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ORIGINAL PAPER

Dry stone walls favour biodiversity: a case-study from the Appennines

Raoul Manenti

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Abstract One of the classical and traditional wall typology built in agricultural or pastoral landscapes are dry stone walls (walls built only of stones without concrete). These vertical surfaces are expected to increase habitat heterogeneity and to play an important role for biodiversity. This study focused on two groups of organisms: amphibians, represented by the rock-dwelling salamander *Hydromantes strinatii*, that are expected to use walls mainly as shelters, and molluscs, which use of walls may be affected mainly by the trophic resources available. A mountain area of the northern Appennines (NW-Italy) was surveyed to assess the differences between dry stone walls and the wall typologies in terms of morphology, surrounding landscape and salamander and mollusc occurrence; the relationships between wall typology features and salamander and mollusc distribution were assessed. Dry stone walls were more heterogeneous than concrete walls and hosted more lichens than natural rocky walls. They were more used by *H. strinatii* juveniles than the other walls and played an important role for their distribution. They were positively related to the occurrence of several molluscan species, including species with high ecological plasticity and rock-dwelling species. Among wall features, the most important for molluscs species distribution was vegetation cover, followed by lichen cover and heterogeneity, confirming the importance of trophic content for mollusc exploitation, while vegetated without concrete walls hosted higher number of species. The results suggest that dry stone walls can be important for fauna biodiversity and should be maintained and preserved as a part of landscape management.

Keywords Stone wall · Biodiversity · Landscape ecology · Salamander · Snail · Agricultural

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R. Manenti (✉)
Dipartimento di Bioscienze, Università degli Studi di Milano, Via Celoria, 26, 20133 Milan, Italy
e-mail: raoul.manenti@unimi.it

Introduction

A variety of natural and artificial rocky vertical surfaces can be found in mountainous and hilly areas. Humans add to natural rock vertical surfaces with a variety of wall typologies for terraced cultivation or the construction of retaining structures. To obtain space to cultivate forage for livestock in steep slope areas, humans have been building terraces supported by dry stone walls (e.g., walls built only of stones without concrete or mortar) since prehistory. Dry stone walls are abundant across the managed landscapes of Europe, Asia, Africa, and the Middle East (Balland 1992; Collier 2013; Larcena 2009). Their pervasiveness results from their temporal scale; in many countries, dry stone walls constitute the only prehistoric retaining or boundary feature that still is used (Collier 2013; Larcena 2009). The ages of dry stone walls has increased their likelihood of exposure to various biotic and abiotic factors, allowing for the establishment of peculiar communities. Interest has increased regarding these long-standing anthropogenic structures, which are considered true habitats with great potential value for landscaping (Collier 2013). Dry stone walls can be found throughout the Mediterranean and in the Alps and Appennines regions, where they often are used as retaining walls for terracing (Makhzoumi 2000), and throughout central and northern Europe, where they are used as field boundaries (Collier 2013; Marshall and Moonen 2002).

During the past decades in the southern Alps and northern Appennines, the relinquishment of traditional agricultural and pastoral activities has allowed forests to regain part of their ancient territories, with advantages for wildlife in general. However, the traditional practice of dry stone wall building has diminished concomitantly. Many of the old traditional walls have not been maintained and have collapsed, and newer artificial vertical surfaces generally have been built as retaining structures for roads or buildings and are made with concrete. These newer walls are compact with few crevices and shelters except for several drainage holes. This situation poses important conservation questions, and an assessment of the biodiversity value of dry stone walls is warranted.

Since the 1980s, walls have been considered important for biodiversity and suitable as a habitat for several flora in urban areas. The popular text of Darlington (1981) brought the potential value of walls as habitats to the public's attention. Wall ecosystems are best defined by their physical and environmental features, which determine their capacity to act as habitats and sustain biota. Many of these characteristics are interconnected, as with all ecosystems, but a key role is played by the physical substrates and nutrients comprising the wall (Francis 2011; Darlington 1981). Dry stone walls are at least as widespread as landscape structures as hedgerows and linear woodlands, which have been investigated extensively. However, the biodiversity value of dry stone walls has been overlooked by empirical studies (Collier 2013). Most research efforts in this area consist of botany studies. For instance, in western Ireland (Holland 1972), dry stone wall boundaries were found to constitute a distinctive habitat promoting rich and diverse plant growth.

Studies examining the importance of dry stone walls to the conservation of fauna biodiversity are scarce (Collier 2013). In a survey of habitats in various agricultural areas, Dover et al. (2000) found that dry stone walls can facilitate the abundance and species richness of butterflies. In an extensive survey of the effects of landscape composition on the similarities of plant and animal communities, Dormann et al. (2007) reported a reduced exchange of species in landscapes dominated by agricultural activities. However, when these authors described the existence of margin structures, they did not account for the potential role of dry stone walls and field margins. An empirical assessment of dry stone walls as promoters of biodiversity, ecosystem linkages or corridors, platforms for supporting endemic flora and fauna, and wildlife shelters in exposed or managed areas (Collier 2013) can have broad interest for conservation and managing purposes worldwide, and especially throughout Europe. The present study focused on amphibians and molluscs because they are distinctly impacted by specific morphological aspects of dry stone walls, namely nutrient availability and shelter.

Walls containing crevices and holes can provide important shelters for amphibians, as reported by (Tanadini et al. 2012) in a study of salamander distribution throughout a vineyard-dominated landscape. These authors reported that dry stone walls could promote salamander occurrence by serving as a useful refuge, even if they are situated along roads. Among amphibians, plethodontid salamanders are highly capable of exploiting vertical surfaces in terrestrial habitats and may be useful in an assessment of the role of surface features as shelters and habitats. *Hydromantes* are lungless rock-dwelling salamanders that exploit vertical surfaces during the wet season (from October to March) in Italy. *Hydromantes* typically are found in caves and other cavities during the dry season from May to September (Ficetola et al. 2013). *Hydromantes* also live in rocky areas from autumn to early spring (Salvidio 1992). Their distribution also may depend on the availability of their invertebrate prey (Ficetola et al. 2012). *Hydromantes* exhibit trophic complexity and occupy many habitats and microhabitats.

Terrestrial molluscs are an attractive model for understanding the role played by various wall typologies in the conservation of biodiversity. Ecological studies of terrestrial molluscs indicate mutual selection between habitats and molluscs and provide parameters for the effective management of both natural and agricultural landscapes for conservation purposes (Bloch et al. 2007; McClain and Nekola 2008). Terrestrial gastropods, including species that are not strictly rock-dwelling, often exploit rocky areas, walls, and other vertical creviced surfaces to look for food. These species often feed on lichens living on or within rocky surfaces (Baur et al. 2007a). Baur et al. (1995) report six species of land snails on the dry stone walls in a Swedish locality, with two lichen feeders (*Chondrina clienta* and *Balea perversa*) being particularly abundant.

Mollusc richness and abundance can be influenced by various environmental factors, including humidity, rainfall, vegetation cover, soil features, leaf litter abundance, and anthropogenic pressures (Patil et al. 2012). At local and landscape levels, moisture, temperature, calcium content, and soil texture are important predictors of mollusc composition (Nekola 2003). Rainfall levels also are crucial, as rains favour the physiological constraints of molluscs and can affect terrestrial gastropod biodiversity through primary productivity (Tattersfield et al. 2001). In mountain areas, the habitat preferences of most Gastropods species are associated with vegetation cover and leaf litter abundance on the ground (Baur et al. 2007a).

The aim of the present study was to assess whether traditional dry stone walls play a positive role in biodiversity, compared with other wall typologies and with natural and artificial wall compositions in a locality of the northern Appennines (northwest Italy). This study focused on the differences between dry stone walls and other wall typologies in terms of morphology, surrounding landscape features, and the occurrence of salamanders and molluscs. We verified which wall features affected the distribution of *H. strinatii* adults and juveniles with a focus on traditional dry stone walls. We also examined which wall features were important for species distribution and richness of land gastropods and whether dry stone walls hosted more species than other walls.

Materials and methods

Study area

The study area was situated in the northern Appennines in the Genoa district, Liguria, Italy, around the ancient village of Roccatagliata between the Lavagnola and Caucaso mountains (lat: 44°28′21″N long: 9°12′03″E) in the Neirone municipality (Fig. 1). The study site was located 610 m above sea level and comprised the catchment basin of the Lavagna stream, which feeds into the Ligurian Sea. In this locality, livestock farming was widespread until the 1960s. During the autumn and winter, livestock were housed in barns, and transhumance (mobile pastoralism) was practiced on the slopes of nearby mountains from late spring until the end of summer. Around the villages, terracing with dry stone walls was common and still persists today in the landscape with terraces either still managed or abandoned. Maintained terraces usually are covered with grass that is cut twice a year to pasture livestock or are cultivated with potatoes or as vegetable gardens for domestic use. Abandoned terraces are covered with xerophile broadleaved woods with a predominance of *Quercus robur* and some *Erica arborea*. These terraces are surrounded by mesophile woods with an abundance of *Fagus sylvatica* populating natural rocky wall outcrops.

In northern Europe, the vegetation cover of field margins occurs on either side of dry stone walls. Field margins are less sensitive to field productivity and management than the fields themselves (Smart 2002) and contribute increased habitat heterogeneity in exposed landscapes (Collier 2013; Dover et al. 2000; Marshall and Moonen 2002). In terraced landscapes, margins occur only on one side at the wall base and at the top of the wall. Their vegetation generally does not differ from the cover of the terraces themselves as the terraces are managed and exploited for their entire surface. This study focused on the

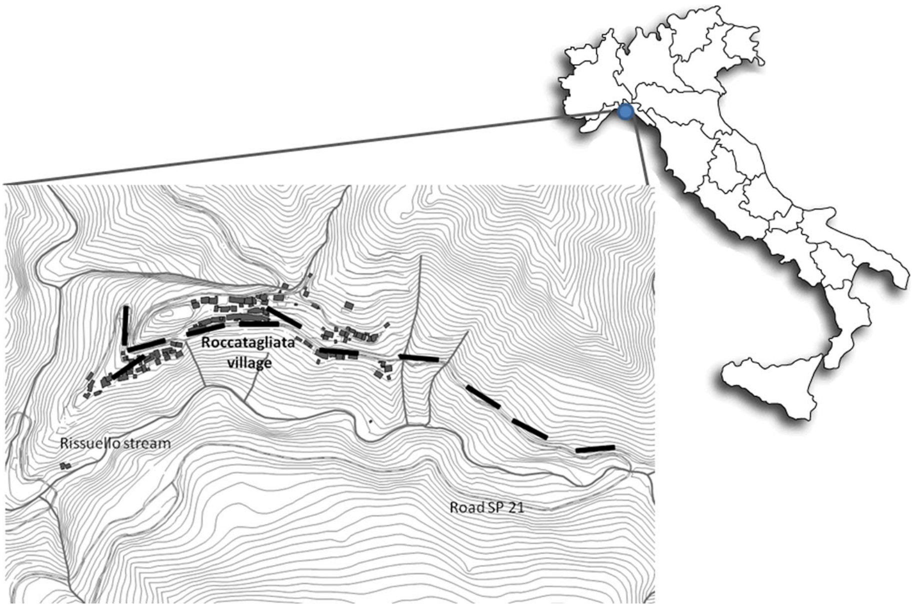

Fig. 1 Study Area. *Black stretches* show surveyed walls

specific role of dry stone walls and their relationships with surrounding habitats considering the whole walls and surrounding cover. Four vertical surface topologies were considered: (1) total concrete walls; (2) natural rocky walls of various heights characterized by sections of local, potentially fractured sandstone rock; (3) traditional dry stone walls; and (4) walls composed of stones with binding mortar that likely were the products of recent rushed restorations of dry stone walls (marginally considered).

Surveys

During the Apennine wet season, from October 2012 to January 2013, night surveys were conducted along all of the wall typologies. Eleven different walls were surveyed and divided into homogenous, 5-m sectors of the same typology (i.e., concrete, natural rock, dry stones, and stones with mortar) with 5 m between each sector, for a total number of 88 sectors covering all of the available wall typologies (dry stone walls: 21 sectors; natural rocky walls: 28 sectors; concrete walls: 32 sectors; and stones with mortar walls: 7 sectors). Each sector was monitored 3–8 times (mean, 4). During the first part of the night (9:00 p.m.–1:00 a.m.), each sector was monitored with a powerful flashlight to detect the occurrence of any active molluscs or *H. strinatii*. Similar to their distribution in caves, *H. strinatii* specimens of different age stages displayed distinct ecological requirements (Ficetola et al. 2013). *H. strinatii* specimens were divided into adults and juveniles, with individuals shorter than 60 mm and without visible sexual characters regarded as juveniles. Shells were collected for species identification, but only live and active molluscs were evaluated on the wall surfaces. During each survey, precipitation was noted, and climatic conditions, such as air temperature and humidity, were recorded with an EM882 multi-function thermo-hygrometer.

The following three wall typologies were distinguished primarily: traditional dry stone walls, natural rock walls, and concrete walls. Walls of mortar and stones were regarded as intermediates between concrete walls and dry stone walls and were assigned to both dry stone walls and concrete walls with an intermediate score of 0.5. Three features related to wall morphology, quality, and structure with relevance to the occurrence of amphibians and molluscs were recorded, as follows: (1) maximum wall height for each sector; (2) number of holes with a dimension of 10 cm in width and at least 20 cm in depth in each sector; and (3) to detect the role of smaller crevices, the maximum wall heterogeneity (i.e., richness of the clefts (Camp and Jensen 2007)) of each sector was measured by placing a string of 1 m in the most heterogeneous and fractured part of the sector and measuring the distance between the two string extremities using a measuring tape.

To evaluate the biotic features of the walls, the following three parameters were evaluated: (a) vegetation cover, measured as the number of interceptions that a sharp wood pole (80 cm long) received from vegetation (e.g., grass stems, blackberry bush leaves) when laid parallel to the surface of the walls at the middle of the sector; (b) cover of the moss, scored as scarce if it covered less than 10 % of the sector, medium if it recovered at least 30 % of the sector, and abundant if it recovered more than 30 % of the sector; and (c) mean lichens cover, measured by the level of their cover over the sector as absent (0) if no lichens were observed on the wall, scarce (1) if lichens covered less than 5 % of the sector, medium (2) if lichens covered at least 20 % of the sector, or abundant (3) if lichens covered more than 20 % of the sector. For this measure, each sector was divided into three parts of the same area from top to bottom. Lichens cover was evaluated, and then the average cover of the sector was calculated. Lastly, the environment surrounding each sector was recorded, taking into account the percentage of wood cover, grass cover, and concrete cover in squares of 25 m^2 surrounding the top of the walls in each sector so as not to superimpose the area on top of the other sectors. Each square was divided in 25 smaller squares, and in each one the predominating cover type was assessed (i.e., grass, wood, or concrete). The percentage of squares with these cover types then was assessed. The sector surrounding the surface at the bottom of the wall was not considered because it was covered by a local paved road and it was similar for each sector.

Statistical analysis

Detectability analysis

A site was considered "occupied" if a species of interest was found at that site, but the inability to detect any species during all sampling occasions did not necessarily indicate that the species was absent (MacKenzie 2006). This sampling approach could lead to an underestimation of occupancy and might influence the results of analyses by increasing the risk of data overinterpretation with type-II errors being potentially significant. PRESENCE 5.5 (Hines 2006) was used to assess the probability of detection per visit as well as the probability of occupancy (psi) of the species. PRESENCE is a powerful method for estimating the probability of site occupancy in situations where a species is not guaranteed to be detected even when it is present at a site. It describes the probability of detecting a species and the number of surveys using a probabilistic argument to describe the observed detection history for a site over a series of surveys (MacKenzie et al. 2002).

For the sectors data set, it was assumed that the probability of detection of a species of interest during a given survey might be affected by five survey-specific covariates: air temperature, percent humidity, date, hour of survey, and whether it was raining. Models were constructed for each species, assuming that the detection probability likely depended on all possible combinations of these covariates. The model with the lowest Akaike's information criterion and the highest weight was considered the minimum adequate model describing species detectability (Burnham and Anderson 2002). The misdetection rate was calculated as the percentage difference between the observed occupancy and the occupancy estimated from the best PRESENCE model for each species occupancy.

Hydromantes species show high detectability levels when they are in caves during the dry season (Ficetola et al. 2012; Salvidio 2013). However, the misdetection rate for both juveniles and adults was 10 %. Mollusc species can be very difficult to detect because, on a rainy night, only a small number of specimens of a certain population may be active (Heller and Ittiel 1990). To avoid data overinterpretation, species that were observed in less than 3 % of the sectors were excluded from the analysis. In the surveys, apart from the species *Charpentiera itala*, *Cryptomphalus aspersus*, and *Arion distinctus*, the misdetection rate was more than 5 %. Thus, for *H. strinatii* and for the molluscs with a misdetection rate exceeding 5 %, analyses were used that accounted for species distribution, with the probability of occupancy at a given sector (as estimated by PRESENCE) as the dependent variable instead of the observed "naive" absence/presence.

Wall features and differences between wall typologies

An unconstrained redundancy analysis (RDA) evaluating the relationships between wall features and surrounding habitat features was built, with wall features defined as the unconstrained matrix, and the surrounding habitat regarded as the constrained matrix. The RDA is a canonical analysis that combines the proprieties of regression and ordination techniques and that evaluates how much of the variation of the structure of one dataset (e.g., community composition in a wetland, endogenous dataset) is explained by the independent variables (e.g., habitat features, exogenous datasets) (Borcard et al. 2011). Dry stone walls then were compared with concrete and natural rocky walls in terms of shelter and food availability for *H. strinatii* and molluscs, using as variables the heterogeneity; number of holes; and moss, vegetation, and lichen cover. We also evaluated differences in the probabilities of occupation (use) by *H. strinatii* juveniles and adults and the number of mollusc species observed. These analyses were performed using ANOVA with the Tukey post hoc test (Gardener 2012).

Hydromantes strinatii and wall features

Generalized linear models with normal error distributions were used to assess the relationships between the observed distributions of *H. strinatii* juveniles and adults and wall types and features. To remove multicollinearity and to limit the number of candidate models, principal component analysis (PCA) with the varimax rotation strategy (Legendre and Legendre 1998) was used to reduce correlated variables to a smaller number of uncorrelated factors. Five components were obtained that explained 86 % of the original variation from environmental variables. To take into account the heterogeneity between the 11 walls to which the 88 sectors belonged, wall identity was included as a random factor in the models.

Molluscs and wall features

A series of constrained RDA were performed to evaluate the relative roles of wall typologies and features on the multivariate structure (i.e., species composition) of molluscan communities, considering the ten species (that were observed in more than 3 % of the sectors. To avoid type-II error, RDA were performed assuming for species a conditional psi (probability of occupancy at a given sector as estimated by PRESENCE) as the endogenous dataset. As the exogenous dataset, two matrices of wall features were considered: wall typology and wall morphology and cover. As reported previously (Kerney and Cameron 2006; Welter-Schultes 2012), the 10 species considered could be described as follows: (1) species often associated with rocky habitats, such as *C. itala*, *Oxychilus draparnaudi*, and *Ena obscura*; (2) species with wide ecological plasticity, including *A. distinctus*, *Cepaea nemoralis*, *C. aspersus*, and *Milax* spp.; (3) species often linked to cultivated areas, such as *Cantareus apertus* and *Deroceras. panormitanum*; and (4) an unusual species of conservational value, such as *Testacella scutulum.* To assess the significance of the explained variance by RDA and avoid type-I error, ANOVA-like permutation tests (10,000 permutations) were performed.

Finally, to detect features that affect the use of wall habitats by molluscs, generalized linear models with a normal error distribution were used to assess the relationships between the number of mollusc species recorded and features of sectors as extracted by PCA. To account for the heterogeneity (variation linked to landscape position or other factors) between the 11 walls comprising the 88 sectors, wall identity was included as a random factor in the models. To improve our interpretation, the statistical significance of PCA components was assessed using a likelihood ratio test (Stephens et al. 2007). All of the analyses were performed in the R 3.01 environment using the vegan nlme, car and Himsc packages (Oksanen J 2005; R Development Core Team 2012).

Results

Wall features and differences between wall typologies

The correlation between walls and surrounding habitat features was highly significant (permutation test: $P \leq 0.001$). This relationship explained 29.5 % of variation. The first RDA axis alone explained 22 % of variance. This axis represented herbaceous areas (Fig. 2). The second axis explained 7 % of variation and represented urbanized parts with concrete cover. Dry stone walls and vegetation cover are found in areas with high herbaceous cover. Concrete walls prevails where there are urbanized areas and natural rocky walls are surrounded by wood cover. Lichens are found mainly in areas with concrete and herbaceous cover. The most heterogeneous walls occur in herbaceous and wood areas.

Considering wall typologies, no significant differences were recorded between them and the level of moss cover, the level of vegetation cover and the number of holes. However there was a significant difference in heterogeneity ($F = 21.87$, $P \leq 0.001$). In particular, concrete walls have a significantly lower heterogeneity than dry stone walls ($P < 0.001$) and natural rocky walls ($P < 0.0001$). The difference between dry stone walls and natural rocky walls was not significant.

Another significant difference concerns the lichen cover ($F = 7.63$, $P < 0.001$). Both dry stone walls ($P < 0.01$) and concrete walls ($P < 0.0001$) harbour higher levels of lichens cover than natural rocky walls.

Moreover there is a significant differences in *H. strinatii* juveniles occupancy of the different wall typologies ($F = 6.96$, $P < 0.0001$). In particular dry stone walls are significantly more used by juveniles than concrete walls ($P < 0.0001$) and natural rocky walls ($P < 0.001$).

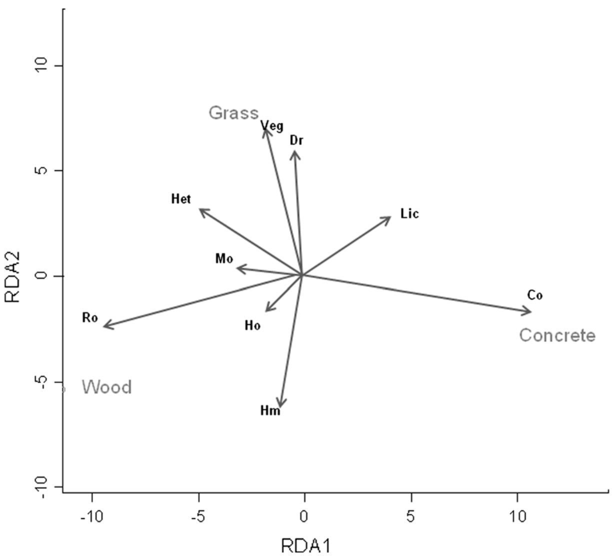

Fig. 2 Constrained redundancy analyses showing the relationship between wall features and surrounding habitat features. *Ro* natural rocky walls, *Co* artificial concrete walls, *Dr* dry stone walls, *Veg* vegetation cover, *Mo* moss cover, *Lic* lichen cover, *Het* wall heterogeneity, *Ho* holes, *Hm* maximum height. Constraining variables are represented by *grey arrows*

No significant differences occurred for *H. strinatii* adults occupancy and number of molluscs species recorded.

Salamanders and walls features

The presence of juveniles cave salamanders was significantly related to component 3 extracted by PCA (Table 1, $P < 0.001$) indicating dry stone walls with high lichen and moss cover. The presence of adults was not related to any of the selected components.

Molluscs and wall features

Among the whole 88 sectors surveyed, 18 gastropod species active on their vertical surfaces were recorded (Tables 2, 3). The most widespread species were the slug *Deroceras panormitanum* and the snails *Charpentiera itala* and *Cryptomphalus aspersus* (Fig. 3).

The relationship between the ten species and wall typologies was significant ($P < 0.01$) and explained 7 % of variation (Fig. 4). The first RDA axis was represented by dry stone walls and explained 63 % of the variance described by the RDA. The snail *C. aspersus* and the slugs *Milax* sp and *Arion distinctus* were the species more related to it. To dry stone walls was also positively related a typical rock-dwelling species as *E. obscura* (Fig. 2). *O. draparnaudi* was related to natural rocky walls and *C. itala* to concrete ones. The relationship between molluscs and wall features was significant too ($P = 0.02$) and explained 13 % of variance. The first axis represented a gradient between high, without vegetation cover and poorly heterogeneous walls to small and highly vegetated ones.

D. reticulatum, C. nemoralis and *C. apertus* were the species mostly linked to highly vegetated walls.

The number of species was positively related to component 5 extracted by PCA indicating highly vegetated without concrete walls ($P < 0.0001$).

Discussion

Dry stone walls differed from other wall typologies in terms of the surrounding habitat, morphology, and biotic features. Dry stone walls were situated in areas generally surrounded by a high grass cover, likely deriving from previously abandoned cultivations. As expected, these walls were more heterogeneous than concrete walls, but they did not significantly differ from rocky walls. Despite being manmade, dry stone walls possessed crevices and potential shelters not unlike natural walls. Stone and concrete walls were associated with increased lichen cover compared with rocky walls, perhaps because they occurred in open areas, whereas natural rocky walls occurred in woody areas. From a biotic point of view, dry stone walls were used more than other walls by *H. strinatii* juveniles. This is confirmed by the fact that the distribution of *H. strinatii* juveniles was positively related to dry stone walls with high lichen cover. Dry stone walls are expected to provide a heterogeneous habitat with shelters for both *H. strinatii* juveniles and their prey (Rebelo and Leclair 2003; Guseinov 2004), and they may be superior to natural rocky walls because lichens and herbaceous surroundings can provide trophic resources for juveniles' prey. Thus, the foraging requirements of juvenile salamanders may be met by the shelters in dry stone walls.

Dry stone walls also are important to various molluscan species, particularly those with high ecological plasticity and an affinity for herbaceous areas, such as *C. aspersus* or *A.*

Table 1 Environmental variables recorded, pairwise correlation among variables, and correlation with five components extracted by a PCA

Variable	RC1	RC2	RC3	RC4	RC5
Height					
r	0.08	−0.79	0.14	−0.17	−0.19
P	0.4552	**0.0000**	0.1943	0.1182	0.0838
Heterogenity					
r	0.48	0.00	0.24	0.06	0.63
P	**0.0000**	0.9828	**0.0272**	0.5994	**0.0000**
Vegetation cover					
r	0.21	0.41	−0.21	−0.15	0.54
P	**0.0471**	**0.0000**	0.0508	0.1677	**0.0000**
Moss cover					
r	0.33	0.07	−0.23	0.73	0.08
P	**0.0016**	0.5451	**0.0276**	**0.0000**	0.4746
Wood cover above wall					
r	0.89	−0.12	0.07	0.00	−0.38
P	**0.0000**	0.2859	0.4994	0.9682	**0.0003**
Herbaceous cover above wall					
r	−0.01	0.32	0.01	0.10	0.84
P	0.9285	**0.0023**	0.9538	0.3470	0.0000
Concrete cover above wall					
r	−0.91	−0.17	−0.06	−0.08	−0.18
P	**0.0000**	0.1204	0.6007	0.4480	0.0896
Dry stone walls					
r	−0.06	0.82	0.27	−0.06	0.19
P	0.5976	**0.0000**	**0.0118**	0.5950	0.0730
Concrete walls					
r	−0.87	0.02	0.02	−0.08	−0.37
P	**0.0000**	0.8316	0.8741	0.4391	**0.0003**
Rocky walls					
r	0.80	−0.41	−0.16	0.09	0.29
P	0.0000	**0.0000**	0.1310	0.4000	0.0055
Lichens					
r	−0.45	0.04	0.46	0.54	−0.05
P	**0.0000**	0.6857	**0.0000**	**0.0000**	0.6474
Holes					
r	−0.27	0.03	0.12	0.04	−0.17
P	**0.0123**	0.7893	0.2778	0.7203	0.1037

Significant correlations are in bold

distinctus, but also typical rock-dwelling species, such as *E. obscura*. The open vegetated areas were mostly terraces that were used for forage production and that are still cut once or twice per year. The level of wood cover in these areas reflects the degree of usage abandonment by humans. These grassy habitats are particularly important for *D.*

Table 2 List of the recorded species, percentage of sectors in which they have been observed and their occupancy estimation (psi = detection probability as estimated by PRESENCE)

Species	% Sectors observed	% Sectors occupied (psi estimate)
Molluscs		
Charpentiera itala	13	14.2
Cryptomphalus aspersus	12	15
Vitrinobrachium baccettii	1.1	
Ena obscura	3.4	7.4
Oxychilus draparnaudi	9.1	15
Cepaea nemoralis	6.8	4.2
Testacella scutulum	5.6	39
Cantareus apertus	6	10
Milax sp.	11.3	43
Arion distinctus	3.4	3.4
Helicodonta obvoluta	1.1	
Cochlostoma septemspirale	1.1	
Limax sp.	1.1	
Tandonia rustica	2.2	
Tandonia sp.	2	
Deroceras reticulatum	1.1	
Higromia cinctella	2.9	
Deroceras panormitanum	18.2	22
Amphibians		
H. strinatii juveniles	30.6	40.9
H. strinatii adults	16	25

Psi has been calculated only fors species occurring in more than 3 % of the sectors

panormitanum and *C. aspersus*. Both of these species are favoured by human land management because they are related to cultivated areas or gardens and may be considered pests for cultivation, especially *D. panormitanum* (Cordoba et al. 2011; Fabian et al. 2012; Iglesias-de la Cruz et al. 2012). The only species strongly related to cemented areas was *C. itala*, a typical rock-dwelling species that feeds on lichens (Kerney and Cameron 2006). This suggests that *C. itala* may favour open areas with compact substrates. Among wall features, vegetation cover played the most important role, providing important trophic resources, exceeding that of lichens, for most species dwelling in or on the walls.

Dry stone walls can provide useful shelters near feeding areas for species exploiting grassy open habitats. In the present study, the number of molluscan species recorded was related to sectors with non-concrete, highly vegetated walls and to sectors with dry stone walls and lichens.

This study represents one of the few attempts to assess the features affecting fauna biodiversity in dry stone walls, using a scarcely analysed area in the Appennines. For species of ecological and conservational value, such as the *H. strinatii* salamanders, dry stone walls promoted the occurrence of juveniles. Previous studies (Baur et al. 1995, 2007b; McMillan et al. 2003) have reported interesting biodiversity in vertical surface communities of molluscs. Moreover, walls and rocky area features may have an important influence on population connectivity and gene flow (Armbruster et al. 2007; Ursenbacher

Table 3 Meteorological conditions influencing species detectability

Species	AIC	W	Suitable model includes as covariate
Molluscs			
Charpentiera itala			
Cryptomphalus aspersus	124.24	0.37	Rain
Vitrinobrachium baccettii	128.05	0.82	All the meteo covariates
Ena obscura			
Oxychilus draparnaudi	42.88	0.45	Humidity
Cepaea hortensis	106.57	0.55	Humidity
Testacella scutulum	63.33	0.9	Humidity
Cantareus apertus	76.85	0.95	Constant detection probability
Milax sp.	106.04	0.34	Rain
Arion distinctus	91.15	0.72	Humidity
Helicodonta obvoluta	35.14	0.69	Temperature
Cochlostoma septemspirale			
Limax sp.			
Tandonia rustica			
Tandonia sp.			
Deroceras reticulatum			
Deroceras panormitanum	127.95	0.468	Rain
Amphibians			
H. strinatii juveniles	163.92	0.92	Humidity
H. strinatii adults	245.17	0.65	Rain

AIC AIC value of the best detection model, *W* weight of the model

et al. 2010). Regarding biodiversity management, this report indicates that walls with vegetation cover and shelter characteristics promote broader biodiversity among amphibians and molluscs. This paper confirms that long-standing anthropogenic structures, such as dry stone walls, can provide suitable habitats for various organisms and can establish a level of biodiversity in managed landscapes (Collier 2013). Our findings may be applicable to research regarding different typologies of European landscapes and the usage of different wall typologies by endemic and widespread species. However further experimental investigation is required especially to assess other factors driving mollusc exploitation of wall surfaces and to understand the role played by dry stone walls as shelters for young salamanders during dry seasons.

Conclusions

The findings of this study highlight the importance of biotic features of wall surfaces for biodiversity. Walls surfaces with high vegetation or lichen cover are suitable for both salamander and mollusc exploitation. This paper underlines that traditional dry stone walls, found in many farming and agricultural landscapes of Europe, play a positive role in biodiversity compared with both natural and other artificial wall typologies. Juveniles salamanders of the genus *Hydromantes* and different species of mollusc, including typical

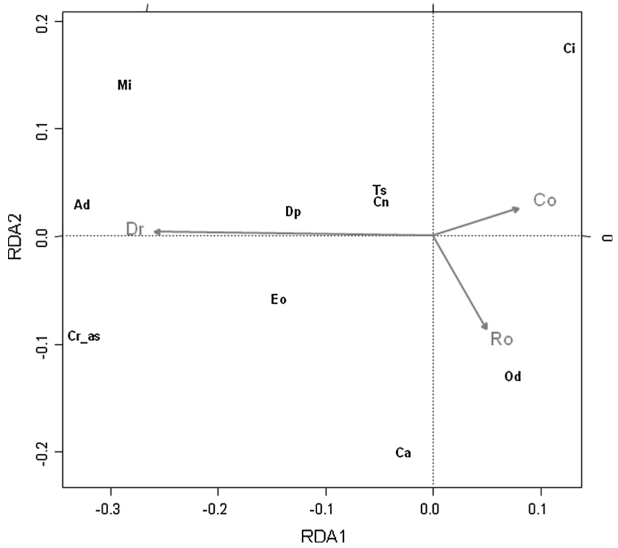

Fig. 3 Constrained redundancy analyses showing the relationship between wall typologies molluscan distribution. Ts, *Testacella scutulum*; Ca, *Cantareus apertus*; Cn, *Cepaea nemoralis*; Ci, *Charpentiera itala,* Ad, *Arion distinctus*; Cr_as, *Cryptomphalus aspersus*; Od, *Oxychilus draparnaudi;* Eo*, Ena obscura;* Dp*, Deroceras panormitanum;* Mi*, Milax* sp. Constraining variables are represented by *grey arrows*

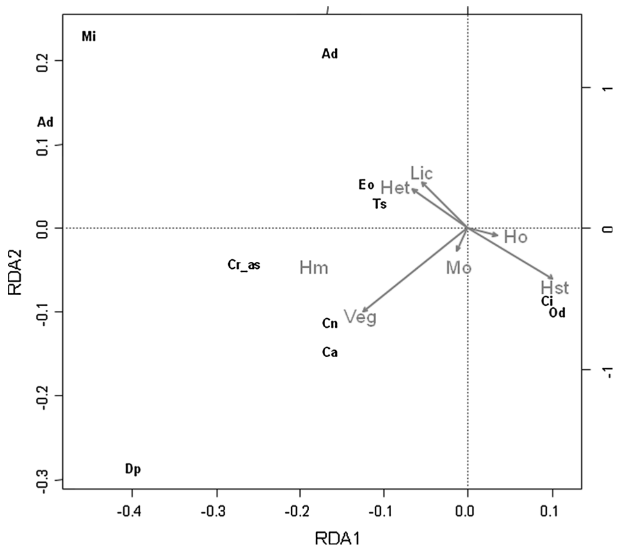

Fig. 4 Constrained redundancy analyses showing the relationship between wall features and molluscan distribution. See Figs. 2 and 3 for acronyms

rock-dwelling species, are linked to dry stone walls. They are more heterogeneous than concrete walls and, at the same time, more covered by lichens that than natural rocky walls as they occur in more open areas. In managed landscapes they are likely to provide both shelters and trophic resources for different rock dwelling organisms. Our findings indicate that landscape management should favour the maintenance of heterogeneous and vegetated wall surfaces.

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