Grazing Effects on Day Butterflies in a Mediterranean Woodland Ecosystem in Northern Israel

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Research article

Keywords: Mediterranean woodland, biodiversity conservation, day-butterflies, cattle grazing, monophagous species, endangered species

Posted Date: November 3rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-99467/v1

Abstract

The effects of cattle grazing on biodiversity in Mediterranean woodlands are yet unknown. To assess these effects on diurnal butterflies, we conducted daytime surveys in the Mt. Meron nature reserve (northern Israel) in two habitats over two different years. In each habitat we chose one site that was grazed by cattle and, as a control, a similar but ungrazed site. Belt transects (5m wide), divided for 100m replications, were surveyed five times on ridges in 2015 (11 replications, 538 butterflies, 25 species), and nine times in valleys in 2016 (12 replications, 3,944 butterflies, 38 species). In both habitats, species similarity index between sites was high. Richness was higher in the ridge control and evenness was higher in the valley grazed site. In both habitats total abundance was ca. twofold higher in the control, and the abundance of woody affiliated butterflies was threefold higher in the control, probably due to overgrazing, which affects butterflies' breeding niches. For batha polyphagous and oligophagous butterfly species, abundance was similar between the sites, and for a few of those, associated with increaser plants, it was even higher in the grazed sites. However, the batha monophagous species were significantly more abundant in the control. Monophagous and endangered species were found to be more sensitive to cattle grazing. We conclude that the current cattle grazing management in Mt. Meron reserve affects butterfly populations negatively. Therefore, we recommend more regulated grazing and early-season deferment precautions, along with designation of no-grazing areas in reserves.

Background

In the eastern Mediterranean region, goat and sheep grazing has been practiced for about 10,000 years, and constitutes an important factor in shaping the ecosystems (Naveh and Dan 1973; Perevolotsky and Seligman 1998). During recent decades, traditional foraging by goats declined due to economic and social changes. The absence of large herbivores together with legal restrictions of wood cutting led to more closed and spatially homogeneous woody vegetation, reduced plant diversity, and increased fire risk due to the accumulation of inflammable material. To cope with these negative phenomena, many Israeli Mediterranean nature reserves have implemented managed beef-cattle grazing. Since the early 1980s, cattle herds have been introduced into about one-third of the Mt. Meron nature reserve, our research area. To explore the effect of this new management method on the herbaceous vegetation components, a five-year research project was established in 79 sites in nature reserves in northern Israel, 10 out of them in woodlands on Mt. Meron (Noy-Meir et al. 1989). In most of the sites, the survey found maximum plant richness and diversity under a medium stocking rate grazing regime. However, in the Mt. Meron sites, no difference was found between cattle-grazed and ungrazed plots in terms of plant richness. Since then, as recommended, seasonal grazing has been applied with early-season deferment in some parts of the reserve (Golodets et al. 2011; Gutman et al. 1999), but year-round grazing is implemented in other parts of the reserve. The above-mentioned findings of Noy-Meir et al. (1989) have been supported by many other studies of cattle grazing in Israel (e.g., Naveh and Whittaker 1979; Perevolotsky and Seligman 1998; Noy-Meir and Oron 2001), which found positive, mainly moderate, effects of grazing management on herbaceous plant richness and diversity, which supporting the intermediate disturbance hypothesis

(Connell 1978). Some studies in Israel have researched the grazing effects on the woody components. In the same area that we examined, Carmel and Kadmon (1999) found that both cattle grazing and goat grazing reduced the rate of tree cover increase, but even intensive grazing did not halt the process. Agra and Ne'eman (2009) found that in the short term (two years), canopy removal had a positive effect, but cattle grazing negatively affected the herbaceous species richness. Glasser and Hadar (2014) concluded that grazing must be considered in the broad perspective of its effects on, and benefits to the natural ecosystem, and not only its agricultural livestock-food-supply aspect. Schoenbaum et al. (2018) found that after four consecutive annual seasons of cattle foraging, no negative effects on woody species richness could be detected, but the vine species richness and abundance decreased significantly. Kirk et al.'s (2019) study of a Mediterranean maquis in north Tunisia mountains showed that the herbaceous community composition was negatively affected by any grazing pressure, but the woody community composition was damaged only under moderate-to-high grazing pressure.

Day butterflies (Lepidoptera, Rhopalocera) are easy to observe and identify and they constitute an important link within the food web. Their short life cycle and high breeding potential enable them to respond quickly to changes in both biotic and abiotic environmental factors, such as habitat, climate, host and food plants, as well as their predators and parasites. These characteristics enable the common use of day butterflies as a bio-indicator for ecosystem status and changes (Nowicki et al. 2008; Pe'er and Settele 2008; Schwartz-Tzachor 2007).

Studies of the impact of grazing on butterfly communities have so far yielded inconsistent conclusions. In research conducted in the Carpathian Mountains, Elligsen et al. (1997) found an advantage for day-butterfly populations under moderate grazing, compared with both heavy grazing and no-grazing regimes. However, in Germany, Kruess and Tscharntke (2002) found that the highest richness, abundance, and diversity of butterfly populations was under no-grazing management, less under light grazing, and the least under heavy grazing. In their study in a nature reserve in Greece, Grill and Cleary (2003) reported a decrease of butterfly richness under grazing, compared with a no-grazing area. They also found that the endangered butterfly species was concentrated at sites with low human impact. A similar result was reported in three other European studies (Börschig et al. 2013 in Germany; Jugovic et al. 2013 in Slovenia; Schtickzella et al. 2007 in France), which also found an advantage for butterfly populations under no grazing, compared with any grazing management.

In their study of the influence of wild boar rooting activity on butterfly populations in Italy, Scandurra et al. (2016) also found higher butterfly species richness, abundance, and diversity in the no-boar area, in comparison with the boar activity area. They reported that butterfly specialist species were significantly more affected by boar activity than generalist species were. In contrast, in northern Israel (Ramat Hanadiv, Carmel Mt.), Schwartz-Tzachor (2007) found that cattle grazing in a garrigue (shrub) area increased butterfly abundance, although it had no effect on butterfly species richness or diversity. A species-specific study in Israel of the butterfly *Tomares nesimachus* also indicated lack of grazing (and with it, a succession progress) as a greater threat for this endangered and protected grassland species than overgrazing (Pe’er and Settele 2008). In another recent Israeli survey, butterfly abundance in a grassland ecosystem on the Golan Heights was found to be higher in the grazed area, and no overall differences were found in butterfly richness and diversity between grazed and ungrazed sites (Pe'er et al. 2016).

The present study aimed to assess the impacts of beef cattle grazing on butterfly communities (richness, abundance, and community structure) in Mt. Meron Nature Reserve, as representative of a northern Israeli Mediterranean mesic woodland ecosystem.

Materials

Study area

Butterfly survey was conducted during 2015 and 2016 in the Mt. Meron Nature Reserve (Upper Galilee, northern Israel, Fig. 1), which comprises about 8,000 ha. The study area is a Mediterranean woodland ecosystem, 700 m to 1000 m above sea level, with a mean annual precipitation of 900 mm; almost all the rain falls between November and March. The rock is limestone and dolomite with thin layers of chalk and marl.

The total vegetation cover in the study area was 95%, with the follow composition: (a) woody patches: composed of ca. 60% broad-leaf trees, 8–12 m high, ever-green (mainly *Quercus calliprinos*) and deciduous (e.g., *Quercus boissieri*, and some *Rosaceae Spp.*), and ca. 15% shrubs (e.g., *Spartium junceum, Rhamnus punctata*); and (b) batha patches: composed of ca. 10% dwarf shrubs (e.g., *Sarcopoterium spinosum*) and ca. 10% herbs (about 150 species, Oron and Lavi 2017). A decrease of about 15% in the cover by wood and shrub components was reported in the areas that had been under cattle grazing for 20 years, that is, our treatment transects (GIS layer of classified vegetation formations, 2013 landsat8 satellite imagery analysis, data by Israel Nature and Parks Authority). Stocking rate in the research area was 200 adult beef cows on 400 hectares, i.e., 0.5 livestock units per hectare, which is considered a high stocking rate (Gutman et al. 2000; Schoenbaum et al. 2018). Since herbaceous component was in shortage in the woodland habitat, and the grazing management was based on woody components along the dry season, a concentrated supplement of protein-rich food was supported in the field.

Two sites were chosen for sampling each year: one had been under cattle grazing for about 20 years, and the control site was free of cattle grazing. The two sites in 2015 were located along ridges, separated by a distance of 2 km: The Neria site was under a winter–spring (December-May) cattle grazing regime; and the Afa'im site was free of cattle. The two sites in 2016 were located along two valleys (narrow valleys that are dry riverbeds), separated by a distance of 3 km: The Hiram site was under a summer–autumn (June–November) cattle grazing regime, and the Tzo'er site had been free of cattle for two years, and under light cattle grazing during the previous four decades. The other physical and biological conditions were similar for the two pairs of sites.

Butterfly observations

Alongside dirt tracks, we marked 1,100 m survey transects on ridges in 2015, and 1,200 m survey transects along valleys in 2016. These transects alternately crossed patches of wood and of batha (open vegetation). The transects were divided into sections of 100 meters each, which were considered as replications for the analysis. Butterfly transect counts were conducted according to the Pollard scheme (Pollard 1977, 1979). For each section, we recorded all the observed butterfly species and individual numbers within a 5-m belt, while walking slowly along the road (an average of 5 min per 100-m section). We walked together; the first author identified the butterflies and the co-author recorded the data. For butterfly identification, we used the *Field Guide to the Butterflies of Israel* (Benyamini 2010). In cases of uncertainty about a butterfly identity, it was photographed, or if necessary, captured using a net and then released at the site. Observations were conducted in appropriate weather for butterfly activity, i.e., with no rain or gusts of wind and within the temperature range of 19º to 32º C. Monitoring at the grazed and the control ungrazed sites was performed at consecutive hours of the same day, or at similar hours on consecutive days, due to weather conditions. We conducted 5 transect counts along ridges between April and September 2015, and 9 transect counts along valleys between March and July 2016.

Definition of the butterfly feeding strategy (Benyamini 2010; Tomer O. personal communication)

Monophagous species: breeding on 1 or 2 closely related plant species.

Oligophagous species: breeding on different plant species of the same family.

Polyphagous species: breeding on plant species of different families.

Statistical analysis

Statistical analysis and figs drawing were performed using Excel software.

To characterize butterfly communities and compare the different sites, we used the following indicators:

Richness: The numbers of species in the grazed and the control (ungrazed) sites, respectively, were compared separately for each year (2015 on ridges, 2016 in valleys), using a t-test for comparing replications, and a paired t-test for comparing survey transect dates.

Richness similarity index: A Jaccard similarity index (Jaccard 2012) was employed separately for each year (2015 on ridges, 2016 in valleys), to evaluate the similarity of the species lists of the two grazing regimes.

Abundance: The total numbers of individuals in the grazed and the control (ungrazed) sites were compared separately for each year (2015 on ridges, 2016 in valleys) using a t-test for comparing replications, and a paired t-test for comparing survey transect dates. The numbers of individuals of each species in the different grazing regimes were compared using a χ^2 test.

Diversity: We used a Shannon diversity index (Shannon 1948) to examine diversity. This index is sensitive to counts of single individuals per species (mainly endangered species). The Shannon indices of the grazed and the control (ungrazed) sites were compared separately for each year (2015 on ridges, 2016 in valleys) using a t-test.

Evenness: A Pielou index (Pielou 1975), which is derived from the Shannon diversity index, was used to examine evenness. The evenness indices for the grazed and the control (ungrazed) sites were compared separately for each year (2015 on ridges, 2016 in valleys) using a t-test.

Abundance according to habitat and host plants: Abundance in the grazed and the control (ungrazed) sites was compared separately for each year (2015 on ridges, 2016 in valleys), according to the butterfly habitat affiliation: trees or batha patches and butterfly species host plants (Benyamini 2010).

Results

A total of 4482 individuals belonging to 36 species and 6 families (Papilionidae, Pieridae, Nymphalidae, Satyridae, Lycaenidae, and Hesperiidae) were recorded during the two research seasons.

Species richness

The mean number of species in ridges (2015) was significantly lower in the grazed site (7.5 species/section) than in the control (11.0 species/section), but no such difference was found in the valleys (2016) (Fig. 2). Maximum richness in picking season was similar in both habitats (16 species, Fig. 3). The total number of species on ridges was 22 in the grazed area and 23 in the control; in the valleys, it was 31 species in the grazed and 35 in the control areas.

Species similarity

Altogether, 39 species were recorded in the two habitats, ridges and valleys, and under the two managements: grazing and control (no grazing) (Table 4). On the ridges (2015), 20 identical species and 5 exclusive species were recorded under the two managements, with high species similarity (80%, Table 1). In the valleys (2016), 28 identical species and 10 exclusive species were recorded under the two managements, with species similarity of 78%.

Table 1
Similarity of butterfly species between cattle grazing and ungrazed sites

Habitat (year)	Management	Total species	Unique species	Identical species	Jaccard Index
Ridges (2015)	Grazing	22	2	20	0.80
	Control	23	3		
Valleys (2016)	Grazing	35	7	28	0.78
	Control	31	3		

Abundance

In both habitats, the mean number of individual butterflies was significantly lower in the grazed sites than in the control: 85% and 79% on ridges and in valleys, respectively (Fig. 4). Maximum abundance was recorded in mid-May in the valleys (2016), and at the beginning of June on the ridges (2015, May transect counts were not implemented) (Fig. 5). On the ridges, the total richness was 189 individuals in the grazed site and 349 in the control; in the valleys, it was 1,415 individuals in the grazed site and 2,529 individuals in the control. Less individuals were recorded in the grazed sites than in the control in all transect counts, in both habitats (Fig. 5).

Evenness (Pielou index)

A relatively high mean of species evenness was found on the ridges (2015), which was similar between the two managements. A lower mean of species evenness was recorded in the valleys (2016), which was significantly higher in the grazed site than in the control (Table 2).

Table 2
Mean species evenness (Pielou index) of butterfly populations in the grazed and the control sites

Habitat (year)	**Management**	**Species evenness**		
		Mean	**S.D.**	**Significance**
Ridges (2015)	Grazing	0.89	0.045	0.68
	Control	0.90	0.045	
Valleys (2016)	Grazing	0.81	0.047	< 0.001*
	Control	0.71	0.082	

* Significant difference ($p < 0.05$, t-test)

Diversity (Shannon index)

The mean diversity of butterfly populations was lower in the grazed site than in the control on ridges, but higher in the grazed site than in the control in valleys (Table 3).

Table 3
Mean diversity (Shannon index) of butterfly populations of grazed and control sites

Habitat		Shannon diversity		
(year)	Management	Mean	S.D.	Significance
Ridges (2015)	Grazing	1.75	0.32	0.0086*
	Control	2.14	0.31	
Valleys (2016)	Grazing	2.30	0.19	0.0093*
	Control	2.05	0.24	
* Significant difference ($p < 0.05$, t-test)				

Abundance according to habitat and host plants

Twenty-five of the 39 observed butterfly species are exclusively (or mainly) active and lay eggs in batha patches, and only 10 are mainly active in wood patches (Benyamini 2010). The other four species are not exclusively connected to a specific habitat (Table 4).

Table 4
List of recorded butterfly species and selected characteristics

Plant formation and butterfly species	Number of individuals				Feeding strategy	Host plants
	Ridges(2015)		Valleys(2016)			
	G	C	G	C		
Batha patches						
Papilio machaon	0	0	0	1	P	Apiaceae-few species, *Ruta chalepensis*
Pieris brassicae	6	6	113	151	P	Brassicaceae species, *Capparis* spp. And more
Artogeia rapae	3	6	13	10	P	Brassicaceae species, *Capparis* spp. And more
Pontia daplidice	11	7	87	17*	P	Brassicaceae species, *Reseda* spp. And more
Anthocharis cardamines	0	0	10	4	O	Brassicaceae species
Anthocharis damone [En]	0	0	1	0	O	*Isatis lusitanica*, *Crambe hispanica* (?)
Colias croceus	54	27*	173	46*	O	Fabaceae species
Vanessa cardui	6	2	51	52	P	Many species of different families
Melitaea telona	1	2	11	5	P	Species of Asteraceae, Dipsaceae and more
Melitaea syriaca	0	0	0	7*	O	Vebascum spp., Scrophularia spp.
Melanargia titea	0	6*	0	1	O	Poaceae species
Lasiommata maera	0	3	12	12	O	Poaceae species (mainly)
Cigaritis acamas	1	0	2	49*	M	Cooperation with ants
Cigaritis cilissa [En]	2	1	62	209*	M	Cooperation with ants

G grazed site, *C* control (ungrazed) site, *P* Polyphagous species, *O* Oligophagous species, *M* Monophagous species

[En] Endangered butterfly species in Israel (Pe'er and Benyamini 2008)

[a] No discrimination was accomplished between the two similar species, *Zerynthia deyrollei* and *Zerynthia cerisyl*, which are common in the research area

*Significant difference between managements within the habitat ($p < 0.05$, χ^2 test)

Plant formation and butterfly species	Number of individuals				Feeding strategy	Host plants
	Ridges(2015)		Valleys(2016)			
	G	C	G	C		
Lycaena phlaeas	1	2	3	2	O	Polygonum spp.
Lycaena thersamon	1	0	2	0	O	Polygonum spp.
Lampides boeticus	14	27	102	179*	P	Fabaceae species, *Capparis* spp. And more
Aricia agestis [En]	0	0	57	8*	O	Geraniaceae species
Cyaniris bellis [En]	0	0	4	3	O	*Trifolium* spp. And other Fabaceae species
Polyommatus Icarus	2	8	41	9*	O	Fabaceae species
Pseudophilotes vicrama	3	18*	3	3	P	Lamiaceae, Rosaceae, Convolvulaceae species and more
Glaucopsyche alexis [En]	0	0	0	27*	O	Fabaceae species
Carcharodus alceae	0	0	0	4	O	Malvaceae species
Muschampia teessalum	0	0	0	23*	M	Phlomis spp.
Thymelicus hyrax	0	0	0	2	O	*Hordeum bulbosum* and other Poaceae spp.
Wood patches						
Zerynthia spp.[a]	9	15	36	20	M	Aristolochia spp.
Gonepteryx Cleopatra	3	48*	78	215*	M	Rhamnus spp.
Limenitis reducta	8	24*	57	164*	M	Lonicera spp.

G grazed site, *C* control (ungrazed) site, *P* Polyphagous species, *O* Oligophagous species, *M* Monophagous species

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Plant formation and butterfly species	Number of individuals				Feeding strategy	Host plants
	Ridges(2015)		Valleys(2016)			
	G	C	G	C		
Hipparchia fatua	1	4	2	1	O	*Piptatherum* spp. And more Poaceae species
Maniola telmessia	14	47*	406	1060*	O	Poaceae species
Kirinia roxelana [En]	5	7	3	5	O	Poaceae species
Satyrium spini	2	16*	57	164*	M	Rhamnus spp.
Satyrium ilicis	19	32	3	17*	M	Quercus calliprinos
Callophrys rubi [En]	0	0	1	0	M	Rhamnus punctata
Celastrina argiolus [En]	0	0	1	5	P	Cooperation with ants, Several families
Unspecified habitat						
Vanessa atalanta	0	2	0	0	O	Urticaceae species
Lasiommata megera	23	39	14	42*	O	Poaceae species
Leptotes pirithous	0	0	1	4	P	Fabaceae species and other families
Spialia orbifer	0	0	9	8	O	*Rubus* spp. And other Rosaceae species

G grazed site, *C* control (ungrazed) site, *P* Polyphagous species, *O* Oligophagous species, *M* Monophagous species

[En] Endangered butterfly species in Israel (Pe'er and Benyamini 2008)

[a] No discrimination was accomplished between the two similar species, *Zerynthia deyrollei* and *Zerynthia cerisyl*, which are common in the research area

*Significant difference between managements within the habitat ($p < 0.05$, χ^2 test)

Abundance of the wood affiliated species

In both habitats (ridges and valleys), the abundance of the wood-affiliated butterfly species was significantly lower in the grazed sites than in the control (one-third to one-half of the individuals, Tables 5, 6).

Abundance of the batha-affiliated species

Abundance of the batha-affiliated butterfly species was lower in the grazing site than in the control on ridges, and similar between managements in valleys (Tables 5, 6). Abundance was lower under grazing than in the ungrazed control on ridges for the butterfly species that are associated with Brassicaceae, Poaceae, and Lamiaceae plants, and in valleys only for the butterflies associated with the Lamiaceae species.

Table 5
Butterfly abundance by plant formation and host plants on ridges (2015)

Plant formation and host plants	Number of species	Number of individuals in the grazed site	Number of individuals in the control	p (χ^2)
Batha patches				
Brassicaceae (mainly)	3	17	58	< 0.001*
Poaceae	2	0	5	0.068
Lamiaceae	1	5	15	0.10
Fabaceae (mainly)	3	60	58	0.90
Other families	5	8	8	1.00
Total	14	90	145	0.011*
Wood patches				
Poaceae	3	14	58	< 0.001*
Trees	4	73	110	0.052
Vines	2	17	33	0.11
Total	9	104	201	< 0.001*

* Significant difference ($p < 0.05$, χ^2 test)

Table 6
Butterfly abundance, by plant formation and host plants in valleys (2016)

Plant formation and host plants	Number of species	Number of individuals in the grazed site	Number of individuals in the control	p (χ^2)
Batha patches				
Brassicaceae (mainly)	5	244	182	0.33
Poaceae	3	12	15	0.68
Lamiaceae	2	3	26	0.001*
Fabaceae (mainly)	5	320	264	0.10
Other families	8	124	79	0.025*
Total	23	683	566	0.019*
Wood patches				
Poaceae	3	411	1,066	< 0.001*
Trees	4	139	396	< 0.001*
Vines	2	93	184	< 0.001*
Total	9	643	1,646	< 0.001*
* Significant difference ($p < 0.05$, χ^2 test)				

Butterfly richness and abundance by feeding strategy

In both habitats (ridges and valleys), the abundance was significantly lower in the grazed site relative to the control for only 17% of the oligophagous and polyphagous butterfly species, and for some of these species it was actually higher in the grazing site (Table 7, Fig. 6). However, for monophagous butterflies, we found a stronger influence of cattle grazing. For 43% and 67% of these species on ridges and in valleys, respectively, lower abundance was found in the grazed sites, and the opposite effect (higher abundance in the grazed sites) was not found in any of them.

Eight endangered butterfly species were recorded in the valleys, and only two on the ridges. Six of these are monophagous or oligophagous (Table 4).

Table 7
Changes in butterfly abundance by feeding strategy

	Polyphagous and oligophagous species			**Monophagous species**		
Habitat	Total number of species	No. of species with lower abundance under grazing	No. of species with higher abundance under grazing	Total number of species	No. of species with lower abundance under grazing	No. of species with higher abundance under grazing
Ridges	18	3	1	7	3	0
Valleys	29	5	4	9	6	0

Discussion

We found in two habitats, ridges (2015) and valleys (2016), in a Mediterranean mesic woodland ecosystem (Mt. Meron, Upper Galilee, northern Israel) evidence of lower day-butterfly-population indices (richness and abundance) in sites under cattle grazing, compared with ungrazed control sites. This is consistent with other studies that found a negative impact of grazing on butterfly communities (Börschig et al. 2013; Grill and Cleary 2003; Jugovic et al. 2013; Kruess and Tscharntke 2002; Schtickzella et al. 2007).

We found the woody-niche-affiliated butterflies to be more severely affected by grazing, in comparison with batha-patch-affiliated butterflies. This could be due to heavy cattle grazing on shrubs, vines (Schoenbaum et al. 2018), lower tree canopies and the understory Poaceae (grasses) plants, which are hosts for butterfly breeding (Schtickzella et al. 2007). The heavy grazing in the woods might be due to a lack of herbaceous pasture in the batha patches during the long Mediterranean dry season. This effect is supported by the findings of Kirk et al. (2019) in northern Tunisia, which showed severe damage to the woody community composition under moderate-to-high grazing pressure.

In the batha patches we found in the grazed sites (mainly on ridges), a lower abundance of butterfly species that breed on Brassicaceae, Lamiaceae and Poaceae (Tables 5, 6). This can be explained by damage incurred by cattle grazing to both nectar and breeding plants of Lamiaceae and Poaceae (Schtickzella et al. 2007). It is possible that some of the Asteraceae and the Fabaceae nectar and breeding plants (and, in valleys, Brassicaceae, as well) did not significantly suffer from grazing. These plants are the hosts of generalist (polyphagous) butterfly species, mainly the Pieridae (Tables 4, 7), which did not show decline in the grazing sites, and some that even increased (Tables 5, 6, 7, Fig. 6). The moderate damage for batha-patch-affiliated butterflies due to grazing corroborates previous studies from batha Mediterranean grassland ecosystems, which reported a diversity increase under a moderate grazing regime (Noy-Meir et al. 1989).

We conclude that monophagous and endangered butterfly species are more sensitive to cattle grazing than the oligophagous and polyphagous species are (Tables 4, 7). Similar findings have been reported from Morocco (Thomas and Mallorie 1985), Greece (Grill and Cleary 2003), and Italy (Scandurra et al. 2016). This may be the result of big mammals' influence on the vegetation, which increases evenness (less available ecological niches) and mainly damages the more specialist and sensitive butterfly species.

The oligophagous species *Aricia agestis* was the only endangered species whose population was significantly larger in the grazed site than in the control site – 57 versus 8 individuals in the valleys, respectively (Table 4, Fig. 6). This butterfly breeds on plant species of the Geraniaceae, which are palatable for cattle (personal knowledge). Geraniaceae were observed in the study area only as a minor vegetation feature and could not explain that intriguing effect. This warrants further research.

The common batha-patch polyphagous species *Lampides boeticus*, which was negatively affected by grazing, behaved almost "monophagously" in our study area. It breeds mainly on young branches of *Spartium junceum* (a bush, Fabaceae), which is eaten rapidly by the cattle.

We found heavier grazing damage on the ridges in 2015 (under winter–spring grazing regime) than in the valleys in 2016 (under summer–autumn grazing regime), in terms of both butterfly richness index (Figs. 1, 2, 5), and the abundance of the batha-affiliated butterfly species. On the ridge even butterfly populations that breed on increaser plants, which may benefit from grazing, still had lower indices than in the control. However, in the valleys some of these species had higher indices in the grazed sites (see also Briske 1996). Butterfly populations that breed on Brassicaceae were lower in the grazed site on the ridges, but did not decline, and were even higher in the valleys (Tables 5, 6). The same applies to *Zerynthia* spp. populations, which breed on the poisonous genera *Aristolochia*. The heavier grazing damage on the ridges, under a winter–spring grazing regime, could be attributed to that more intense management, compared with the valley grazing management of summer–autumn, with early season deferment.

The above difference between the ridges and the valleys habitats might explain the different effect there of cattle grazing on butterfly population evenness (Table 2) and diversity (Table 3). On the ridges we found high and similar evenness for the two managements, but greater diversity in the control. However, in the valleys we recorded in the control lower values of both diversity and evenness, and the evenness was there even lower than on the ridges. This lower evenness resulted from the higher number of endangered butterfly species there, most of which consist of very small populations (Table 4). The higher diversity of the control butterfly population on the ridges, compared with the grazing site, was a result of the control's higher richness combined with a similar evenness under the two managements. Nevertheless, in the valleys, the lower control's diversity resulted from a similar mean richness in the two sites but a lower evenness in the control. This is since Shannon diversity index is positively correlated with both evenness and richness indices.

We suggest that the significant changes in the butterfly populations under cattle grazing in the Mt. Meron region can be attributed to changes caused by grazing to their host and nectar plants (Pe'er and Settele 2008; Thomas and Mallorie 1985; Schtickzella et al. 2007). This is supported by the findings of a concomitant study done on the effect of cattle grazing on the herbs' communities (Oron and Lavi 2017), which was carried out on the same transect lines and years. In this research the herbaceous species richness was found to be lower in the grazed sites compared with the control; species diversity indices were lower under heavy winter–spring grazing management, compared with the less severe summer–autumn grazing regime; and the occurrence frequencies of the plant functional groups was found to differ clearly by management regime. All these changes would be expected to influence some of the butterfly populations. Another concomitant study, on the fungi in the woody patches of the same transects (Perelberg et al. 2016), also found a significant decrease in most of the ecological factors, which may emphasize the deep negative effect of cattle grazing on our research region.

The significantly lower butterfly population indices in the grazed sites, and almost total disappearance of the endangered species, under both heavy winter–spring grazing regime (on the ridges) and more moderate summer–autumn grazing (in the valleys), are consistent with Scandurra et al. (2016) and Schtickzella et al. (2007). However, other studies have reported significant advantages for butterflies under extensive grazing management compared with a no-grazing regime (Bartoňová et al. 2017; Munguira et al. 2017; Slancarova et al. 2015; Stefanescu et al. 2011). These contradicting findings might result from the ambiguity of the definition of "light-medium grazing management." Differences could also stem from the changing balance between the contradicting influences of grazing on plants and butterfly populations. Light-to-medium grazing may open the vegetation complex for more plant species (increase richness and diversity), but at the same time can damage or eliminate plant species of the butterflies' nectar and food complex.

The present research results demonstrate that cattle grazing, as conducted for two decades in the woodland ecosystem in northern Israel, has had significant harmful effects on the butterfly populations, apparently as a result of decreasing the habitat heterogeneity and reducing the food resources, and specifically by impairing plants. We hypothesized that in contrast to thousands of years of traditional goat grazing, the new cattle introduction in this area poses the potential for overgrazing damage. Further research is needed to support this assumption.

Conclusions

We conclude that overgrazing by beef cattle occurs in the woodland ecosystem of the Mt. Meron Nature Reserve, including the more moderate grazing regime areas in the reserve. This grazing management significantly reduces most butterfly species populations, and specifically the wood-breeding species. Most alarming are the effects on monophagous and endangered butterfly species. We suggest that this degradation in the condition of butterfly populations is a result of deterioration of their host and nectar plant populations. Far more regulated grazing management and early-season grazing deferment might mollify the damage of the cattle grazing to this ecosystem. Closed refuge areas of the nature reserve, with no grazing, are essential for protecting the endangered butterfly species.

Abbreviations

G grazed site

C control (ungrazed) site

P Polyphagous species

O Oligophagous species

M Monophagous species

[En] Endangered butterfly species in Israel

Declarations

Ethics approval –

Not applicable (the research involved only monitoring existing butterfly population without any manipulation).

Consent for publication –

Not applicable (the research did not involve Human subjects).

Availability of data and material -

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Competing interests –

The authors declare that have no competing interest.

Funding -

The research was fully funded by the Nature and Park Authority of Israel.

Authors contribution -

Both authors contributed equally to the research: both were involved in monitoring, in collecting data, in analyzing data and in actual writing the paper.

Acknowledgements –

We are grateful to Guy Pe'er for his valuable professional manuscript revision, and to Jonathan Saferstein for the language revision.

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Figures

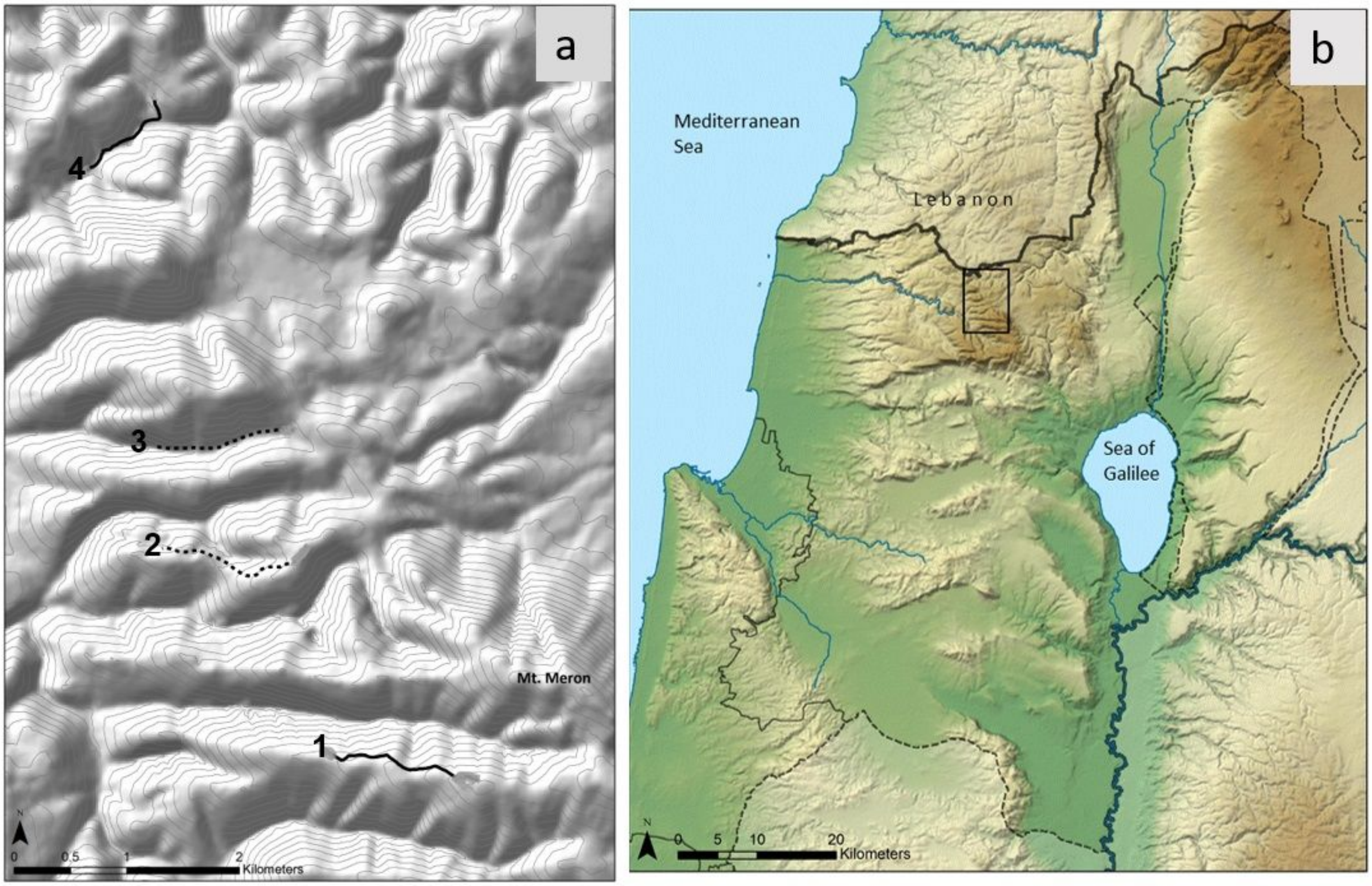

Figure 1

Topographic map of the four study transects in Mt. Meron Nature Reserve (a) and location within northern Israel (b, inset). 1) Afa'im Ridge, control, 2015; 2) Neria Ridge, grazed, 2015; 3) Hiram valley, grazed, 2016; 4) Tzo'er valley, control, 2016 Fig1a: Esri. "Topographic" [basemap]. Scale not given. "World Topographic Map". July 27, 2020. http://www.arcgis.com/home/item.html?id=30e5fe3149c34df1ba922e6f5bbf808f Fig1b: http://www.maps-of-the-world.net/ Large relief map of Israel. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

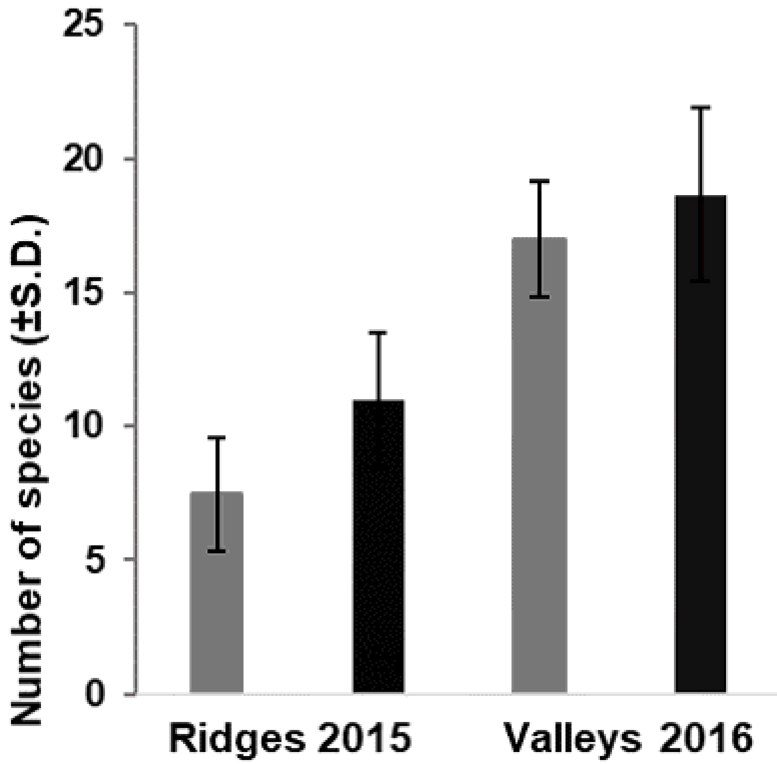

Figure 2

Butterfly species richness in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Seasonal mean number of species (±S.D.). Significance of difference between managements: ridges (2015), $p = 0.0028$*; valleys (2016), $p = 0.17$ * Significant difference ($p < 0.05$, t-test)

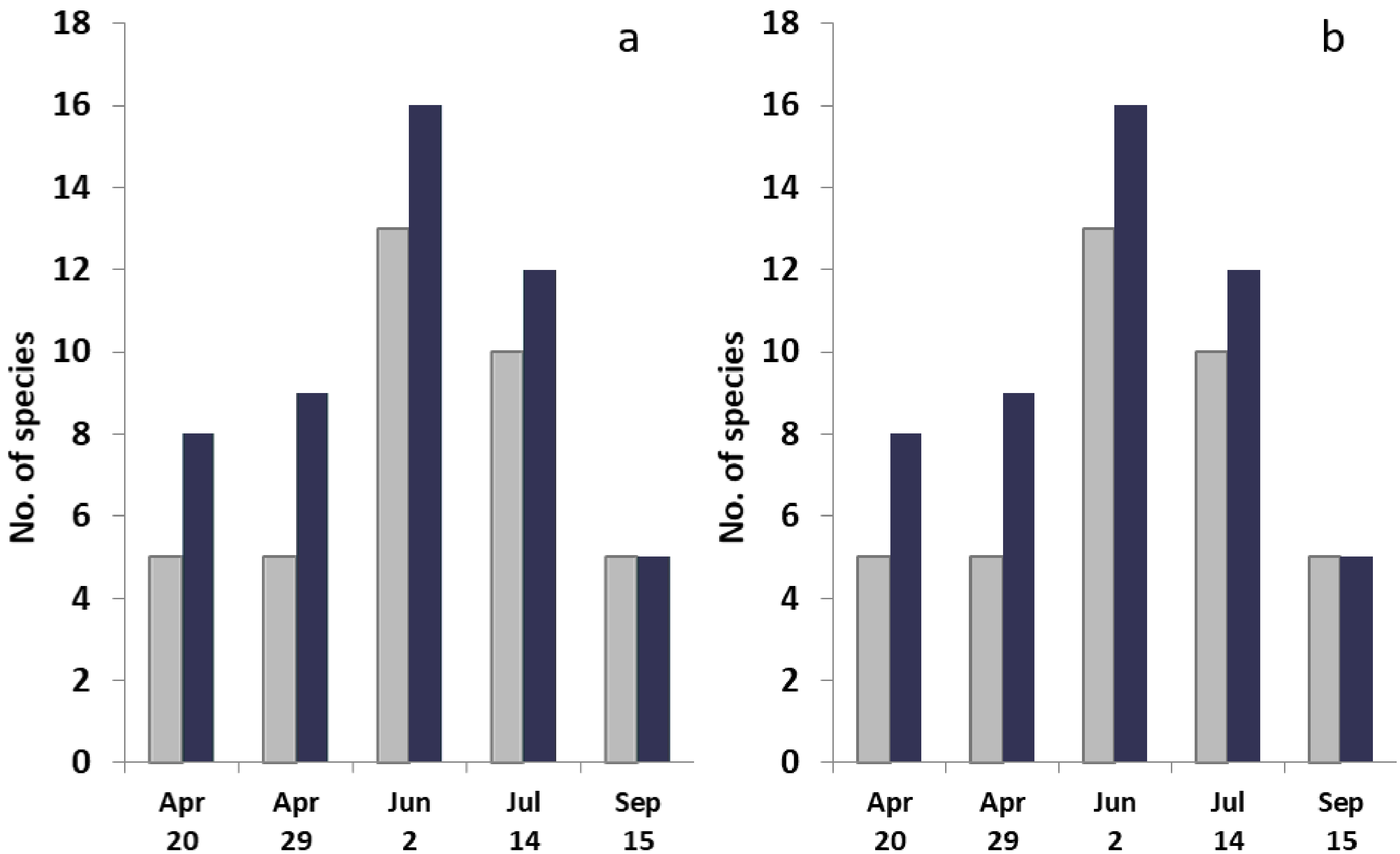

Figure 3

Butterfly species richness along the sampling period, in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Seasonal mean number of species and significance of difference between managements: a: ridges (2015), grazed – 7.6, control – 10.0, $p = 0.024$*; b: valleys (2016), grazed – 12.7, control – 14.0, $p = 0.10$ * Significant difference ($p < 0.05$, t-test)

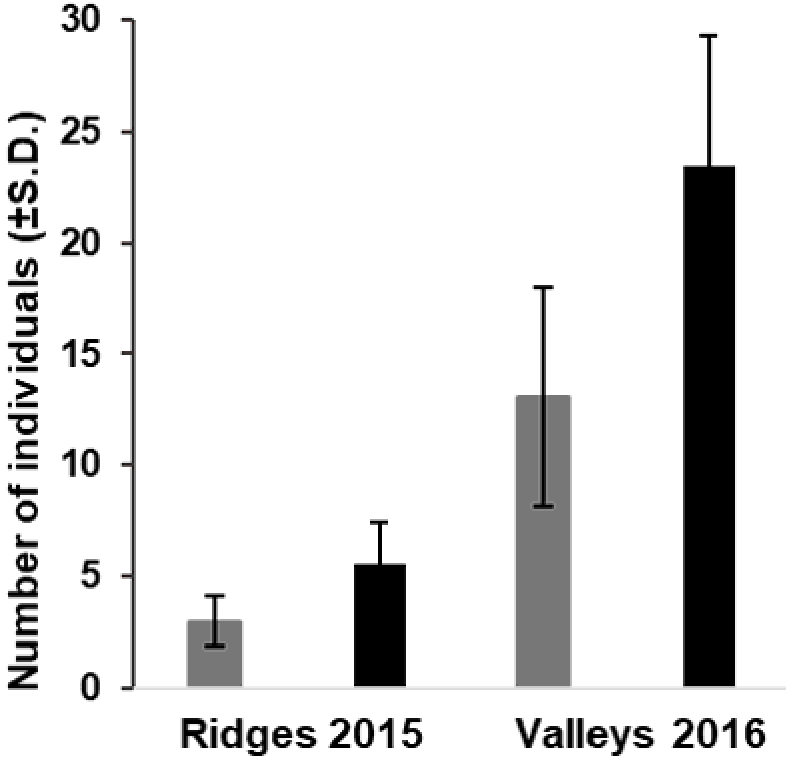

Figure 4

Butterfly abundance in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Mean number of individuals (±S.D.). Significance of difference between the managements: ridges (2015), $p = 0.0015$*; valleys (2016), $p < 0.001$* * Significant difference ($p < 0.05$, t-test)

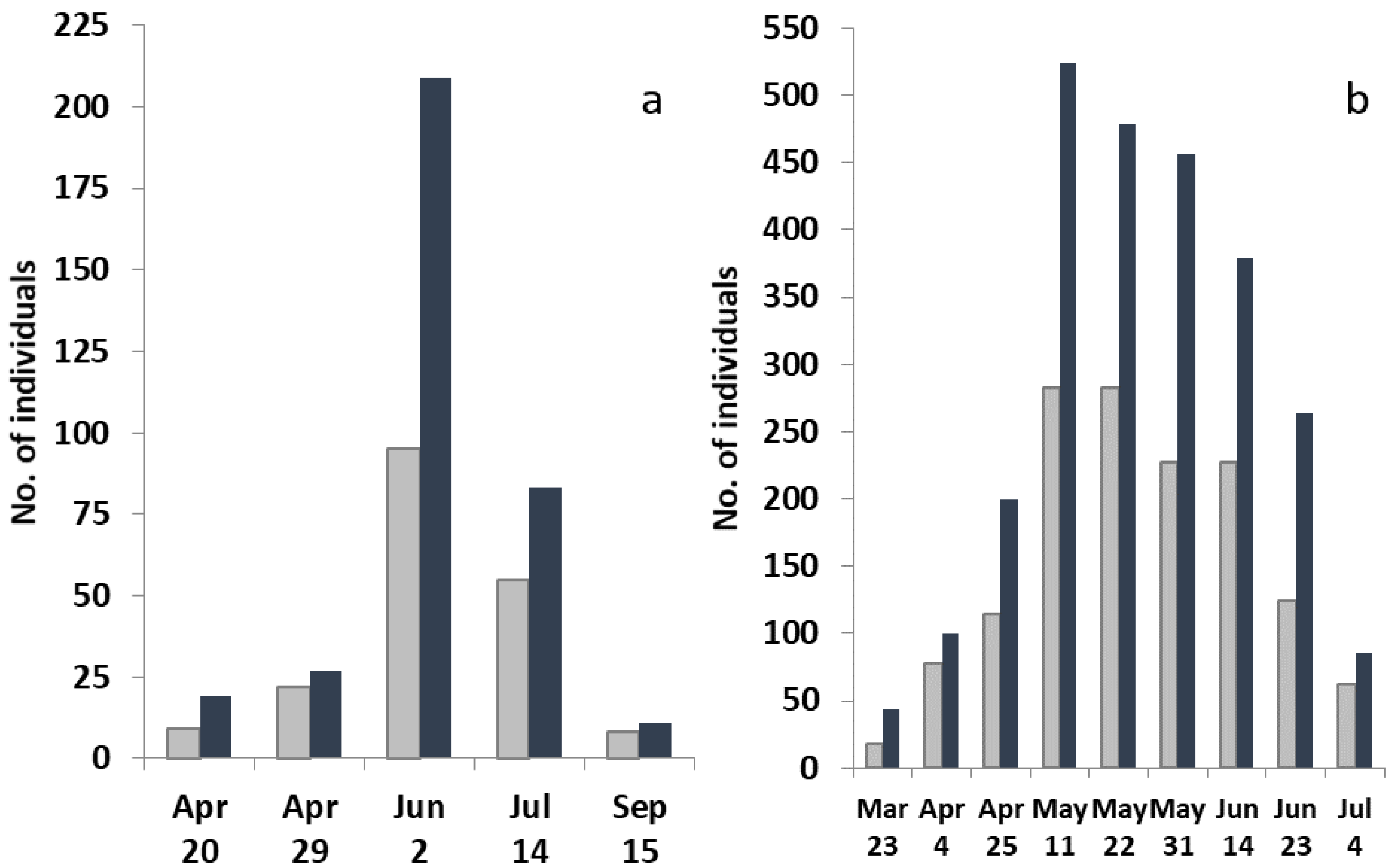

Figure 5

Butterfly abundance along the sampling period, in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Mean number of individuals and significance of difference between managements: a: ridges (2015), grazed – 37.8, ungrazed – 69.8, p = 0.20; b: valleys (2016), grazed – 157.2, ungrazed – 281.0, p = 0.0030* * Significant difference ($p < 0.05$, t-test)

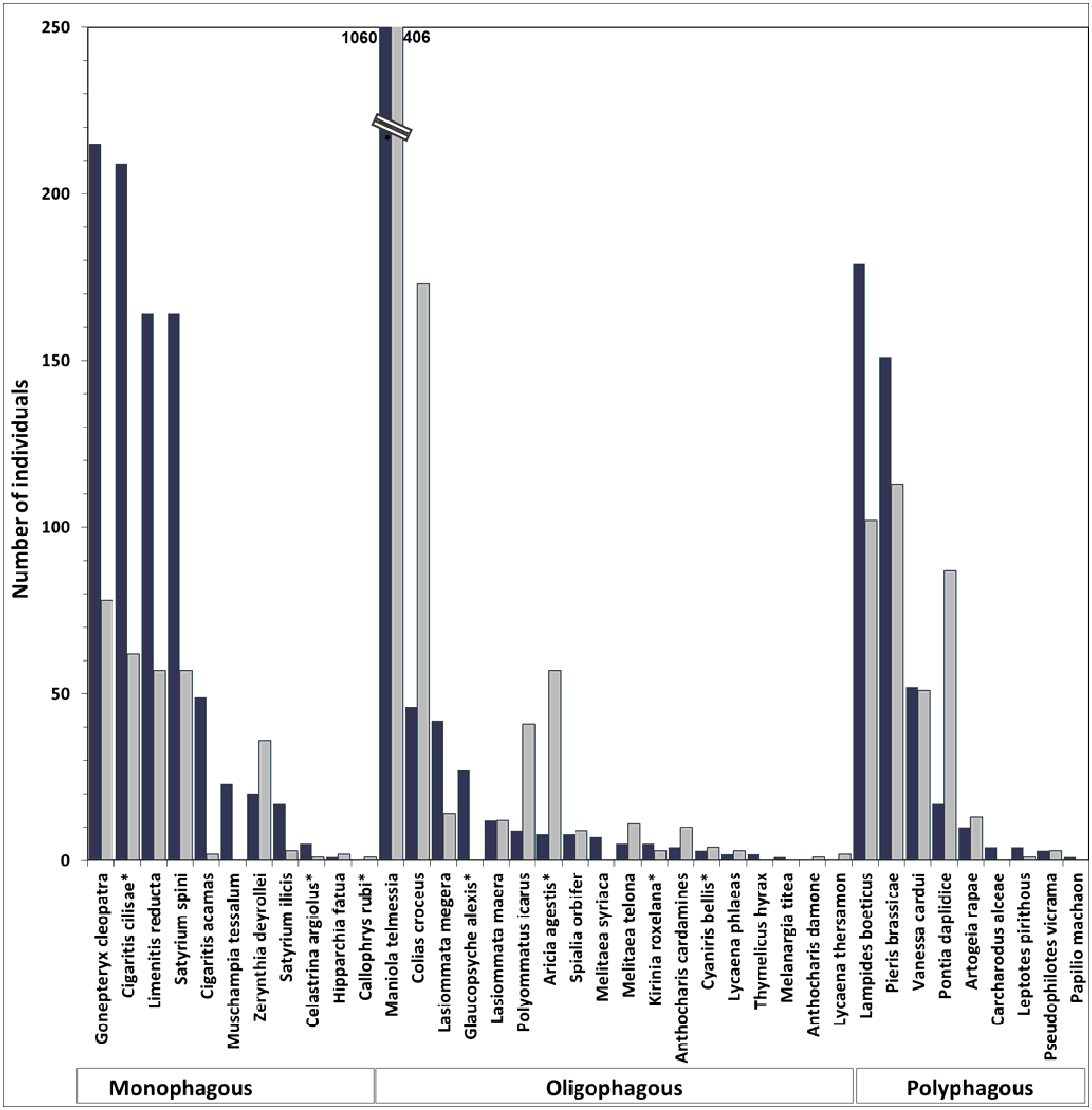

Figure 6

Butterfly abundance in valleys (2016), by feeding strategy, in cattle grazing site (light bars) and in the control site (ungrazed, dark bars). X axis: 38 butterfly species, arranged according to the three feeding strategies (see Table 4). Y axis: accumulation of individual numbers along the research season. Maniola telmessia numbers are out of bounds (marked)