Research and Reviews: Research Journal of Biology eISSN: 2322-0066

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

Gad Ish-Am[1]*, Talia Oron[2]

[1]Department of Molecular and Computational Biosciences and Biotechnology, the Israeli Lepidopterists Society, Betarye, Israel

[2]Department of Plant Sciences, Israel Nature and Parks Authority, Jerusalem, Israel

Research Article

Received: 22/11/2021

Accepted: 06/12/2021

Published: 13/12/2021

***For Correspondence:**

Gad Ish-Am, Department of Molecular and Computational Biosciences and Biotechnology, Upper Galilee R&D, the Israeli Lepidopterists Society, Betarye, Israel

E-mail: ishamgadi@gmail.com

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

ABSTRACT

The effects of cattle grazing on biodiversity in Mediterranean woodlands are yet unclear. To assess these effects on butterflies, we conducted surveys in the Mt. Meron nature reserve (northern Israel) in two habitats over two years. In each habitat we chose one site that was grazed by cattle and, as a control, a similar ungrazed site. Belt transects (5 m wide) divided to 100 m replications, alternately crossed woody and batha (open vegetation) patches. Those transects were surveyed on ridges in 2015 (five times, 11 replications, 538 butterflies, 25 species), and in valleys in 2016 (nine times, 12 replications, 3,944 butterflies, 38 species). Each habitat was analysed separately. In both habitats, species similarity index between sites was high. Richness was higher in the ridge's control and evenness was higher in the valley's grazed site. In both habitats total abundance in the control was twofold higher, and for the woody affiliated butterflies it was even threefold higher. For the batha polyphagous and oligophagous butterfly species, abundance was similar between the sites, and for a few of those, associated with grazing increaser plants, it was even higher in the grazed than in the control sites. However, the batha monophagous species were 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 suspension precautions, along with designation of no-grazing areas in reserves.

ABBREVIATIONS

G: Grazed site; C: Control (ungrazed) site; P: Polyphagous species; O: Oligophagous species; M: Monophagous species; En: Endangered butterfly species in Israel.

BACKGROUND

General effects of grazing in mediterranean woodland ecosystems

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 [1,2]. 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 flammable material. To cope with these negative phenomena, beef-cattle grazing was implemented in many Israeli Mediterranean nature reserves. 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 [3]. In most of the 79 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 suspension in some parts of the reserve [4,5], but year-round grazing is implemented in other parts of the reserve. The above-mentioned findings [3] have been supported by many other studies of cattle grazing in Israel [6,2,7], which found positive effects of the grazing management, mainly moderate, on herbaceous plant richness and diversity, which supporting the intermediate disturbance hypothesis [8]. In the same area that we examined, [9] found that both cattle grazing and goat grazing reduced the rate of increase in tree cover, yet even intensive grazing did not halt the process [10] found that in the short term (two years), canopy removal had a positive effect on the herbaceous species richness, though cattle grazing at the canopy removal plot negatively affected that richness [11] 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 [12] 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 [13]. 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.

The effects of grazing on butterflies

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 butterflies as a bio-indicator for ecosystem status and changes [14-16].

Studies of the impact of grazing on butterfly communities have so far yielded inconsistent conclusions. In research conducted in the Carpathian Mountains, [17] found an advantage for day-butterfly populations under moderate grazing, compared with both heavy grazing and no-grazing regimes. However, in Germany, [18] 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, [19] 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: in Germany [20], in Slovenia [21], and in France [22], which also found an advantage for butterfly populations under no grazing, compared with any grazing management.

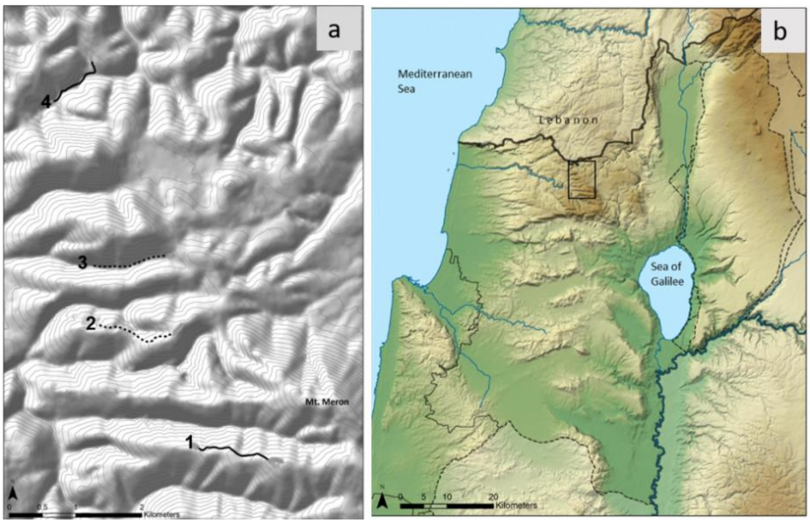
In their study of the influence of wild boar rooting activity on butterfly populations in Italy, [23] also found higher butterfly species richness, abundance, and diversity in the no-boar area, in comparison with the boar activity area. They reported that butterfly specialist species were significantly more affected by boar activity than generalist species were. In contrast, in northern Israel [24] found that cattle grazing in a garrigue (shrub) area increased butterfly abundance, although it had no effect on butterfly species richness or diversity (Figure 1). 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 [16]. 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 [25].

Our present study

We studied the influence of beef cattle grazing on butterfly communities in Mt. Meron Nature Reserve, as representative of a northern Israeli Mediterranean mesic woodland ecosystem. Our specific hypotheses were:

- Beef cattle grazing will significantly affect the butterfly communities in Mt. Meron Nature Reserve.
- Beef cattle grazing will scale down the butterfly communities' richness and abundance.
- Beef cattle grazing will mainly reduce the monophagous and endangered butterfly species' richness and abundance.

Figure 1. Topographic map of our four studies 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. Figure 1a. Esri. "Topographic" [base map]. Scale not given. "World Topographic Map". July 27, Figure 1b. Large relief map of Israel.



MATERIALS AND METHODS

Study area

The butterfly survey was conducted during 2015 and 2016 in the Mt. Meron Nature Reserve (Upper Galilee, northern Israel (Figure 1), which comprises about 10,000 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, Pistacia palaestina*, *Crataegus azarolus, Pyrus syriaca and Prunus ursina*), and ca. 15% shrubs (e.g., *Spartium junceum, Rhamnus punctata*); and (b) batha (open vegetation) patches: composed of ca. 10% dwarf shrubs (e.g., *Sarcopoterium spinosum*) and ca. 10% herbs (about 150 species, 25). 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 where our treatment transects were performed (GIS layer of classified vegetation formations, 2013 landsat-8 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 [26,12]. Since along the dry season herbaceous component was in shortage in the woodland habitat, and the grazing management was based on woody components, a concentrated supplement of protein-rich food was provided 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 narrow dirt tracks, we marked two 1,100 m survey transects on ridges (in 2015), and two 1,200 m survey transects along valleys (in 2016). The transects were divided into sections of 100 meters each, which were considered as replications for the analysis. Each of these sections alternately crossed wood and batha (open vegetation) patches. Transect design and butterfly counts were conducted according to the Pollard scheme [27,28]. For each section, we recorded all the observed butterfly species and 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 [29]. 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 19ºC to 32ºC. 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. The first site to be monitored, the grazed or the control, was alternately chosen. 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 butterfly feeding strategy

- 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

The two studied habitats were surveyed on different years; in accordance, they were analyzed separately.

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

Richness similarity index: A Jaccard similarity index (14) 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 habitat (ridges on 2015, valleys on 2016), once using transect sections as replications (t-test), and once again using survey dates as replications (paired t-test). The numbers of individuals of each species were compared between managements using an χ^2 test.

Diversity: We used a Shannon diversity index [30] 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 habitat (ridges on 2015, valleys on 2016) using a t-test.

Evenness: A Pielou index [31], 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 habitat (ridges on 2015, valleys on 2016) 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 habitat (ridges on 2015, valleys on 2016), according to the butterfly habitat

Affiliation: Trees or batha patches and butterfly species host plants.

Statistical analysis and figs drawing were performed using Excel software

RESULTS

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

Species richness

The mean number of species in ridges 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 (Figure 2). Maximum richness in peak season was similar in both habitats (16 species, Figure 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 and 35 species in the grazed and in the control, respectively.

Figure 2. Butterfly species richness-seasonal mean number of species per section ± S.D. in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Note: Difference between managements: ridges (2015), n=11 sections per treatment, t_{20}=3.41, p=0.0028*; valleys (2016), n=12 sections per treatment, t_{22}=1.42, p=0.17. *Significant difference (p<0.05, t-test)

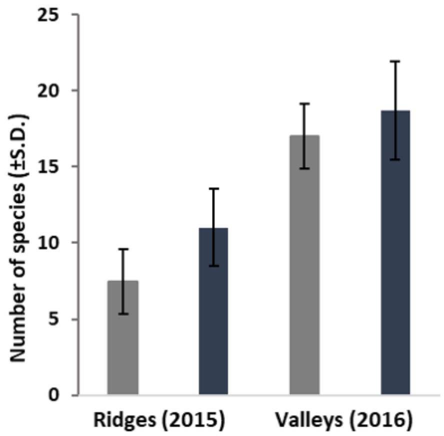
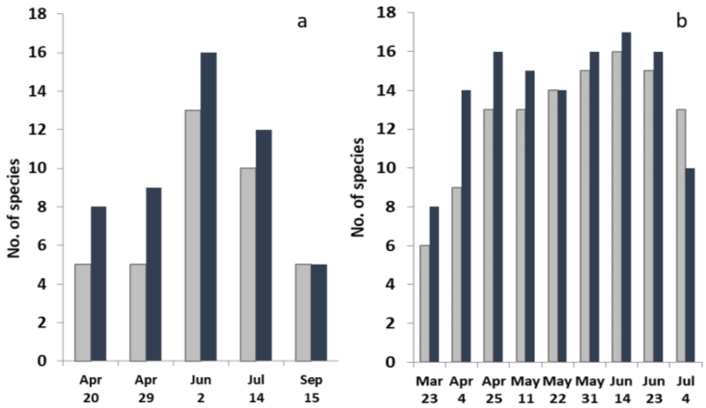


Figure 3. Butterfly species richness-number of species per survey, along the sampling period, in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats: a: ridges (2015) b: valleys (2016). Note: Seasonal mean number of species: a: Ridges (2015): grazed–7.6, control–10.0, n=5 surveys, t_4=3.54, p=0.024*; b: Valleys: (2016) grazed–12.7, control–14.0, n=9 surveys, t_8=1.84, p=0.10.*Significant difference (p<0.05, paired t-test)



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 (per habitat) between cattle grazing and ungrazed sites.

Habitat (year)	Management	Total species	Unique species	Identical species	Jaccard Index
Ridges (2015)	Grazing	22	2	20	0.8
	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 only 85% and 79% in the grazed site comparing to the control, on ridges and in valleys, respectively (Figure 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 in this year) (Figure 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 and 2,529 individuals in the grazed and in the control, respectively. In both habitats fewer individuals were recorded in the grazed sites than in the control, in all transect counts (Figure 5).

Figure 4. Butterfly abundance-seasonal mean number of individuals per section ± S.D, in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats. Note: Difference between the managements: ridges (2015), n=11 sections per treatment, t_{20}=3.68, p=0.0015*; valleys (2016), n=12 sections per treatment, t_{22}=4.49, p<0.001*. * Significant difference (p<0.05, t-test).

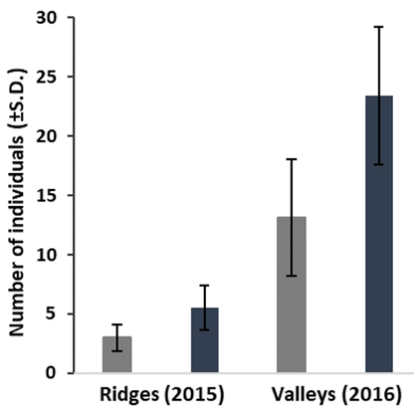
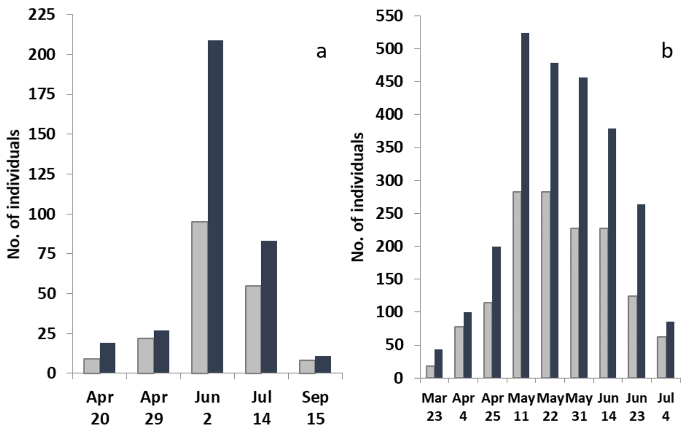


Figure 5. Butterfly abundance-number of individuals per survey, along the sampling period, in cattle grazing sites (light bars) and in the control sites (ungrazed, dark bars), in two research habitats: a: ridges (2015) b: valleys (2016). Note: Seasonal mean number of individuals a: Ridges (2015), grazed–37.8, ungrazed–69.8, n=5 surveys, t_4=1.53, p=0.20; b: Valleys (2016), grazed–157.2, ungrazed–281.0, n=9 surveys, t_8=4.19, p=0.0030*. *Significant difference (p<0.05, paired t-test).



Evenness (Pielou index): Relatively high species evenness was found on the ridges (2015), which was similar between the two managements. Lower species evenness was recorded in the valleys (2016) that were significantly higher in the grazed site than in the control (Table 2).

Table 2. Seasonal mean species evenness (Pielou index, per habitat) of butterfly populations in the grazed and the control sites **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).

Habitat (year)		Species evenness				
	Management	Mean	S.D.	N (sections)	T	P
Ridges (2015)	Grazing	0.89	0.045	11	0.41	0.68
	Control	0.9	0.045			
Valleys (2016)	Grazing	0.81	0.047	12	3.94	<0.001*
	Control	0.71	0.082			
Note: *Significant difference (p<0.05, t-test)						

Table 3. Seasonal mean diversity (Shannon index, per habitat) of butterfly populations of grazed and control sites.

Habitat (year)	Management	Shannon diversity				
		Mean	S.D.	n (sections)	t	p
Ridges (2015)	Grazing	1.75	0.32	11	2.91	0.0086*
	Control	2.14	0.31			
Valleys (2016)	Grazing	2.3	0.19	12	2.85	0.0093*
	Control	2.05	0.24			
Note: * 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 10 are mainly active in wood patches [29]. The other four species are not exclusively connected to a specific habitat (Table 4). Eight of the 39 observed species are endangered ones [32].

Table 4. Total individual numbers (per habitat) of the recorded butterfly species and selected characteristics.

Plant formation and Butterfly species	Number of individuals					
	Ridges(2015)		Valleys(2016)		Feeding	
	G	C	G	C	Strategy	Host plants
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	0	*Brassicaceae* species
Anthocharis damone En	0	0	1	0	0	*Isatis lusitanica*, *Crambe hispanica* (?)
Colias croceus	54	27*	173	46*	0	*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*	0	*Vebascum spp.*, *Scrophularia* spp.
Melanargia titea	0	6*	0	1	0	*Poaceae species*
Lasiommata maera	0	3	12	12	0	*Poaceae* species (mainly)

Cigaritis acamas	1	0	2	49*	M	Cooperation with ants
Cigaritis cilissa En	2	1	62	209*	M	Cooperation with ants
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* 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.
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	0	*Rubus* spp. and other *Rosaceae* species
Note: Significant difference (per habitat) between managements (d.f.=1, $p<0.05$, $\chi 2$ 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 and 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 and 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) d.f=1
Batha patches				
Brassicaceae (mainly)	3	17	58	<0.001*
Poaceae	2	0	5	0.068
Lamiaceae	1	5	15	0.1

Fabaceae (mainly)	3	60	58	0.9
Other families	5	8	8	1
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*
Note: * 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) Df=1**
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	0.1
Other families	8	124	79	0.025*
Total	23	683	566	0.019*

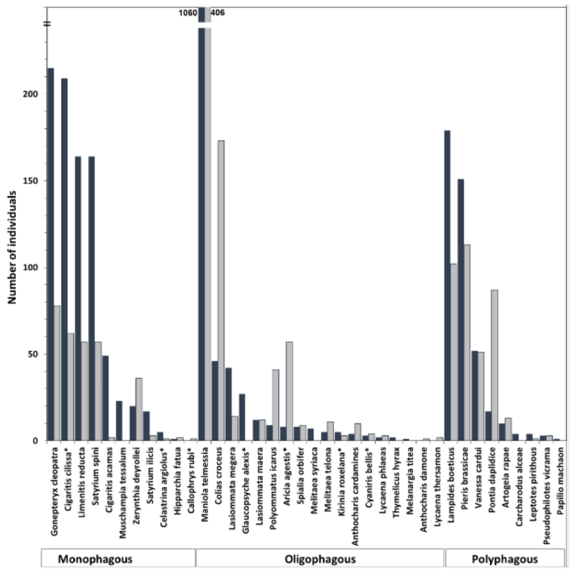
Wood patches				
Poaceae	3	411	1,066	<0.001*
Trees	4	139	396	<0.001*
Vines	2	93	184	<0.001*
Total	9	643	1,646	<0.001*
Note: *Significant difference (p<0.05, χ^2 test)				

Butterfly richness and abundance by feeding strategy: In both habitats (ridges and valleys), the abundance was lower in the grazed site relative to the control for only 17% of the oligophagous and polyphagous butterfly species, and for some of them it was even higher in the grazing site (Table 7; Figure 6). Contrary to that, for monophagous butterflies the recorded cattle grazing influence was stronger: Lower abundance was found in the grazed sites for 43% and 67% of these species, on ridges and in valleys, respectively, and the opposite effect (higher abundance in the grazed site) was not found for any of them.

Table 7. Changes (per habitat) in butterfly abundance between grazed and control sites according to 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

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: Total individual numbers along the research season. *Maniola telmessia* numbers are out of bounds (marked).



DISCUSSION

As predicted by our hypotheses (A and B), we found in a Mediterranean mesic woodland ecosystem (Mt. Meron, Upper Galilee, northern Israel), in two habitats, ridges (2015) and valleys (2016), evidence of lower 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 [18-22].

Therefore, after the results obtained from the present study, we conclude that overall there is inadequate knowledge of the congenital heart disease by the patients and their parents. We believe that an effort should be made by professionals to try to explain congenital heart disease in an illustrative manner in order to achieve a greater understanding of the disease and thus optimize behavior in terms of health.

Grazing effect on Woody and Batha affiliated butterflies

We found the woody-niche-affiliated butterflies to be more severely affected by grazing, in comparison with batha-patch-affiliated butterflies. 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, which causes heavy cattle grazing on shrubs and vines [12], lower tree canopies and the understory *Poaceae* (grasses) plants, that are hosts for butterfly breeding [22]. This effect is supported by the findings of [13] in northern Tunisia, which showed severe damage to the woody community composition under moderate-to-high grazing pressure.

Grazing effect according to butterfly host plants

We found a lower abundance in the grazed sites (mainly on ridges) of butterfly species that breed on batha patches' *Brassicaceae, Lamiaceae* and *Poaceae* plants (Tables 5 and 6). This can be explained by damage incurred by cattle grazing to both nectar and breeding plants of *Lamiaceae* and *Poaceae* [22]. However, 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 5-7, Figure 6). This 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 [3].

Monophagous and endangered butterfly species sensitivity

As predicted by our hypotheses (C), 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 [33], Greece [19], and Italy [23]. 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 found to be larger in the grazed site than in the control–57 versus 8 individuals, respectively, in the valleys (Table 4, Figure 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 in our study area almost "monophagously". It breeds mainly on young branches of *Spartium junceum* (a bush, *Fabaceae*), which are surely eaten by the cattle.

A need for early season grazing suspension

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 (Figures 1, 2, 5), and the abundance of the batha-affiliated butterfly species. On the ridge grazed site even butterfly populations that breed on grazing increaser plants, which may benefit from grazing, still had lower indices than in the control, while in the valley's grazed site some of these species had higher indices (see also 5). 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 valley's grazed site (Tables 5 and 6). The same applies to *Zerynthia* spp. populations, which breed on the poisonous genera *Aristolochia*. The heavier grazing damage on the ridge, under a winter–spring grazing regime, could be attributed to the more intense management, compared with the valley grazing management of summer–autumn, with early season suspension.

Shannon diversity and evenness changes

The above difference between the ridge and the valley habitats might explain the different effect 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, with lower evenness values there than on the ridges. The lower evenness resulted from the higher number of endangered butterfly species there, most of which consist of very small population (Table 4). The higher diversity of the control butterfly population on the ridges, compared with the grazing site, resulted from the control's higher richness whilst a similar evenness for 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. Note, Shannon diversity index is positively correlated with both evenness and richness indices.

Changes in butterfly populations may result from their host plants' changes

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 [15, 33, 22]. This is supported by the findings of a concomitant study done on the effect of cattle grazing on the herbs' communities [34], which was carried out on the same habitat transect lines and years. In this research the herbaceous species richness was found to be lower in the grazed sites compared with the control, and species diversity indices were lower under heavy winter–spring grazing management, compared with the less severe summer–autumn grazing regime. These changes could influence the butterfly populations.

Does grazing management benefit, or hurt butterfly populations

The 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 [22,23]. However, other studies have reported significant advantages for butterflies under extensive grazing management, compared with a no-grazing regime [35-38]. 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 hence on 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, have 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. Another concomitant study, on the fungi species in the woody patches of the same transects [39-41], 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. We hypothesized that in contrast to thousands of years of traditional goat grazing; the relatively new cattle introduction in this area poses the potential for overgrazing damage. Further research is needed to support this assumption.

CONCLUSION

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 suspension 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.

DECLARATIONS

Acknowledgement

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

Funding

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

REFERENCES

1. Naveh Z, et al. The human degradation of Mediterranean landscapes in Israel. In Mediterranean type ecosystems.1973; 7:373-90.
2. Perevolotsky A, et al. Role of grazing in Mediterranean rangeland ecosystems. Biosci. 1998; 1; 48(12):1007-17.
3. Noy-Meir I, et al. Responses of Mediterranean grassland plants to grazing and protection. J Ecol. 1989 1:290-310.
4. Golodets C, et al. Plant diversity partitioning in grazed Mediterranean grassland at multiple spatial and temporal scales. J Appl Ecol. 2011; 48(5):1260-8.
5. Gutman M, et al. Mediterranean herbaceous vegetation response to high animal density and grazing deferment: implications for management and conservation. Zaragoza: Ciheam-Iamz. 1999; 161-4.
6. Naveh Z, et al. Structural and floristic diversity of shrub lands and woodlands in northern Israel and other Mediterranean areas. 1980; 41(3):171-90.
7. Noy-Meir I, et al. Effects of grazing on geophytes in Mediterranean vegetation. J Veg Sci. 2001; 12(6):749-60.
8. Connell JH. Diversity in tropical rain forests and coral reefs. Sci. 1978; 199(4335):1302-10.
9. Carmel Y, et al. Effects of grazing and topography on long-term vegetation changes in a Mediterranean ecosystem in Israel. Plant Ecol. 1999; 145(2):243-54.
10. Agra HE, et al. Woody species as landscape modulators: their effect on the herbaceous plants in a Mediterranean maquis. Plant Ecol. 2009; 205(2):165-77.
11. Glasser TA, et al. Grazing management aimed at producing landscape mosaics to restore and enhance biodiversity in Mediterranean ecosystems. 2014; 109:437-52.
12. Schoenbaum I, et al. Cattle foraging in Mediterranean oak woodlands–Effects of management practices on the woody vegetation. For Ecol Manage. 2018; 419:160-9.
13. Kirk DA, et al. Grazing effects on woody and herbaceous plant biodiversity on a limestone mountain in northern Tunisia. Peer J. 2019; 7:e7296.
14. Nowicki P, et al. Butterfly monitoring methods: the ideal and the real world. Isr J Ecol Evo. 2008; 54(1):69-88.
15. Peer GU, et al. The rare butterfly Tomares nesimachus (Lycaenidae) as a bioindicator for pollination services and ecosystem functioning in northern Israel. Isr J Ecol Evo. 2008; 54(1):111-36.
16. Schwartz-Tzachor R. Multi-factorial analysis of a butterfly community used as bio indicator for

anthropogenic activity and habitat quality in Ramat Hanadiv Nature Park.

17. Elligsen H, et al. Effects of large-scale cattle grazing on populations of Coenonympha glycerion and Lasiommata megera (Lepidoptera: Satyridae). J Insect Conserv.1997 1(1):13-23.
18. Kruess A, et al. Grazing intensity and the diversity of grasshoppers, butterflies, and trap-nesting bees and wasps. Conserv Biol. 2002; 16(6):1570-80.
19. Grill A, et al. Diversity patterns in butterfly communities of the Greek nature reserve Dadia. Biol Conserv. 2003; 114(3):427-36.
20. Borschig C, et al. Traits of butterfly communities change from specialist to generalist characteristics with increasing land-use intensity. Basic Appl Ecol. 2013; 14(7):547-54.
21. Jugovic J, et al. The impact of grazing, overgrowth and mowing on spring butterfly (Lepidoptera: Rhopalocera) assemblages on dry karst meadows and pastures. Nat Croat. 2013; 22(1):157.
22. Schtickzelle N, et al. Grazing management impacts on the viability of the threatened bog fritillary butterfly Proclossiana eunomia. Biolog Conserv. 2007; 136(4):651-60.
23. Noy-Meir I, et al. Responses of Mediterranean grassland plants to grazing and protection. J Ecol. 1989; 290-310.
24. Am GI, et al. Grazing Effects on Day Butterflies in a Mediterranean Woodland Ecosystem in Northern Israel.
25. Gutman M, et al. A case study of beef-cattle grazing in Mediterranean-type woodland. Agrofor Syst. 2000; 48(2):119-40.
26. Pollard E. A method for assessing changes in the abundance of butterflies. Biol conserv. 1977;1; 12(2):115-34.
27. Pollard E. Population ecology and change in range of the White Admiral butterfly Ladoga camilla L. in England. Ecol Entomol. 1979; 4(1):61-74.
28. Benyamini D. A field guide to the butterflies of Israel.
29. Shannon CE. A mathematical theory of communication. Bell Syst tech J. 1948; 27(3):379-423.
30. Jaccard P. Nouvelles recherches sur la distribution florale. Bull Soc Vaud Sci Nat. 1908; 44:223-70.
31. Pielou EC. Ecological diversity New York.1975.
32. Peer GU, et al. A template for publishing the" conservation chain" from problem identification to practical action, exemplified through the campaign for butterfly protection in Israel. Isr J Ecol Evol. 2008; 54(1):19-39.
33. Thomas CD, et al. Rarity, species richness and conservation: butterflies of the Atlas Mountains in Morocco. Biol conserv. 1985; 33(2):95-117.
34. Am GI, et al. Grazing Effects on Day Butterflies in a Mediterranean Woodland Ecosystem in Northern Israel.
35. Bartonova A, et al. Isolated Asian steppe element in the Balkans: habitats of Proterebia afra (Lepidoptera: Nymphalidae: Satyrinae) and associated butterfly communities. J Insect Conserv. 2017; 21(3):559-71.
36. Munguira ML, et al. Ecology and recovery plans for the four Spanish endangered endemic butterfly species. J Insect Conserv. 2017; 21(3):423-37.
37. van der Colff D, et al. Invasive plant species may serve as a biological corridor for the invertebrate fauna of naturally isolated hosts. J Insect Conserv. 2015; 19(5):863-75.

38. Stefanescu C, et al. Recent trends in butterfly populations from north-east Spain and Andorra in the light of habitat and climate change. J Insect Conserv. 2011; 15(1):83-93.

39. Perelberg A, et al.Effects of cattle grazing on Basidiomycotina and Ascomycotina fungi in a Mediterranean woodland ecosystem in the upper Galilee, northern Israel. A survey report.

40. Thomas CD, et al. Rarity, species richness and conservation: butterflies of the Atlas Mountains in Morocco. Biolo conserv. 1985; 33(2):95-117.

41. Briske DD. Strategies of plant survival in grazed systems: a functional interpretation. The ecology and management of grazing systems. 1996:37-67.