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Managed mountain forests as diversity reservoirs in Mediterranean landscapes: new data on endemic species and faunistic novelties of moths

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Abstract

Mediterranean mountain forests represent hotspots of diversity despite managed for longtime for timber and fruit production. In the last decades their role as biodiversity reservoirs increased also as a consequence of European Union policies that designed some forested habitats as a priority for diversity conservation in the Habitat Directive. Nevertheless, large areas of Mediterranean forests are under-investigated from a faunistic point of view. An increasing number of species having small and isolated populations are from time to time added to the fauna inhabiting Mediterranean forests. In this paper we improved the knowledge on the distribution of endemic species and provide new faunistic data that increase the value of Mediterranean forests as biodiversity reservoirs. Altogether 36 forest stands were monitored in the main mountain forest types of Calabria, namely in beech, chestnut, Calabrian black pine and silver fir forests. We found 10 species considered as Italian endemics and 12 species as new to Calabria, significantly increasing the knowledge on regional fauna. They were more abundant and frequent within the mid and late successional stages of forests than within the early successional ones. Most of them feed on herbaceous plants growing in the understory and this should be taken into account in forest planning. Distributional patterns of endemics and faunistic novelties found in this paper underline the importance of mountain forested habitats in the Mediterranean Basin as biodiversity reservoirs, despite they have been managed for long time.

Key words: biodiversity, moths, forest planning, silviculture, Calabria, Italy.

Introduction

Natural ecosystems are nowadays seriously endangered because of human activities, making biodiversity protection one of the most important goals of ecology (Naveh and Whittaker, 1980). Forests represent the climax vegetation in most of Europe, from the Mediterranean maquis through the deciduous forests of Central and Western Europe to the boreal forests in Northern Europe. In last decades intense human activities impacted on forest plants and animals and some of them are nowadays threatened (Bengtsson *et al*., 2000).

Mediterranean countries show closer interrelations between their flora and major landscapes modified by human activities during the centuries than any other region in the world (Quézel *et al*., 1999). In the last decades the forest management has shifted from timber production to the provision of multiple forest ecosystem services such as biodiversity conservation (Corona *et al*., 2011). Preserving biodiversity at local scale can be one of the most interesting developments of forest management. In fact, a forest planning that promote the coexistence of different successional stages of forest stands in a given landscape fosters the persistence of species of conservation concern linked to different forest ages (Merckx *et al*., 2012). Coupling forest productions with biodiversity conservation is a challenge for the modern silviculture, especially at lower altitude where the economic aspect predominates on conservation (Marchetti *et al*., 2014). In fact, the importance of conservation is generally accepted for beech and silver fir forests, whilst it is often neglected for chestnut and oak forests.

Mediterranean basin is considered a biodiversity hotspot, which presents a considerable tree diversity (Quézel *et al*., 1999), and several endemic plants and animals to preserve (Myers *et al*., 2000). Various forested habitats are recognized as relevant to biodiversity conservation for European Union, and many of them occur in Mediterranean mountains, sometimes as relicts and isolated stands especially in the southern tip of the Italian peninsula (Biondi *et al*., 2010). Some species have a major role in characterizing Natura 2000 habitats in southern Italy (Habitat Directive 92/43/EEC). This is the case of the beech, characterizing the Apennine beech forests with *Taxus* and *Ilex* (code: 9210); the silver fir, characterizing the Southern Apennine *Abies alba* forests (code: 9510); the endemic Calabrian black pine (*Pinus nigra laricio*), characterizing the (Sub-) Mediterranean pine forests with endemic black pines (code: 9530); and the chestnut, managed for longtime for timber and fruit production but characterizing the *Castanea sativa* woods (code: 9260). These forest types altogether cover the 23.7% of the Italian forested surface (www.infc.it), and understanding their value as biodiversity reservoirs assumes a key role to forest management, especially in protected areas such as national and regional parks.

Many threatened animal species find their habitats in Mediterranean managed forests. Among them, endemic species are the best descriptor of how much a habitat can represent a biodiversity "reservoir". In fact, they can be considered as a target for biodiversity conservation because their uniqueness is linked to a given geographic range (Mosseler *et al*., 2003; Callisto *et al*.,

2005; Cabecinha *et al*., 2009; Brin *et al*., 2009; Bonacci *et al*., 2012).

Lepidoptera have often been used as ecological indicators, and in forested habitats it is preferable to use moths instead of diurnal Lepidoptera because more abundant in forested environments (Usher and Keiller, 1998; Summerville *et al*., 2004; 2009). Moreover, moths play a key role in several food chains, and their communities rapidly react to environmental changes in response to climate (Wilson *et al*., 2005) and landscape attributes (Scalercio *et al*., 2012) by modifying species composition. Lepidoptera is also among the most studied invertebrate groups. Small and isolated populations are more prone to extinction risks due to genetic impoverishment (Bürger and Lynch, 1995), and more important from a conservation point of view because sometimes these populations have unique genetic lineages (Zakharov and Hellmann, 2008; Hausmann *et al*., 2013). Southern Italy forested habitats have been poorly explored and many faunistic novelties, usually having small and isolated populations, are from time to time added to its lepidopteran fauna (Efetov *et al*., 2011; Scalercio, 2014a; Badano *et al*., 2015; Infusino and Scalercio, 2015). Furthermore, several Italian endemic species have been described from southern Italy (Parenzan and Porcelli, 2007), increasing the role of this geographic area as a biodiversity reservoir.

The main goal of this paper is to increase the knowledge on mountain forests as key ecosystems to preserve biodiversity in the Mediterranean Basin, despite the largest part of them has been managed for longtime. We provide original data (i) on Italian endemic moths and (ii) on moth species newly recorded for Calabria, the southernmost region of Peninsular Italy. All species considered in this paper increase the conservation value of surveyed Mediterranean mountain forests.

Materials and methods

Study areas

Our study was carried out within four of the main forest types (sensu Barbati *et al*., 2007) that develop in mountainous areas of Calabria, the southernmost region of Peninsular Italy. In detail, we investigated the beech forest of the Pollino Massif, the chestnut forest of the Catena Costiera Mountains, the Calabrian black pine forest of the Sila Massif, and the silver fir forest of the Serre Mountains. Beech forests of the Pollino Massif are almost entirely included in the Pollino National Park, and comprised between 800 and 1900 meters of altitude. They cover a surface of 77,237 ha in Calabria, the 7.5% of Italian beech forests (www.infc.it). Most of them are left to natural dynamics. The main disturbance of this forested ecosystem is represented by cow grazing that stabilize herbaceous habitats within beech forests. Forest fires are very rare and private harvesting of small dead wood is the only human disturbance in forested habitats. Chestnut forests of the Catena Costiera Mountains occur between 400 and 1100 meters of altitude. They cover 69,370 ha in Calabria, which are 8.8% of the all Italian chestnut forests (www.infc.it). Most of them are submitted to a clear-cutting with cycles of 12-25 years, and only small areas are dedicated to fruit production. Calabrian black pine forests are partly included in the Sila National Park, and occur between 900 and 1600 meters of altitude. Black pines cover a surface of 74,625 ha in Calabria, which are 31.6% of all Italian black pine forests (www.infc.it). The management of the forests included in the Sila National Park is mainly devoted to conservation purposes, while that of the forests outside of National Park limits, are submitted to various timber harvest strategies. Several hectares are covered by Calabrian black pine reforestations, only rarely managed and then prone to fires and damages due to severe climatic conditions. Silver fir forests of the Serre Mountains are almost entirely included in the Serre Natural Regional Park. They cover 4,851 ha in Calabria, which are 7.1% of all Italian silver fir forests (www.infc.it). Stands at higher altitude are mainly mixed with beech. Large surfaces were reforested 50 years ago, but trees older than 100 years grew in many areas. Forests are usually selectively thinned.

The sampling design was composed of 3 triplets of forest stands (A-B-C) in the four selected forest types (PO: Pollino beech forests; CC: Catena Costiera chestnut forests; SL: Sila Calabrian black pine forests; SR: Serre silver fir forests), resulting in a total of 36 stands (table 1). Any triplet was composed of forest stands which only differed for the developmental stage: (1) forests composed of trees of mixed ages with individual trees older than 80 years were considered as late-forest stages; (2) 10-30 years old both natural and artificial forests were considered as mid-forest stages; (3) clear-cuttings, just thinned forests, small clearings, and small pastures immersed in a forested matrix were considered as early-forest stages. The stands composing a triplet were usually close to each other in order to minimize the effects of other parameters acting on a large scale.

Sampling methods

Moths were sampled by high brightness UV-LED strips-based light traps (emission peak 398 nm, light angle 120°). 2.5 m of UV-LED light strips, for a total of 150 LEDs (~15 W), were enveloped around a tube and placed above a collecting funnel. Traps were positioned at approximately 1.30 meters above the ground and powered by a 12V battery. Each trap was equipped with a timer to switch the light on at dusk and off at dawn. Sampling was performed one night per month from May to October 2015, during nights favourable to moth activity. Nine traps worked contemporaneously within a given forest type. Eleven days were usually necessary to complete the sampling rotation of all forest types.

Tissue samples of some specimens were submitted to the standard animal sampling procedures of the Canadian Centre for DNA Barcoding (CCDB) and sent to their laboratories for sequencing the mitochondrial 5' cytochrome oxidase subunit 1 gene (COI), the standard utilized for the identification of animals (Hajibabaei *et al*., 2006). DNA Barcoding Analysis was used in order to identify endemic genetic lineages. Voucher specimens have been deposited in the collection of Lepidoptera of the Unità di Ricerca per la Selvicoltura in Ambiente Mediterraneo.

Table 1. Description of sampled forest stands and sample data observed in individual sites: observed number of species (Sobs); total number of specimens (N).

Site code	Locality	UTM E	UTM N	Altitude (m a.s.l.)	Dominant forest type	Forest stage	Sobs	N
PO_A1	Serrapaolo	593380	4408629	990	Beech	Late	195	6,270
PO_A2	Serrapaolo	593146	4408625	1010	Beech	Mid	219	8,243
PO_A3	Serra Ambruna	592154	4408713	1035	Beech	Early	161	1,938
PO_B1	Bocca di Novacco	589227	4407585	1315	Beech	Late	106	834
PO_B2	Bruscata	589605	4407229	1370	Beech	Mid	124	2,124
PO_B3	Bocca di Novacco	589457	4407641	1340	Beech	Early	86	525
PO_C1	Timpone della Magara	590076	4405412	1465	Beech	Late	91	1,575
PO_C2	Timpone della Magara	589926	4405142	1460	Beech	Mid	112	1461
PO_C3	Timpone della Magara	590112	4404524	1475	Beech	Early	114	600
CC_A1	Fiego di San Fili	597305	4354806	720	Chestnut	Late	141	1,020
CC_A2	Fiego di San Fili	597338	4354031	740	Chestnut	Mid	143	968
CC_A3	Fiego di San Fili	597282	4353875	740	Chestnut	Early	116	476
CC_B1	Bosco dei Gesuiti	597467	4357525	620	Chestnut	Late	133	627
CC_B2	Bosco dei Gesuiti	597428	4357562	630	Chestnut	Mid	181	1,587
CC_B3	Mandarino	597424	4358610	540	Chestnut	Early	115	443
CC_C1	Glicarello	596907	4362576	550	Chestnut	Late	126	616
CC_C2	Vallone Argentino	596502	4362680	565	Chestnut	Mid	159	1,570
CC_C3	Vallone Argentino	596858	4362840	545	Chestnut	Early	112	605
SL_A1	Montagna Grande	638895	4348709	1380	Black pine	Late	145	1,110
SL_A2	Montagna Grande	639198	4349346	1294	Black pine	Mid	152	2,506
SL_A3	Montagna Grande	638566	4348166	1352	Black pine	Early	134	1,003
SL_B1	Torre Scarda	630586	4344332	1310	Black pine	Late	133	1,341
SL_B2	Quaresima	625635	4341417	1382	Black pine	Mid	131	858
SL_B3	Quaresima	630208	4343972	1300	Black pine	Early	73	242
SL_C1	Colle Macchie	631754	4346636	1436	Black pine	Late	140	1,111
SL_C2	Vallivone	632070	4346713	1453	Black pine	Mid	142	1,780
SL_C3	Colle Macchie	631592	4346649	1433	Black pine	Early	79	399
SR_A1	Santa Maria	614535	4268065	847	Silver fir	Late	114	655
SR_A2	Il Palmento	614557	4269042	840	Silver fir	Mid	133	744
SR_A3	Il Palmento	614593	4269034	827	Silver fir	Early	72	142
SR_B1	Cattarinella	614989	4267584	940	Silver fir	Late	96	477
SR_B2	Cattarinella	615110	4267307	970	Silver fir	Mid	102	623
SR_B3	Cattarinella	615262	4266271	1039	Silver fir	Early	72	212
SR_C1	Sietto dello Caricatore	617087	4267949	1120	Silver fir	Late	91	621
SR_C2	Pietra del Signore	615992	4266586	1080	Silver fir	Mid	107	1,137
SR_C3	Sietto dello Caricatore	616907	4267754	1110	Silver fir	Early	64	233

Data analysis

We focused our attention on Italian endemics and on Calabrian faunistic novelties. In this paper we defined as endemic those species having their range completely comprised within the Italian boundaries. Under the definition of faunistic novelties we included those species never found before in Calabria, usually having small populations with scattered distributions. Understanding the role of managed forests to preserve this unique biodiversity at a local, regional and national scale is a key point to promote environmental friendly management strategies for forests.

Faunistic data for the study area has been obtained from several papers among which the most comprehensive are Parenzan and Porcelli (2007; 2008; and literature therein), and Scalercio (2014a; and literature therein). Nomenclature of species follows Karsholt and van Nieukerken (2015).

The number of specimens was used as a measure of species abundance. The occupancy, i.e. the number of stands occupied by a given species or group of species within a given group of stands, was used as a measure of species occurrence. For example, if we found 5 endemic species within 10 stands, their occupancy could vary from a minimum of 5 (one species within one stand) and a maximum of 50 (all species within all stands).

Results

We collected 46,676 individuals belonging to 531 species. The trapping data for each sampling site are reported in table 1.

A total of twenty-two species, represented by 1,693 individuals, met the definitions of endemics and faunistic novelties (table 2).

Table 2. List of endemics and faunistic novelties and their occurrence in sampled forests.

	Pollino beech forests									Catena Costiera chestnut forests									Sila pine forests									Serre silver fir forests								
Endemic species	PO_A1	PO_A2	PO_A3	PO_B1	PO_B2	PO_B3	PO_C1	PO_C2	PO_C3	CC_A1	CC_A2	CC_A3	CC_B1	CC_B2	CC_B3	CC_C1	CC_C2	CC_C3	SL_A1	SL_A2	SL_A3	SL_B1	SL_B2	SL_B3	SL_C1	SL_C2	SL_C3	SR_A1	SR_A2	SR_A3	SR_B1	SR_B2	SR_B3	SR_C1	SR_C2	SR_C3
Geometridae																																				
Hylaea mediterranea	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	121	2	8	3	-	9	66	1	13	28	-	7	8	-	9	13	1
Itame sparsaria	45	130	36	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Xanthorhoe vidanoi	6	4	4	11	2	1	2	-	3	-	1	-	-	-	-	-	5	-	-	-	1	13	16	-	1	-	-	5	7	3	6	8	-	3	6	6
Itame messapiaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	19	32	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hemistola siciliana	3	2	1	-	-	-	-	-	-	1	-	2	1	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	4	2	-	1	-	-	-	-
Megalycinia serraria	1	1	-	-	-	-	-	-	-	4	1	4	-	-	-	-	-	-	-	1	-	2	-	-	-	1	-	1	-	2	1	-	1	-	2	-
Nychiodes ragusaria	-	-	-	-	-	-	-	-	-	-	3	9	-	-	1	-	-	-	1	1	3	-	1	-	2	-	-	-	-	-	-	-	-	-	-	-
Idaea mutilata	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	5	2	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-
Hydriomena sanfilensis	6	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Noctuidae																																				
Clemathada calberlai	-	4	-	-	-	1	-	-	1	72	172	96	9	39	28	34	109	55	-	-	-	-	-	-	-	-	-	4	4	-	4	8	-	1	2	-
Species	6	6	4	1	2	3	1	1	2	3	4	4	2	1	2	1	3	1	4	5	5	3	3	0	4	2	1	4	4	3	4	4	1	3	4	2
Individuals	62	143	42	11	3	3	2	1	4	77	177	111	10	39	29	34	120	55	29	160	14	23	20	0	14	67	1	23	43	7	18	25	1	13	23	7
Faunistic novelties																																				
Geometridae																																				
Nothocasis sertata	11	2	-	-	21	2	16	59	2	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypomecis roboraria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	28	1	-	-	-	-	-	-	-	-	-	23	4	-	8	7	-	8	22	2
Odontopera bidentata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	3	-	-	-	1	-	1	1	-	-	-	-	4	7	-
Perizoma juracolaria	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Erebidae																																				
Chelis maculosa	-	-	-	1	1	10	-	1	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Calyptra thalictri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1	-	-
Noctuidae																																				
Phragmatiphila nexa	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	-	-	-	3	3	-	-	1	-	-	-	-
Apamea epomidion	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Apamea scolopacina	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tiliaceacitrago	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhizedra lutosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Naenia typica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Species	2	1	0	1	2	3	1	2	2	1	1	0	1	1	1	1	2	1	1	1	0	2	0	0	0	1	0	3	4	0	2	2	0	3	3	1
Individuals	12	2	0	1	22	13	16	60	12	1	1	0	1	1	1	3	29	1	1	1	0	4	0	0	0	1	0	27	9	0	9	8	0	13	31	2

Italian endemics

We found 10 endemic moth species in monitored forests (table 2). Among them *Hemistola siciliana* Prout, *Xanthorhoe vidanoi* Parenzan et Hausmann, *Hylaea mediterranea* Sihvonen Skou Flamigni Fiumi et Hausmann, and *Clemathada calberlai* (Staudinger) were reported for the first time from the Serre fauna, and *Idaea mutilata* (Staudinger) was reported for the first time from the Sila fauna. Eight endemics have been sampled in beech forests, six in Calabrian black pine forests, and five in chestnut and silver fir forests. Endemics were collected within the 97.2% of stands, being missed only within one early-stage forest stand. *H. mediterranea* was the species showing the most significant fidelity to forested stands where the 98.7% of individuals was sampled (table 2). Six endemic species were shared among at least two forest types, four species were exclusively collected in one of them, and two were found in all forested areas.

Occupancy of endemics was lower in chestnut forests than in other forest types, reaching the maximum value in fir forests (figure 1). Abundance pattern was the opposite, being endemics less abundant in silver fir forests and more abundant within chestnut, beech and Calabrian black pine forests, where *C. calberlai*, *Itame sparsaria* (Hubner) and *H. mediterranea* respectively were particularly abundant and determined the observed pattern (figure 1).

Although most endemics were found in all forest successional stages, the total occupancy was higher in mid-stages (32.5%, i.e. 39 observations out of a total of 120 for 10 species in 12 stands) and in late-stages (30.0%) than in early-stages (23.3%). Endemics were also more abundant within mid (58.2% of individuals) than within late (22.4%) and early (19.4%) forest stages. Among early successional stages, abundant populations of endemics were found only within early chestnut forests (figure 2).

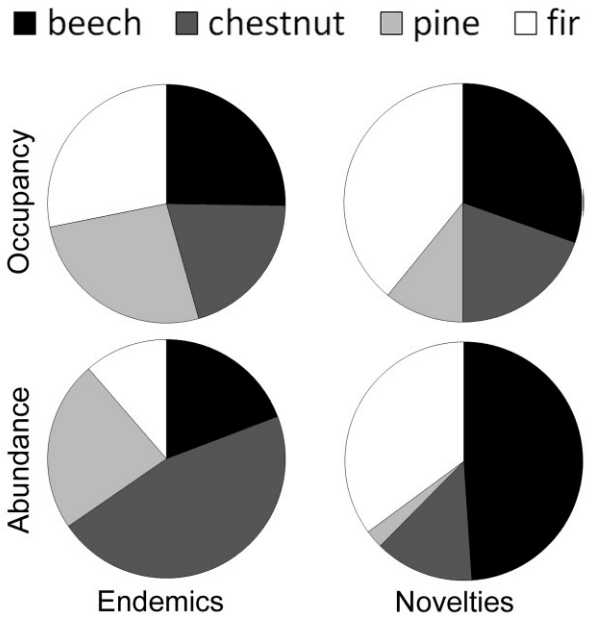

Figure 1. Occupancy and abundance of endemic species and faunistic novelties within surveyed forest types.

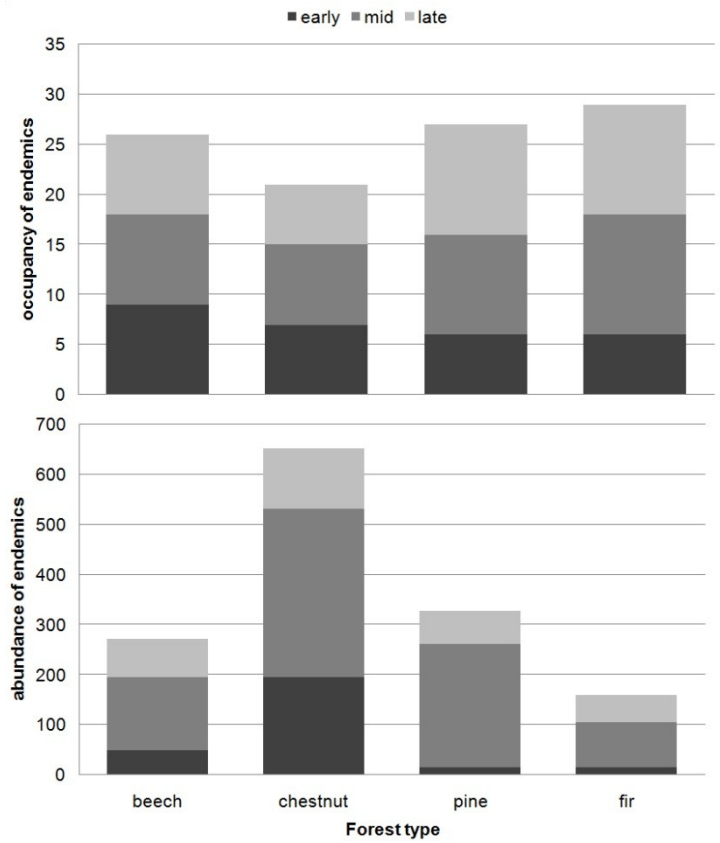

Figure 2. Occupancy and abundance of endemics in different successional stages of investigated forest types.

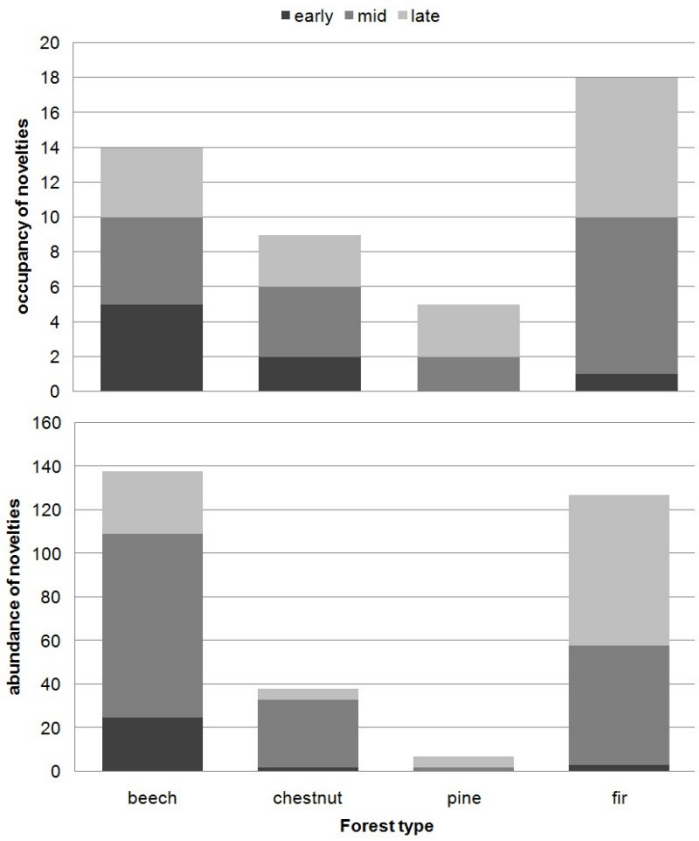

Figure 3. Occupancy and abundance of faunistic novelties in different successional stages of investigated forest types.

Faunistic novelties

12 species met the definition of faunistic novelties. Six species were very rare in our samples, being collected only in one or two individuals (table 2). Five species were shared between two forest types, involving three times a pair deciduous/conifer forests and in two cases a pair conifer/conifer.

Silver-fir forests inhabited the highest number of faunistic novelties (6 species), followed by beech and chestnut (4 species), and Calabrian black pine forests (3 species) (table 2). Occupancy and abundance of faunistic novelties were higher in beech and silver fir forests than in chestnut and Calabrian black pine forests (figure 1).

Occupancy and abundance of faunistic novelties equally occurred between mid and late successional stages of forests, with the exception of mid beech and chestnut forests that inhabited much more individuals than late ones (figure 3). In early successional stages occupancy and abundance of faunistic novelties were negligible. Only early beech forests inhabited a significant number of novelties.

Barcoding analyses

We carried out barcoding analysis for four species in order to test genetic affinities of their populations. Barcoded specimens of *Odontopera bidentata* (Clerck) (specimens: LEP-SS-00173, LEP-SS-00174; sequence pages: BIBSAA553-15, BIBSAA554-15; GenBank: KU497392, KU497393) and *H. mediterranea* (specimens: from LEP-SS-00144 to LEP-SS-000154; sequence pages: from BIBSAA524-15 to BIBSAA534-15; GenBank: KU497366, KU497364) did not show significant genetic differences compared to other specimens in Barcode of Life Data Systems (BOLD). Barcoded specimen of *Perizoma juracolaria* (Wehrli) (specimen: LEP-SS-00319; sequence page: BISA-809-15; GenBank: KU497401) allowed us to correctly identify this species, which until now was considered as *Perizoma obsoletata* (Herrich-Schaffer) in Apennine Mountains. Sequences of *Nothocasis sertata* (Hubner) (specimens: LEP-SS-00162, LEP-SS-00163; sequence pages: BIBSAA542-15, BIBSAA543-15; GenBank: KU497383, KU497388) diverge significantly from Central European populations showing 2.8% difference, which justifies further taxonomic studies in order to evaluate if southern Italian populations possibly belong to an undescribed species (figure 4).

Discussion

The distribution pattern of endemics and faunistic novelties of moths underlined the importance of forested habitats as biodiversity reservoirs, whenever was the successional stage under investigation and despite that they had been managed for longtime. The highest values of this precious portion of diversity were found within mid and late successional stages of forests, significantly decreasing in early successional stages represented by young coppices, meadows or just thinned forests. Forests were important as suitable habitats for the studied

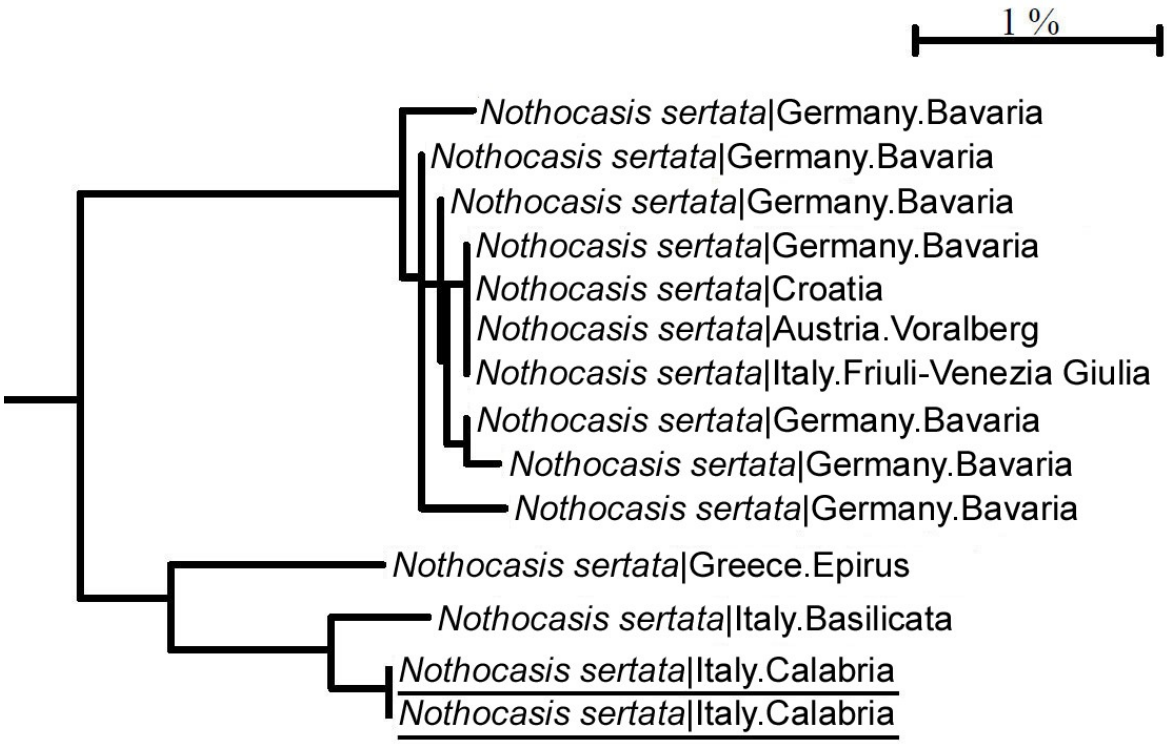

Figure 4. Cluster of *N. sertata* barcodes available on BOLD. The sequences of specimens collected in this study are underlined. Neighbor-joining tree was constructed using Kimura 2 parameter as distance model.

species, probably because of their microclimate and undergrowth. Nevertheless, tree species characterizing monitored forest stands represent feeding plants for many species (Scalercio *et al*., 2008; Scalercio, 2014b).

Species' perspective

The distribution patterns of endemics were mainly determined by ecological needs, but in some cases biogeography played an important role as occurred for *Itame messapiaria* Sohn-Rethel, vicariant of *I. sparsaria* in the Sila Mountains (Flamigni *et al*., 2007). *H. mediterranea* is the only endemic species whose larvae certainly feed on trees. It develops on conifers (Sihvonen *et al*., 2014) and it is very abundant and frequent in the Calabrian black pine forests of the Sila massif and in silver fir forests of the Serre Mountains. This species demonstrated a high fidelity to forested habitats being negligible its presence in early forest stages. Larvae of many endemic species are unknown, but those with known biology feed on plants growing in the understory of forests or at their margin. *C. calberlai* feeds on *Clematis vitalba* (Berio, 1985), common in young and perturbed forests, *X. vidanoi* feeds on *Galium mollugo* (Hausmann and Viidalep, 2012), larvae of *Nychiodes ragusaria* Milliere feed on bushes of Rosaceae and Fabaceae, and maybe also on *Quercus* spp. (Flamigni *et al*., 2007).

Early phenology of *Hydriomena sanfilensis* (Stauder) could be the cause of its scarce abundance within samples, being this study started at the end of the flying season of this species (Hausmann and Viidalepp, 2012). In fact, with the exception of the Serre Mountains, it is known from the Sila (Parenzan, 1994) and it was originally described from the Catena Costiera (Stauder, 1914-1915).

Feeding preferences of larvae belonging to faunistic novelties emphasized the role of associated species in the tree layers. In fact, only the polyphagous *O. bidentata* can develop on dominant trees species, while 4 out of 12 mainly develop on associated trees: *Hypomecis roboraria* (Denis et Schiffermuller) mainly on *Quercus* spp. (Redondo *et al*., 2009), *N. sertata* on *Acer* spp. (Hausmann and Viidalepp, 2012), and *Tiliacea citrago* (L.) on *Tilia* spp. (Berio, 1985).

Furthermore, the presence of 8 out of 12 species feeding on herbaceous plants underlined the importance of understory flora as a key factor to sustain forest moth diversity.

P. juracolaria and *Chelis maculosa* (Gerning) are linked to open habitats (Bertaccini *et al*., 1995; Mironov, 2003; Hausmann and Viidalepp, 2012). They were collected in meadows surrounded by beech forests on the Pollino Mountains, where open habitats have a natural origin on steep slopes at high altitudes. All other species are sylvicolous and clearly linked to mesophilous habitats in all areas but also to hygrophilous habitats on the Catena Costiera chestnut forests and on the Serre silver fir forests.

Most faunistic novelties are Eurasiatic species having isolated populations in the study area. These newly discovered populations can assume a particular importance for diversity conservation not only at local level, because in some cases they have unique genetic lineages (Hausmann and Viidalepp, 2012). This was observed in this study for *N. sertata*, but it was also reported for other species. *Orthostixis cribraria* (Hubner) is an Ira-

nian-South East European species, known in Italy from only eight localities of central and southern Italy and Sicily (Parenzan, 1994; Hausmann, 2001). The barcoded population of Central Italy shows a significant divergence from eastern populations (Hausmann *et al*., 2013), suggesting the presence of a distinct undescribed entity in Italy. Furthermore, barcoding analyses showed that the Calabrian population of *P. obsoletata* belongs to *P. juracolaria*, which has never been before reported from Italy (Parenzan and Porcelli, 2007).

Forests' management perspective

Surveyed beech forests inhabit the highest number of endemics, occurring with high frequency, and a good number of faunistic novelties. Our data confirmed the known importance of this forest type in Mediterranean areas as biodiversity reservoir (Walentowski *et al*., 2014). We also underlined the role of its early and mid-successional stages where endemics are similarly represented than in late forest stages. Furthermore, more faunistic novelties inhabit early-stages of beech forests than any early-stages of any other forest type. This can probably be linked to the availability of open habitats of natural origin in the surveyed beech landscapes, located at higher altitudes, acting as a source of species. In fact, although sometimes generated by human activities, open habitats were preserved for longtime by the cow pressure, facilitating their role as sinks of species coming from natural open habitats.

Human pressure is certainly higher on chestnut forests than on other investigated forest types, due to the short periodical cutting and to the presence of urbanized areas in the neighbourhood. This probably caused the lowest number of endemic species, but endemic abundance and faunistic novelties were still comparable and sometimes higher than in other forest types. A 25 year rotation with at least one thinning has been suggested as an optimal management strategy that enhances biodiversity preserving timber production (Mattioli *et al*., 2016). Our results seem to reinforce these suggestions, because mature coppices inhabit higher abundance of endemic species and faunistic novelties than stands managed for fruit production with sparse old trees. In fact, whilst in chestnut coppices the understory is left more or less at its natural dynamic for several years, in chestnut forests oriented to fruit production the annual removal of the understory to facilitate fruit harvesting has probably a great impact on moth diversity.

Mediterranean black pine forest is a habitat protected by European legislation due to its fragmentation and to endemic pine species that compose this habitat. Zaghi (2008) recommends to maintain irregular structures in pinewood in order to preserve diversity. In the Sila Massif this is guaranteed by a within-stand heterogeneity of managed woodlots (Ciancio *et al*., 2006) and by an among-stand heterogeneity due to a mosaic-like alternation between mature forests and young reforestations. As a consequence, this forest type inhabits a unique invertebrate diversity in Mediterranean mountains (Bonacci *et al*., 2012; Brandmayr *et al*., 2013). Previous studies on Calabrian Lepidoptera carried out in Sila pinewoods emphasized the role of this habitat as a diversity reservoir. In this paper we found few faunistic novelties because lepidopteran fauna has been more explored than other forest types. Literature data, jointly with our data on endemics, clearly indicated this forest type as remarkable from a conservation point of view. It inhabits the only Apennine population of *Brentis ino* (Rottemburg) (Verity, 1950-1951), whilst *Eupithecia conterminata* (Lienig) (Infusino and Scalercio, 2015), *Zygaena nevadensis* Rambur (Efetov *et al*., 2011) and others were found in Italy in this forested area only. Furthermore, here one of the most important endemic moths of the Italian fauna is present, *I. messapiaria*, known for the Sila Massif only (Flamigni *et al*., 2007).

Silver fir forests are relict in the Mediterranean Basin (Bottalico *et al*., 2014) and are usually included in protected areas as occurs in the State Reserve of Collemeluccio, and in the Serre Natural Regional Park. The traditional management regime of silver fir forests is compatible with conservation purposes because they usually have a 100-years-long rotation, enough to promote the establishment of diversified forest stages, with gaps in the forest coverage due to natural events that enhance biodiversity in the understory (Bottalico *et al*., 2014). Also in silver fir forests the understory seems to play a key role for promoting the presence of very isolated populations of species feeding on herbs, namely *Phragmitiphila nexa* (Hubner), *Apamea epomidion* (Haworth), *Calyptra thalictri* (Borkhausen), and *Naenia typica* (L.). Traditional management regime coupled with the wet and cold environmental conditions necessary for the development of a silver fir forest, promote also the persistence of a peculiar fauna that have found a suitable microclimate in silver fir forests far south from their main range. Furthermore, the type locality of *Megalycinia serraria*, an Italian endemic geometrid moth described by Costa (1882), is located in Serre silver fir forests, which reflects its unique role as biodiversity reservoir.

Conclusions

This study reinforces the knowledge on the contribution to regional biodiversity of mountain forests that provide suitable habitats and shelters against hot summer temperatures to more cold-adapted and hygrophilous species. A number of stenotopic species, with Eurasiatic range, were found in chestnut plantations despite they are repeatedly and deeply altered by human activities such as coppicing.

In this paper we used an approach that integrates insights provided by endemic species which are in the core of their range, and faunistic novelties which are in most cases at the border of their ranges. Altogether these species depict a favorable context for diversity conservation in Calabrian forests, although most of them have been managed for longtime. Probably, the presence of a mosaic-like forest landscape composed by young reforestations and mature forest patches allows many species to survive for long time even the populations are isolated from their core ranges long periods during interglacials. In fact, the surveyed Mediterranean forests are characterized by peculiar moth diversity, at

both species and population level. We underline that barcoding analyses have been carried out only for few species, and further investigations will likely lead to discoveries of new endemic genetic lineages among other species.

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