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Compact vs. Linear: Effects of Forest Structure, Patch Shape and Landscape Configuration on Black Alder Macromoth Communities

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Abstract: Landscape configuration and forest structure assume an increasing importance as determinants of animal communities. This paper focused on nocturnal lepidoptera inhabiting alder patches in the Sila National Park, Italy. According to their shape, patches were divided into linear and compact ones to disentangle the role of forest structure and landscape configuration in determining the composition of nocturnal lepidopteran communities at different observation scales. We used the Mann-Whitney test for medians to Shannon diversity, Equitability, Fisher's alpha, and nestedness to test differences among moth communities. We found that compact patches inhabit richer and more abundant communities. The abundance-based Correspondence Analysis showed moth communities clustered according to woodlot shape, except a compact woodlot having a linear-like moth community because entirely surrounded by grasslands. Percentage of forested area and abundance and composition of communities are positively correlated at 50 and 200 m buffers, while correlations are absent at smaller and larger buffers. Our results demonstrated that a width of 50 m may not be sufficient to give proper functionality to the wooded area, at least for moths. As consequence, planning of forest restorations should consider the importance to increase structural habitat continuity at larger scales.

Keywords: lepidoptera; landscape ecology; riparian forest; *Alnus glutinosa*; natural park; beta-diversity; South Italy

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1. Introduction

Forests have been managed by man from long time to produce timber and their surfaces have been reduced for the increasing demand of pastures, agricultural and anthropic land [1,2]. Deforestation disrupts ecosystem equilibrium and threats associated biodiversity [3–7], mainly because of habitat reduction and fragmentation that modify patch shape and woodlot structure [8–13]. When a forest is highly fragmented, there is an inevitably increase in forest edges leading to a higher margin effect on species assemblages, but also structure and ecological processes of ecosystems near the ecotone are affected [14]. In addition, modifications of habitat quality and heterogeneity, as well as surrounding matrix attributes, are known to have significant effects on species occurrence and population size [15–19]. Proper forest management devoted to habitat restoration should ameliorate connectivity and reduce fragmentation through the establishment of ecological corridor and increasing patch size, both with positive effects on biodiversity [20–23], and the latter favouring the presence of the more vulnerable core species [24]. Besides landscape drivers, also pure dendrometric parameters and spatial tree arrangement affect abundance and composition of animals and plants communities. Structural parameters of forest are relevant for animal and plant diversity [25], i.e., age of trees affects lichen and bird diversity [26], tree species composition affects animal community composition [27–29], and tree density and basal area affects diversity in dry and tropical forests [30].

Among forest types, riparian ones and associated biodiversity are those that suffer more from severe deforestation because of the additive detrimental effects of climate change [31], mainly due to the expected alteration of rainfall regimes. Fragmentation of riparian forests has been observed all around the world [32–34] and protected areas have not been spared. In the Mediterranean Basin, they are particularly vulnerable because climate change is there stronger than elsewhere, with temperatures and aridity increasing faster than the global average [35].

Several studies analysed the effects of changes in patch structure and shape of woodlots on biodiversity such as birds and mammals [8,10], reptiles [36], amphibians [37] and invertebrates [9]. Among invertebrates, nocturnal Lepidoptera communities are often used to investigate the effects of changes in patch shape and size of forests [13,24] as well as bioindicators for agricultural intensification and forest quality [38–41]. It is known that abundance and richness of moth species are influenced by patch size, quality of woodlot, surrounding matrix attributes and edge length [15–19]. As the size of a woodlot patch increases, the richness and the abundance of moth species increases for the addition of forest core species [24]. Moth occupies several environments, and many species are linked to forested habitats [42]. Those linked to riparian habitats have rarely been studied [23,43], especially in Italy where knowledge increased only in the last decades [44–48]. Riparian habitats are essential to preserve many lepidoptera's species some of which find here suitable habitat against global warming induced range shift [49]. In fact, despite exclusive species weren't among the most abundant ones, sampled riparian forest resulted an important component of beta-diversity [47].

Black alder (*Alnus glutinosa* (L.) Gaertn.) forests of the Sila plateau, in the middle of Mediterranean Basin, are a perfect model to study the effects of landscape structure on biodiversity hosted in riparian forests as they are (i) threatened by severe climate change, and (ii) mostly reduced to stripes surrounded by pastures and cultivated lands, then with a significant edge length and potentially with a marked margin effect.

In this paper, we analysed nocturnal lepidoptera sampled by Leonetti et al. [47] in linear and compact alder woodlots in order to test the hypotheses that linear woodlots inhabit an impoverished version of moth communities inhabiting compact woodlots. The latter are supposed to host a well-preserved moth community also composed by core species, as the margin effect is supposed to be lower than in linear ones. Then, we assessed the role of landscape drivers and forest structure in shaping moth communities, providing suggestions to manage this vulnerable habitat.

2. Material and Methods

2.1. Study area

Study area is entirely comprised within the Sila National Park, Calabria region, Italy (Figure 1). Most of the territory extends between 1,100 and 1,200 metres of altitude, reaching the highest altitudes with Mount Botte Donato (1,928 m a.s.l.) and Mount Curcio (1,768 m a.s.l.). The climate of the study area is warm temperate with relatively humid summers typical of upland Mediterranean zones. Mean annual precipitation is around 1,240 mm, with a mean monthly maximum of 180 mm recorded in November and a mean monthly minimum of 33 mm in July [50]. Snow cover usually occurs from December to April. The metamorphic and granite substratum of the plateau, since it has poor permeability, favors the surface flow of the abundant rainfall with the formation of a capillary network of watercourses which flow into four main rivers: Neto, Crati, Trionto and Tacina. Landscape is mostly composed by woodlands with a predominance of *Pinus nigra* Poir. subsp. *calabrica* (Loud.) Cesca & Peruzzi forests at lower altitude and *Fagus sylvatica* L. in the upper belt [51]. Woodlands are interrupted by grasslands and cultivated fields. Riparian woodlots only extents along water courses. In detail, sampled woodlots have been selected along the Neto and Cecita riversides with altitudes ranging between 1,250 and 1,397 m a.s.l.

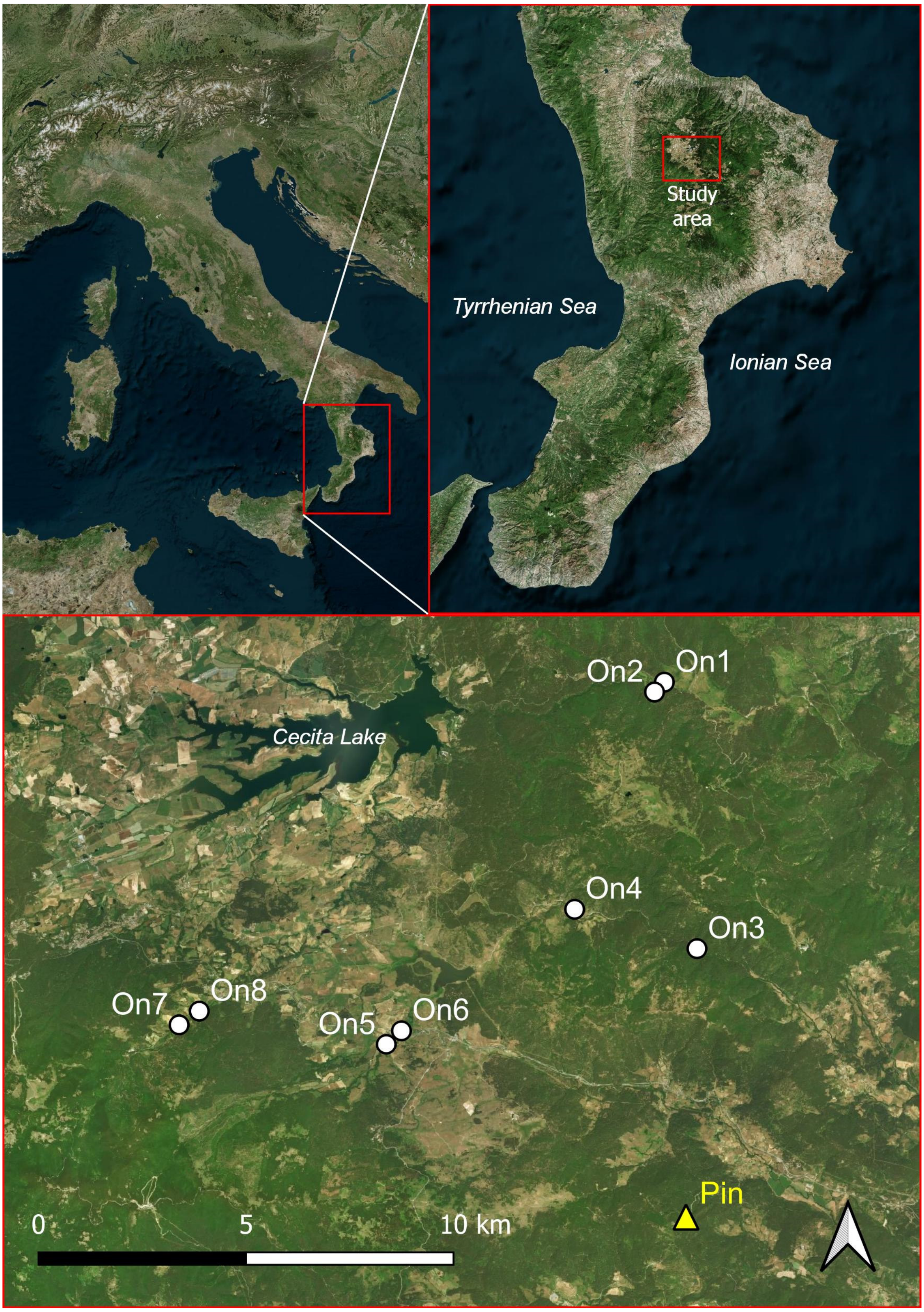

Figure 1. Localization of study sites. White circles indicate alder woodlots, the yellow triangle indicates the pine woodlot.

Eight sites were monitored by Leonetti et al. [47], representative of riparian alder woodlots and of the main landscapes of the study area. Leonetti et al. [47] selected four pairs, each of them represented by a linear and a compact alder woodlot located in the neighbouring of each other for minimizing the bias due to local abiotic factors. Linear woodlots were those composed by alder trees growing along watercourses surrounded by open herbaceous habitats, whilst compact woodlots were defined those at least 50 meters wide with or without lateral continuity with other forest types (Table 1). One more site was monitored in this study within a pine woodlot for a better characterization of alder communities.

Table 1. Diversity and abundance of moths in sampled sites. Number of species (*S*); number of individuals (*N*); Shannon index (*H*); Equitability (*J*); Fisher's alpha (*α*).

	S	*N*	*H*	*J*	*α*
Linear woodlots					
On1	131	663	4.07	0.83	48.92
On4	86	359	3.62	0.81	35.84
On6	137	635	4.35	0.88	53.69
On8	131	669	4.16	0.85	48.69
Compact woodlots					
On2	157	1179	4.17	0.82	48.63
On3	151	1140	4.05	0.81	46.66
On5	151	849	4.23	0.84	53.41
On7	147	704	4.36	0.87	56.57

2.2. Moth sampling

Moth data were mostly gathered from Leonetti et al. [47], supplemented by original data sampled in a pine woodlot and with taxonomic changes occurred in recent years [52]. Due to the confirmed presence of both species in the study area [53] and their hard discrimination, we considered the recent recognised *Hoplodrina alsinides* and *H. octogenaria* as a species pair cited in this paper as *Hoplodrina* cfr. *octogenaria*.

Leonetti et al. activated an UV LED light trap per site one night per month from March to November 2017 in georeferenced points obtaining a total of 72 samples. Traps worked simultaneously in all sites reducing the effects of different weather conditions on collected data. Sampling nights were chosen near the new moon phase (±7 days), with temperature no lower than the mean of the period, with low wind (<10 km/hour), and possibly with no or low rain. Collected material was sorted in laboratory and moths belonging to the selected superfamilies (Hepialoidea, Zygaenoidea, Cossoidea, Lasiocampoidea, Bombycoidea, Drepanoidea, Geometroidea, and Noctuoidea) were identified at species level and counted. Voucher specimens were preserved in the scientific collection of Lepidoptera of the Research Centre for Forestry and Wood, Rende, Italy. For any further detail on samplings see Leonetti et al. [47]. We sampled a pine woodlot from April to October 2022 following the same trapping design obtaining a total of 6 samples. Data from 78 samples were pooled and arranged in a species/site matrix and then submitted to statistical analyses.

2.3. Forest structure

In this study we selected structural parameters of forest which are known to be relevant in determine animal and plant diversity [25] i.e. age of trees, that determines lichen and bird diversity [26], tree density and basal area that affects diversity in dry and tropical forests [30]. Furthermore, we separately evaluated these parameters for dead and alive trees, as the former seems to affect forest diversity differently [54,55]

We evaluated classical dendrometric parameters within a radius of 25 meters around sampling points in order to characterise alder woodlots. In detail, we measured separately for alive and dead trees, the followings: estimated tree age, mean tree hights (m), tree density (n/ha), mean diameter of stems at breast hight (DBH_{mean}), total basal area (BA_{tot}), total dendrometric volume (V_{tot}). Tree heights were measured using an infrared ipsometer Vertex III, whilst diameters were extrapolated from measured stem circumferences. Tree age for a plot was extrapolated measuring the age of the tree

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with the DBH nearest to the mean of the plot by using a Pressler's coring device. Dendrometric volumes were computed by using volume table for alder forests of Sila Mountains [56].

2.4. Landscape configuration

Landscape was described around each moth trap (sampling point) using circular buffers of 25, 50, 200, 500, and 1,000 meters. The smallest radius is those describing the landscape from which the trap is expected to attract moths [57], the largest is those describing the landscape where most moths are expected to live due to their dispersal abilities [58]. Resulting circular landscapes were analysed using two landscape metrics: proportion of classes and shared edge length, both at a class level [59]. Three classes were selected according to the study goals, including alder woodlots, forests, and grasslands (Figure 2). Alder woodlots are the subject under study from which moths were sampled and analysed. Forests, whichever their composition was, share similar abiotic conditions with alder woodlots having higher permeability to moth movements than herbaceous habitats. Shared edge length is the measure of the ecotone between forests and grasslands, becoming a proxy of habitat fragmentation in fixed buffers. Every single patch was manually digitized as a polygon in GIS environment, based on satellite image as background layer, and then merged by attributes. Features areas and shared edges were automatically computed using QGis processing tools.

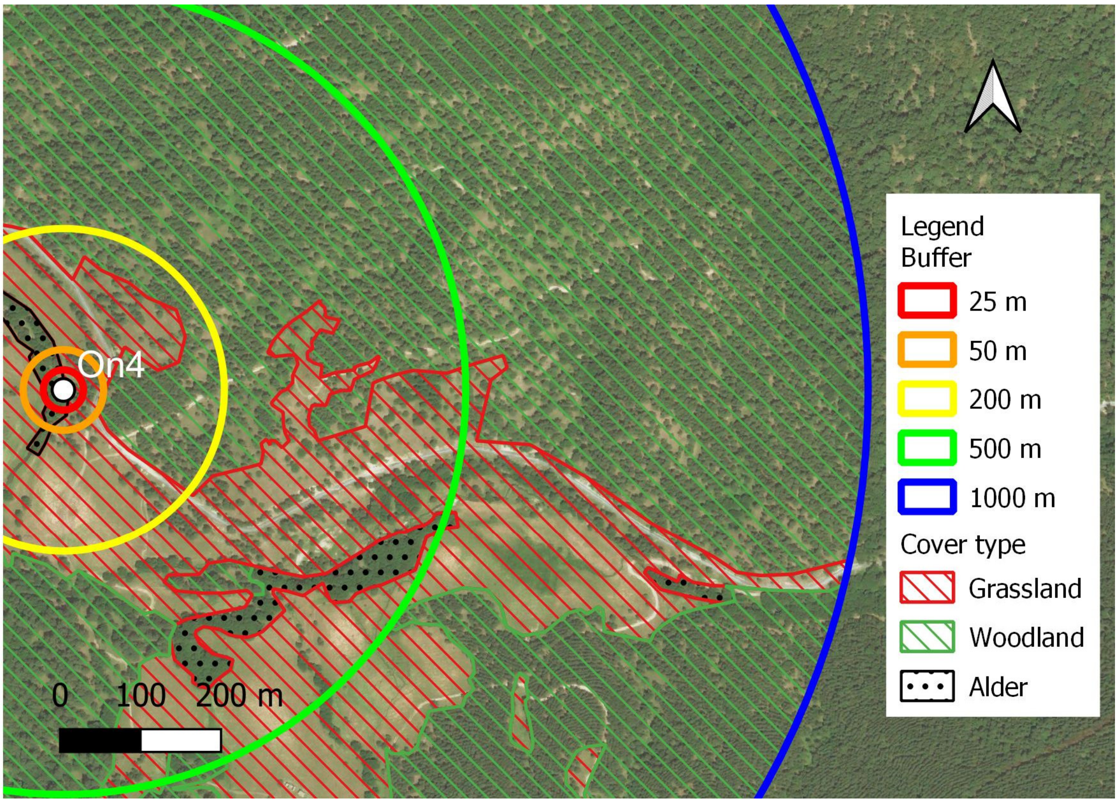

Figure 2. Schematization of landscape interpretation and analysis around light trapping points at five different buffers. The white dot indicates the location of the light trap.

2.5. Moth analysis

Differences in abundance and richness of moth communities between linear and compact black alder woodlots were compared by mean of the Mann-Whitney test for medians running PAST 4.03 [60]. Diversity indices were also computed, namely Shannon (H), Equitability (J), and Fisher's alpha (α).

Main ecological processes shaping beta-diversity are known to be the turnover, or species substitution, and the nestedness, or species impoverishment. Diversity of altered habitats as we hypothesized linear woodlots to be, usually tends to be nested within the natural ones, as compact woodlots are assumed to be in this study. Then, we expect that in woodlot pairs, linear alder moth communities are nested within compact ones. To test this hypothesis, we computed the "Nestedness metric based on Overlap and Decreasing Fill" (NODF) for a binary matrix following Almeida-Neto et al. [61], running Nestedness for Dummies (NeD) [62].

Then, abundance matrix of sampled alder and pine woodlots were submitted to Correspondence Analysis (CA) by running PAST 4.03 [60].

3. Results

3.1. Moth

A total of 8,451 individuals belonging to 332 taxa were included in this study, of which 6,198 individuals belonging to 309 taxa were collected in alder woodlots (Table S1). Most abundant species were *Orthosia incerta*, *Eilema lurideola*, *E. complana*, and *Hoplodrina* cfr. *octogenaria*, representing altogether the 18% of the whole sample.

Linear woodlots inhabit communities with significantly less species ($p = 0.028$) and less individuals ($p = 0.030$) than compact ones, but computed diversity indices are not statistically different (Table 1). However, linear communities were not nested within the respective compact pair, with one exception only represented by On4 (Table 2).

Table 2. Nestedness metric based on Overlap and Decreasing Fill (NODF) for sampled woodlot pairs.

alder woodlots linear vs. compact	NODF	nested	
On1 vs. On2	49.344	NO	$p > 0.05$
On4 vs. On3	45.554	YES	$p < 0.001$
On6 vs. On5	50.064	NO	$p > 0.05$
On8 vs. On7	50.177	NO	$p > 0.05$

The abundance-based Correspondence Analysis (CA) showed that moth communities were primarily shaped by forest types being the pine strongly separated from alder communities along the Axis 1. On the other hand, alder communities were only slightly separated along the Axis 1, having most of compact alders lower values than linear ones (Figure 3). A fairly better separation of alder woodlots was observed along the Axis 2 assuming most of compact ones negative and all linear ones positive values. CA showed that the supposed compact woodlot On5 inhabits a linear community despite its forest structure at stand level (Figure 3).

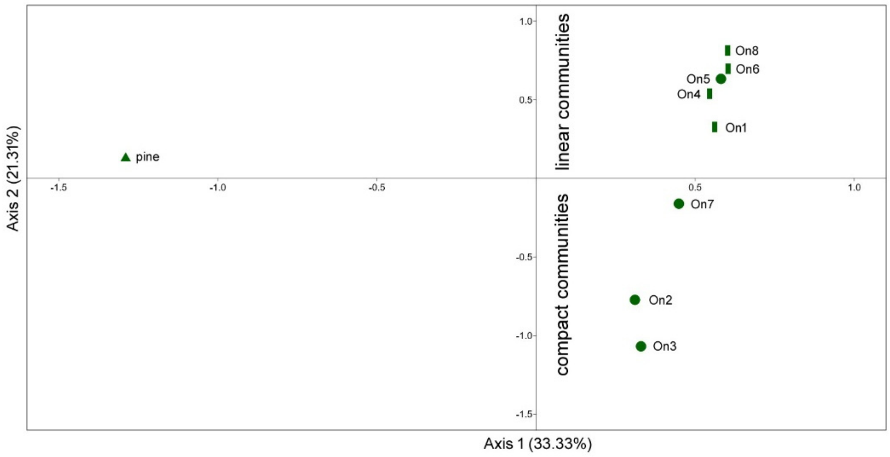

Figure 3. Moth communities sampled within sampled alder (circle: compact; bar: linear) and pine (triangle) woodlots plotted on a cartesian plan individuated by axis 1 e axis 2 of Correspondence Analysis.

By splitting individual moth samples according to CA in two groups, we found that among the ten most abundant species in linear communities only two were also among the ten most abundant species in compact communities, namely *Orthosia incerta* and *Hoplodrina* cfr. *octogenaria* (Table 3). Most characteristic species for linear communities were *Agrotis cinerea*, *Luperina testacea*, and *L. dumerilii*, whilst those characterising compact communities were *Eilema lurideola*, *E. complana*, and *Lithosia quadra* (Table 3).

Table 3. Abundance (N) and rank of the ten most abundant species within linear and compact black alder woodlots.

Species	**Linear communities (N = 5)**		Compact communities (N = 3)	
	N	Rank	N	Rank
Non characteristic species				
Orthosia (Orthosia) incerta	229	1	103	4
Hoplodrina cfr. *octogenaria*	166	2	62	9
Peribatodes rhomboidaria	67	8	52	13
Epirrhoe alternata	65	9	23	34
Pachetra sagittigera	61	10	25	32
Lycia hirtaria	48	14	145	3
Characteristic species for linear woodlots				
Agrotis cinerea	145	3	21	36
Luperina testacea	105	4	14	49
Luperina dumerilii	82	5	4	105
Mythimna (Mythimna) impura	79	6	16	44
Agrotis exclamationis	76	7	8	43
Characteristic species for compact woodlots				
Eilema lurideola	19	44	289	1
Eilema complana	25	31	221	2
Lithosia quadra	5	106	96	5
Xestia (Megasema) triangulum	14	59	81	6
Diarsia mendica	20	43	64	7
Dysstroma truncata	2	155	64	8
Alcis repandata	10	73	60	10

3.2. Forest structure

Among the parameters involved in the dendrometric analysis, only the tree density showed results driven by the woodlot choice. In fact, all compact woodlots were denser than linear ones in the analysed buffer of 25 meters, considering both all tree species and alders alone (Table 4). Most of linear woodlots had older and larger trees than those composing compact ones, but they showed lower values of total basal area and total dendrometric volume (Table 4). The woodlot On1 was an exception among the linear ones as those with the highest trees and the highest amount of total dendrometric volume. Similarly, On2 was an exception among the compact woodlots because of the very low total dendrometric volume. Dead trees were present in three compact woodlots and in one linear woodlot only. Tree species different than alders were present within two sites of both woodlot shapes, but more abundant within compact ones. Summarising, linear woodlots were composed by less trees than compact woodlots resulting in a lower amount of wood, but these trees were older and larger than those in compact woodlots.

Table 4. Forest structure of sampled woodlots. DBH$_{\text{mean}}$: mean±S.D. of diameters at breast high; BA: basimetric area; V$_{\text{tot}}$: estimated total volume of wood.

Shape of alder woodlots	**Linear**				Compact			
Woodlot	**On1**	**On4**	**On6**	**On8**	On2	On3	On5	On7
All tree species								
Height$_{\text{mean}}$ (m)	35.9±3.9	19.6±1.9	18.9±3.2	14.1±4.7	20.6±1.7	21.8±3.6	16.2±3.7	23.1±2.6
Estimated age (y)	46	45	31	35	26	33	23	34
Density (n/ha)	589	287	597	342	835	916	1,989	995
DBH$_{\text{mean}}$ (cm)	41.0±8.9	41.2±14.5	25.1±12.1	32.3±16.6	21.8±11.2	27.2±10.0	17.6±6.4	28.0±7.5
BA$_{\text{tot}}$ (m^2/ha)	77.7	36.8	29.6	28.0	31.2	53.3	48.3	61.3
V$_{\text{tot}}$ (m^3/ha)	745.3	369.0	268.6	269.1	270.6	479.8	378.6	558.2
Alders total								
Density (n/ha)	589	279	597	326	716	836	1,989	995
DBH$_{\text{mean}}$ (cm)	41.0±8.9	40.2±13.7	25.1±12.1	29.9±13.7	20.4±10.6	27.9±8.9	17.6±6.4	28.0±7.5
BA$_{\text{tot}}$ (m^2/ha)	77.7	35.3	29.6	23.0	23.4	51.0	48.3	61.3
V$_{\text{tot}}$ (m^3/ha)	745.3	338.1	268.6	214.3	196.5	455.2	378.6	558.2
Alive alders								
Density (n/ha)	557	279	597	326	716	820	1,870	971
DBH$_{\text{mean}}$ (cm)	41.5±8.6	40.2±13.7	25.1±12.1	29.9±13.7	20.4±10.6	28.0±8.9	17.9±6.5	28.1±7.4
BA$_{\text{tot}}$ (m^2/ha)	75.2	35.3	29.6	23.0	23.4	50.6	47.0	60.2
V$_{\text{tot}}$ (m^3/ha)	720.7	338.1	268.5	214.3	196.5	450.9	371.2	549.1
Dead alders								
Density (n/ha)	32	0	0	0	0	16	119	24
DBH$_{\text{mean}}$ (cm)	31.5±8.9	0	0	0	0	19.0±6.4	11.6±2.7	24.1±11.0
BA$_{\text{tot}}$ (m^2/ha)	2.47	0	0	0	0	0.45	1.27	1.09
V$_{\text{tot}}$ (m^3/ha)	24.6	0	0	0	0	4.3	7.4	9.1
Other trees								
Density (n/ha)	0	8	0	16	119	80	0	0
DBH$_{\text{mean}}$ (cm)	0	69.0±0.0	0	63.5±5.4	28.9±12.7	19.2±14.1	0	0
BA$_{\text{tot}}$ (m^2/ha)	0	1.6	0	5.0	7.9	2.3	0	0
V$_{\text{tot}}$ (m^3/ha)	0	30.9	0	54.8	74.2	19.6	0	0

3.3. Landscape configuration

At large scale, woodland was the prevalent cover type from 200 m to 1,000 m buffer for On2 and On3, while grassland prevailed for On5 and On6. At smaller scale, in the 25 m buffer, the percentage of alder cover type was always over 90% for compact alder patches while it ranged between 50% and 90% among the linear ones. Alder surface was less than 50 % only for the On8 site. Moving from 25 to 50 m buffer alder area proportion did not varies significantly for On4 and On6 among the linear and for the compact On2. Among compact alder woodlots, On5 was associated with the greatest increase in grassland as the buffer radius increased. In the 50 m radius buffer grassland prevailed for all the linear patches. Cover type percentage was quite constant for linear woodlots while for compact ones it varied significantly for On5 and On7. Alder percentage variation became irrelevant beyond the 200 m buffer. Ecotone forest/grassland was similar for the same buffer radius for all the site except for the 50 m buffer where edge length was longer in linear than in compact woodlots (Table 5).

Table 5. Landscape analysis performed around light trapping points at different buffers. Total forest cover at 25 and 50 meters of buffers correspond to alder forest cover and was not duplicated in the table.

Shape of alder woodlots	**Linear**				**Compact**			
Woodlot	**On1**	**On4**	**On6**	**On8**	**On2**	On3	On5	On7
Landscape composition								
Grassland cover (%)								
buffer_25	14	46	46	59	0	0	3	0
buffer_50	50	68	68	77	0	0	40	0
buffer_200	62	62	92	58	9	1	82	29
buffer_500	40	36	92	53	19	0	92	51
buffer_1,000	24	27	92	40	18	1	86	32
Alder forest cover (%)								
buffer_25	86	54	54	41	100	100	97	100
buffer_50	50	31	32	23	100	84	60	74
buffer_200	7	6	8	9	32	22	18	7
buffer_500	6	4	6	3	7	7	7	3
buffer_1,000	2	1	3	2	2	3	5	1
Total forest cover (%)								
buffer_200	38	38	8	42	91	99	18	71
buffer_500	60	64	8	47	80	100	8	49
buffer_1,000	76	73	8	60	82	99	14	68
Ecotone forests/grasslands (m)								
buffer_50	205	210	230	242	0	0	196	0
buffer_200	1,490	1,584	739	1,453	915	225	1,647	1,292
buffer_500	5,697	7,731	4,267	6,097	3,496	375	4,236	7,176
buffer_1,000	1,365	17,436	13,220	22,135	10,833	1,524	22,642	17,279

3.4. Moth-forest relationship

Moth-forest relationship was investigated searching for correlations of moth data with forest structure and landscape configuration of sampled woodlot. We found very few significant correlations between forest structure and moth data. DBH and the linked estimated tree age were negatively correlated with species richness, whilst tree density was positively correlated with compositional aspects of moth communities (CA Axis2 values) and with moth abundance (Table 6).

Table 6. Linear correlation (Pearson) between moth community variables and structural attributes of forests. Only parameters with at least one significant correlation were included in the table. CA Axis 2: values of moth communities along the axis 2 of Correspondence Analysis; S: number of species; N: number of individuals; a: Fisher's alpha diversity index.

	CA Axis 2	***S***	***N***	***a***
Forest total				
Estimated age (y)	N.S.	-0.754*	N.S.	N.S.
Density (n/ha)	-0.765*	N.S.	N.S.	N.S.
DBH_{mean} (cm)	N.S.	-0.784*	N.S.	N.S.
Alders total				
DBH_{mean} (cm)	N.S.	-0.761*	N.S.	N.S.
Alive alders				
DBH_{mean} (cm)	N.S.	-0.754*	N.S.	N.S.
Other trees				
Density (n/ha)	-0.821*	N.S.	0.825*	N.S.
DBH_{mean} (cm)	N.S.	N.S.	N.S.	-0.774*

$p<0.05$ = *.

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Community composition, synthesised by the values of CA Axis2, was significantly related to selected landscape variables mostly at the buffers of 50 and 200 meters, but never to the largest one of 1,000 meters. Number of individuals was significantly correlated at the buffers of 50 and 200 meters, and equitability only to the 500 meters buffer. Grasslands and ecotones were positively correlated with moth compositional aspects (CA Axis2 values) and equitability, but negatively correlated with moth abundance. Consequently, the opposite occurred for forests (Table 7).

Table 7. Linear correlation (Pearson) between moth community variables and landscape configuration. Only parameters with at least one significant correlation were included in the table. CA Axis 2: values of moth communities along the axis 2 of Correspondence Analysis; *N*: number of individuals; *J*: Equitability.

	CA Axis 2	***N***	***J***
Grasslands cover (%)			
buffer_25	0.719*	N.S.	N.S.
buffer_50	0.898**	-0.760*	N.S.
buffer_200	0.932***	N.S.	N.S.
buffer_500	0.786*	N.S.	0.732*
Alder forest cover (%)			
buffer_25	-0.719*	N.S.	N.S.
buffer_50	-0.893**	0.847**	N.S.
buffer_200	N.S.	0.910**	N.S.
Forest cover (%)			
buffer_200	-0.932***	N.S.	N.S.
buffer_500	-0.784*	N.S.	-0.732*
Ecotone forests/grasslands (m)			
buffer_50	0.928***	-0.709*	N.S.

$p<0.05$ = *; $p<0.01$ = **; $p<0.001$ = ***.

4. Discussion

Black alder forests inhabit well characterized moth communities, that resulted very different from those found in a pine forest located at the same altitude, on the same geological substratum, and near to sampled alder woodlots. This occurred despite black alder forests are usually surrounded by pine forests. Ienco et al. [29] demonstrated that community composition is mainly driven by vegetation type, but our data also demonstrated an important role of other drivers when an individual forest type is analysed.

The study concerned eight sampled woodlots that can be considered a low number of sites, but it is very hard to find in the field woodlots pairs having in the shape the only difference. Furthermore, the dataset we used covered the whole flight period of moths encompassing the main beta-diversity driver for Lepidoptera. i.e. phenological changes [63], resulting in well-established datasets.

We found that moth communities of black alder forests of the Sila Massif were primarily shaped by landscape configuration, having forest structure a weaker effect. Furthermore, our hypothesis that linear woodlots inhabit an impoverished version of communities inhabiting compact ones seemed to be not confirmed.

As expected for impoverished communities, a lower species richness resulted within linear moth communities, thus apparently supporting our main hypothesis. On the contrary, the NODF analysis failed to support it, as most of linear communities were shaped by the turnover, with only one exception. The latter concerned a woodlot surrounded by a heavy grazed grassland, where cows were present constantly across the summer. Grazing is known to be detrimental to the moth diversity [64,65]. In our case, the impoverished moth community of grassland was not able to support the turnover, increasing the contribution of nestedness. Then, the turnover was the main beta-diversity process involved in shaping linear woodlot communities, with grassland species entering the community in substitution of forest ones when meadows are well preserved.

In multivariate analysis moth communities were mostly grouped accordingly to forest patch shapes, with one exception concerning the sole compact woodlot surrounded by grasslands (On5). We defined as compact the woodlots at least 50 metres wide, but our results demonstrated this measure be too small for reducing the edge effect when a riparian woodlot is not surrounded by other forest types. In fact, the On5 community resulted richer than expected in grassland individuals and poorer in forest ones. As an example, *Agrotis cinerea*, very abundant in mountain grasslands of South Italy [66], was particularly common within the On5 community. On the other hand, *Diarsia mendica*, living within different kind of forests [67] and common within compact alder woodlots, was found with only one individual in this woodlot. It has already been observed that the increasing of edges, a proxy of forest fragmentation, leads to a decrease of forest species populations [12,68,69]. However, the edges have not all the same ecological significance, as those between different forest types are obviously milder than those between forest and non-forest habitats, due to the similar abiotic conditions. Then, the edges between forests are weaker barriers to moth movements allowing the persistence of a characteristic alder moth community also in case of small woodlots.

Only few forest structure variables we studied were correlated with moth community attributes, i.e. estimated tree age, tree density, and diameter at breast high (DBH). Tree age, and the related DBH, was negatively correlated to diversity, apparently in contradiction with previous papers that found a higher diversity in older forests [70,71]. However, we found this discrepancy because trees growing along riverbanks, and then composing linear woodlots, were older than those growing within compact woodlots. This finding points out that a forest ecosystem could be defined old not only when composed by old trees, but when all the portion of a given ecosystem are at a mature successional stage as observed in old-growth forests [72].

Tree density seems to be effective in determining moth community composition as previously observed for other animals [73–75] due to changes in biotic and abiotic parameters. In addition, we found a positive correlation between tree density and moth abundance, as also observed by Fuentes-Montemayor et al. (13,75). In denser forests we would expect a reduced abundance of moths because the abundance and diversity of larval food plants is reduced due to low light [76–78]. On the contrary, we found an increased abundance of moths. This anomaly could be due to the lower predation pressure of Chiroptera registered in denser forests [79–81], but this should be better investigated.

Our data confirmed the findings of previous studies in which a buffer of about 200 metres is the best to describe the relationships of Lepidoptera community composition with landscape metrics [82–84], being always not significant at 1,000 metres of buffer. Black alder forests usually occupy very small surfaces [85], having a decreasing relationship with moth community composition when the buffer under consideration is too large. However, considering the surface of all forest types, the correlation between forest cover and moth community composition is still very significant. The negative correlation we found between equitability and forest cover at 500 meters of buffer, could be due to the increasing of the abundance of individual species linked to this habitat.

From a practical point of view, our study suggests that a width of 50 m may be not enough to give functionality to isolated riparian woodland patches, at least for moth communities. Our outcome may help not only forest habitat restoration planners aiming at increasing landscape connectivity [75], but also policy-makers. For the Italian law (D.Lgs 03 April 2018 n. 34, Testo Unico in materia di Foreste e Filiere Forestali [Consolidated Act on Forestry and Forest Chain]) a forest, to be such, must have a minimum width of 20 meters, significantly narrower than needed according to our results. Narrow and isolated forest patches can play at their best only the role of corridors and/or stepping-stones for forest specialist species [58]. Maintenance of large riparian forests promotes the integrity of waterways [86], being beneficial for both biodiversity and water quality.

5. Conclusions

Riparian forests provide several ecological services, among which biodiversity conservation is of relevant importance especially within national parks. However, in times of rapid habitat degradation, a more effective and informed riparian woodlot management is needed, and it should be supported by inter-disciplinary analyses. In this paper we found a secondary role of forest structure in

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driving composition and diversity of moth communities, having patch shape and landscape configuration a major role. Differences between linear and compact woodlot pairs were mostly due to the turnover, not confirming the original hypothesis that linear woodlots inhabit an impoverished version of moth communities, but only when grasslands are in a good conservation status. Our results can help to improve forest management planning because of the importance arisen from woodlot width and landscape configuration. Silvicultural intervention and forest restoration should avoid isolated spotted forest patches since they may not deliver the expected ecological benefit, being unable to support a forest specialist community. Increasing the minimum sizes for a forest, to be considered as such, leads to reduce the edge effect especially when other forests do not surround the riparian woodlot. This may assume an even greater significance in times of rapid landform transformation and climate changes that are expected to make riparian woodland more and more vulnerable.

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