this calcicolous species (Kerney & Cameron, 1979) which was absent there. Retiella olivetorum was found only in oak and mixed-deciduous forest woodland, but it was particularly common and widespread in low-altitude oak woodland. The alien species Bulgarica denticulata was among the most abundant species of Pineta di Classe and was found at each station. The size of dominant species is remarkably smaller in the montane forests of Lago Brasimone; here only the tiny Punctum pygmaeum and Vitrea subrimata dominate the community. These species are typical of northern European forests. This is again possibly related to the oligotrophy and colder temperatures of higher-elevation habitats.

Composition of the communities across the transect

When species composition is considered, it is easy to discriminate between all habitats as they have low levels of similarity computed by the Jaccard index. This is not always the case if relative abundances are also considered. The nMDS of Figure 4 and the corresponding ANOSIM test do not reveal any significant differences between the two forest types at Lago Brasimone, as a consequence of the dominance of the same tiny species Punctum pygmaeum and Vitrea subrimata, coupled with sharing nine species between them.

The lowland habitat at Ripristini di Bentivoglio is the only one not hosting exclusive species. It is also the most uniform habitat in terms of sample heterogeneity evaluated by Whittaker’s I. On the other hand, the maritime Pineta di Classe and the mid- to high-altitude habitats have several exclusive species (up to one third of each of the faunas of the two habitats of Lago Brasimone), implying that an altitudinally and vegetationally diverse network of protected areas is needed to conserve the regional land-mollusc biodiversity.

Comparison with other European land-mollusc forest faunas

The maximum observed species richness at any of our sites was 35 in the poplar woodland of Destra Reno (its Chao1 estimation being 36), 29 at Pineta di Classe (its estimation being 30) and 28...
in the oak woodland of Destra Reno (its Chaon estimation being 37, however). The other habitats had less than 21 species each, whether observed or estimated. Richness at single stations (the statistic most readily compared with other studies) was never greater than 25 species (poplar woodland of Destra Reno) and below 17 species in all other habitats. It is important to highlight that these numbers include slugs, which have an increasing weight on the total diversity with altitude. The survey of habitats along an altitudinal transect with diverse vegetation certainly contributed to differences among the faunas studied.

In contrast, in northern and central Europe, high local diversity and a low regional diversity are shown by the low differentiation in the faunas among sites (Pokryszko & Cameron, 2005). For example, in woodlands of southern England the observed species richness at each station was usually above 30, considering only snails (Cameron et al., 2006). If slugs were added, the figure was 40 or above. However, the major feature of those snail faunas was their uniformity, as evidenced both by a low Whittaker’s I index and a high similarity (overall mean similarity among sites by Nei’s index 82.5 ± 0.25). A wider-scale work on the land-snail faunas in Polish forests (Cameron et al., 2010) reported mean station species richness in each investigated area above 19 and up to 36.4, with single-sample richness up to 41. Again, slugs were not considered. Whittaker’s index values were higher than in England and closer to our values, but regional heterogeneity was low, as the high values of the Simpson index of similarity demonstrated. Even the snail forest faunas of northern Italy, with notes on the date of settlement of the alien species Bulgarica denticulata. Bollettino Malacologico, 49: 81–101.


**REFERENCES**


