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Exploring biodiversity and users of campsites in desert nature reserves to balance between social values and ecological impacts

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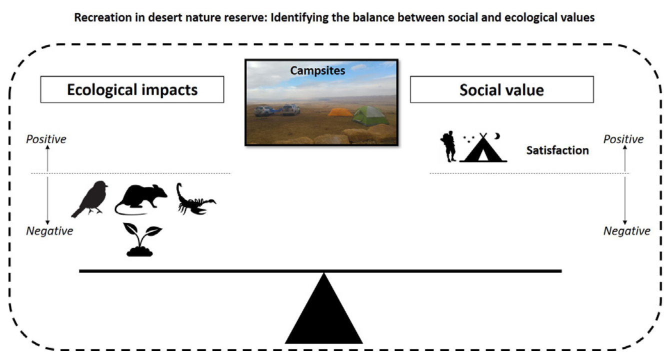
HIGHLIGHTS

- Balancing social and ecological aspects of recreational activities is vital in PAs.
- We assessed both ecological impacts and social value of desert campsites in PAs.
- There is a relatively moderate ecological impact on three out of four studied taxa.
- Users' satisfaction was high, despite poor ecological quality of campsites.
- Individuals seek nature but also comfort (e.g., bathroom) in desert campsites.

GRAPHICAL ABSTRACT



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ABSTRACT

Protected areas (PAs) are key conservation areas designed to limit the impacts of human activities on biodiversity. PAs also provide great opportunities for individuals to experience nature complexity, through recreational activities, and can contribute to restore the non-material and intangible services nature provides to people (i.e., cultural ecosystem services). However, recreational activities may negatively affect biodiversity. Identifying the right balance between promoting nature interactions and safeguarding biodiversity in PAs is challenging. Current knowledge gaps on the social value and ecological impacts of recreational activities, such as camping in PAs, hinder our ability to address this challenge. This is particularly true for PAs located in desert ecosystems. In this interdisciplinary study, we surveyed biodiversity and people to assess ecological impacts and social values of campsites in desert PAs in Israel. Ecological surveys included birds, plants, rodents and scorpions in campsites and control plots. We conducted two social surveys: (1) in situ survey of campsite users ($N = 280$) on satisfaction, motivations and perceptions of campsites and (2) online nation-wide survey ($N = 322$) on perceptions of campsites and investigation of the attributes individuals prioritize in campsites. Our results demonstrate that when desert campsites are located outside nature-rich areas (i.e. the wadis), they have relatively moderate negative impact on biodiversity for three out of the four taxa studied (birds, scorpions and rodents). Bird communities were dominated by synanthropic species in high intensity campsites. Surprisingly, even when campsites were located in nature-poor areas, users' satisfaction was relatively high. Among the broader population, ecological quality (i.e. vegetation complexity) did not have strong influence on people's preferences of/for campsites, and comfort-related aspects were prioritized over vegetation in campsites. Overall, our results demonstrate that placing desert campsites outside ecologically rich areas can serve as optimal solution to balance impacts on biodiversity and social value of recreation activities in PAs.

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1. Introduction

Protected areas (PAs) are recognized as a central tool to mitigate the accelerating biodiversity crisis by separating biodiversity from humans and destructive human activities (Gray et al., 2016; Shwartz et al., 2017). Despite this separation, PAs offer important opportunities for nature experiences, although some restrictions on nature-related activities (e.g., camping, hiking, touching wildlife) may also contribute to the increased alienation between humans and nature. This process, which was termed by Robert Pyle as the 'extinction of experience' (Pyle, 1978), represents a key contemporary issue, since nature provides a variety of intangible and non-material services (often referred as 'cultural ecosystem services' MEA, 2005) to people (e.g., individual well-being, environmental and social stewardship). Although the extinction of experience is commonly attributed to urbanization and urban lifestyle (Colléony et al., 2020a), the restrictions applied in PAs to protect biodiversity can also play a part in the extinction of experience. One the one hand, PAs provide great opportunities for individuals to experience and benefit from nature's complexity, through outdoor recreational activities, which are becoming increasingly popular (Balmford et al., 2015, 2009). On the other hand, outdoor recreational activities can have detrimental impacts on biodiversity, especially in PAs, and represent one of the leading cause of declines in threatened and endangered species (Czech et al., 2000; Losos et al., 1995; Monz et al., 2013; Reed and Merenlender, 2008). Restoring human-nature intimate relationship can thus come at some cost for biodiversity conservation and it is crucial to identify management strategies that can benefit people and maintain their interactions with nature at minimum ecological costs.

Recreational activities largely impact the natural environment, and those impacts have been increasingly studied through the field of 'recreation ecology' (Liddle, 1991; Monz et al., 2013). Recreational activities in PAs have direct negative impacts on plant biodiversity and vegetation, through clearing of vegetation for infrastructure, trampling, horse riding, mountain biking and off-road vehicles, or self-propagating of weeds from trails and roads (Pickering and Hill, 2007). Recreation and tourism can also modify resource availability for wildlife, through vegetation loss or increased dependence on humans as source of food (Orams, 2002). Large impacts have been documented for birds in PAs, with either short term (i.e. birds fleeing when approached by individuals) or long term impacts with complete avoidance of areas that are more intensively used, resulting in decreased animal diversity close to high-use sites (Steven et al., 2011; Thompson, 2015). Recreational activities in PAs are also associated with declines in density of native carnivores and changes in community composition from native to nonnative species (Reed and Merenlender, 2008). Additionally, since PAs are designed to limit the deleterious impacts of human activities on biodiversity, they can help safeguard some of the multitude of ecosystem services nature provides to people (e.g., regulating and provisioning services; MEA, 2005). Negative impacts of recreational activities on biodiversity in PAs can therefore endanger the delivery of ecosystem services (Cole and Monz, 2004; Taylor and Knight, 2003).

Despite mounting empirical evidence, the understanding of the impacts of recreational activities on the natural environment in PAs remains limited for different reasons. First, birds and mammals have been particularly studied, while other taxa have been overlooked (Larson et al., 2016). Second, most studies on recreation ecology focused on a limited number of countries, mostly in the American and Oceanian continents, whereas other regions of the globe have been poorly studied, limiting our understanding of impacts to only a few habitats (Buckley, 2005; Steven et al., 2011). Impacts can largely vary across habitats, and management strategies need to be adapted to each habitat or cultural context. Comprehensive knowledge on the impacts of recreational activities on several taxa in PAs is vital for decision makers to identify adequate solutions limiting the negative pressure on biodiversity in those PAs. Knowledge gaps on those impacts can therefore seriously undermine our ability to mitigate the biodiversity crisis. Drylands constitute some of the largest terrestrial biomes, host many endemic animal and plant species and are highly vulnerable to global environmental change and desertification (MEA, 2005; Reynolds et al., 2007). However, deserts represent the least studied habitat with regards to impacts of recreation (Larson et al., 2016). Little understanding of the impacts of recreational activities on deserts is thus likely to impair our ability to conserve these habitats.

Recreational activities, on the other hand, generate economic revenues for PAs through visitor expenditures (Balmford et al., 2015) and also provide a key opportunity for bringing people to experience nature complexity (Cazalis and Prévot, 2019). Mounting empirical evidence demonstrates that these meaningful interactions can be beneficial for individual well-being and also enhance people's affinity to nature and environmental attitudes (e.g., Colléony et al., 2020b; Duvall, 2011; Prévot et al., 2018). Promoting meaningful nature interactions in PAs could thus go a long way towards mitigating the deleterious consequences of the extinction of experience. In particular, this could help address more specifically four of the eight types of extinction of experience, i.e. childhood interactions with wild nature, lifetime interactions with wild nature, childhood experiences with wild nature and lifetime experiences with wild nature (Gaston and Soga, 2020). Camping in PAs represents an important mean for individuals to physically immerse in nature. In a campsite, individuals can get fresh air, sit outside, look at the stars and enjoy nature (Brooker and Joppe, 2013). Hence, one of the main driver of camping experiences in national parks is the desire to be in close contact with nature and escape from the everyday routine (Brooker and Joppe, 2013; Hassell et al., 2015). Accordingly, a previous study found that nature-based activities, such as chopping wood, building and watching a campfire, exploring the creeks or birding, were particularly prevalent in forest camping experiences; social interactions were another important aspect of camping experiences, especially with family members (Garst et al., 2009). However, these studies, and most existing studies exploring social dimensions of camping experiences, were mainly conducted in the 60s and 70s and in North America (Garst et al., 2009), limiting our understanding of the social value of campsites nowadays and in other ecosystems.

Camping experiences come at some cost for biodiversity, like most recreational activities, and several studies have reported negative impacts of camping on vegetation and soil (Cole, 2004; Eagleston and Marion, 2017; Pickering and Hill, 2007). However, research examining the impacts of camping on biodiversity seems relatively limited to vegetation and soil and impacts on other taxa (e.g., birds, mammals) have been poorly examined (Clevenger, 1977; Larson et al., 2016; Neatherlin and Marzluff, 2004). Additionally, there is no study, to our knowledge, exploring the impacts of camping in desert areas. Establishing the knowledge on both the impacts of campsites and the benefits to visitors is pivotal for understanding how to balance between delivery of various ecosystem services and limiting the deleterious impacts of recreational activities on biodiversity in PAs. Interdisciplinary studies that focus on both social and ecological aspects of outdoor recreation in PAs can help establish this knowledge.

In this study, we seek to bridge an important knowledge gap by focusing on the least studied habitat and recreational activity, camping in desert PAs in Israel, and investigating jointly the social aspects of camping experiences and their ecological impacts. We conducted four ecological surveys to characterize the communities of plants, birds, scorpions and rodents in campsites and control sites. We also designed two different social surveys, an in situ survey to study the attitudes of visitors to desert campsites and an online survey to explore usage, attitudes and preferences of the general public towards desert campsites. Specifically, our objectives were to (1) assess the ecological impacts of campsites on several taxa to understand the means to minimize those impacts; (2) investigate users motivations for camping, expectation and level of satisfaction from the campsites and the nature experience they provide, so as to identify how to maximize the recreational value of campsites for existing users; and (3) explore the attitudes of the general public towards campsites and the specific attributes that individuals prioritize in campsites, to understand which strategies could help enhance visitors' experience and attract new visitors. This interdisciplinary approach allows to jointly explore the ecological impacts and social value of desert campsites to help identify adequate management strategies for maximizing the recreational value of campsites while minimizing their ecological impacts.

2. Method

2.1. Study areas and campsites selection

Israel is a small and narrow country (ca. 20,500 km^2) located in the eastern Mediterranean, of which nearly two-third of the land area is occupied by the Negev desert region. A large proportion of this region is occupied by nature reserves and national parks (Portnov and Safriel, 2004). While some of these require an entrance fee (e.g., archeological sites or oases), others are accessible free of charge during daylight. Camping overnight in the nature reserves and national parks is only allowed in campsites that are specifically designed for this purpose. There are two types of campsites in the Negev desert: (1) 'pay campsites' – campsites composed of many amenities (e.g., toilets, shared tents, dorms) and that require an entrance fee. Three campsites are available in the whole Negev desert; and (2) 'sign campsites' – the most common campsites ($n = 57$), consisting in designated areas where visitors are permitted to sleep overnight, with no or relatively few amenities (e.g., toilets, bins). Sign campsites are designed to accommodate between a few dozens to a few hundreds of people, depending on their size. Both ecological and social part of this focused on the abundant sign campsites located in the Negev mountains (the central part of the Negev desert).

The study of sign campsites in the Negev mountains was conducted during 2018–2019. Out of the 57 sign campsites available in the Negev, we selected 19 sign campsites. At a first step we visited the 48 campsites located at Negev mountains and recorded six variables that indicate the intensity of use (e.g. number of fires remains and waste items; see Text S1 for the full list). We also used ArcMap 10.5.1. to calculate spatial characteristics of each campsite, such as size, distance to a main road, access (2×4 or 4×4) and number of hiking trails in proximity (Text S1). We then used Ward Hierarchical Clustering analysis (stats package; R core team 2019) based on the 15 attributes (Text S1) to classify the sign campsites into three categories of intensity levels of use (low, medium and high). This analysis yielded 13, 10 and 25 campsites with high, medium and low intensity of use, respectively. We then searched for areas that contains the three levels of intensity in close proximity to each other, to allow cost-effective ecological and social surveys. We identified four areas that met our criteria (Paran and Zin wadis, Ramon and Great craters; Fig. S1) with 19 sign campsites and excluded additional 19 campsites that were either isolated from our clusters or remote (i.e. required a long 4×4 drive to reach).

Finally, we selected for each campsite either one or two control points. To reduce their ecological impacts, campsites in the PAs were often located on moderate mountain slopes or ancient floodplain of streams, areas of poor ecological value compared to ecologically rich wadis. Therefore, we allocated for each campsite two controls topographically similar to the campsites: one was located nearby and in similar conditions ('control', i.e. on the slopes, floodplains), and the other was located nearby, but in a more biodiverse areas ('ecological control'; i.e. in the wadis; Fig. S1). We ensured that the distance between campsites and control sites is a least 200 m. In total, this resulted in 19 sites, each composed of three plots (campsite – control – ecological control); however, for three campsites, we were not able to identify an ecological control in their close vicinity, and another campsite was located in a place with significant ecological value (e.g., inside riverbed) and thus paired only with one control site with matching ecological value, i.e. ecological control (hence no control for this campsite). This resulted in 53 studied plots in total. For each campsite, we recorded the boundary type (none, boulder, or soil, see Fig. S2) in the campsites as it may influence presence of scorpions and rodents.

2.2. Ecological surveys

We surveyed four taxa (birds, rodents, scorpions and plants) across the 53 plots. Bird surveys were conducted from April to end of June 2018. Each site was visited six times, three times in the morning (30 min before sunrise to 2.5 h after) and three time in the evening (2.5 h before sunset to 30 min after). The observer stood at the center of each plot, waited for at least 2 min for the birds to settle, then recorded all birds seen and heard for 5 min. We also estimated the proportion of sky covered by clouds, and temperature and windspeed were recorded with a multi-function environmental meter (Lutron LM 8000).

Woody plants were sampled during January and February 2018. Since campsites varied in size, campsite and control plots were divided into three groups: small (<7500m^2), medium (<15000m^2) and large (>15000m^2). Random points were chosen in each plot using ArcGIS; 10, 20 or 30 points were defined according to the site group (small, medium or large). A random azimuth was chosen to each point, redrawn in case of collision with other points. We sampled 10x2m transects from the point to the direction of the azimuth that were chosen using a compass. All perennial plants seen along the transect were recorded and identified; unidentified plants were photographed and identified later.

Rodent surveys were conducted in July and August 2018. Each site was surveyed once for rodents, during two consecutive moonless nights. In each plot, 45 Sherman traps were set along three rows (15 traps each), positioned 8–10 m apart; two rows at the perimeter of the site, and one row at the edge outside of the plot. The traps were set for 48 h, opened during the night and closed during daytime. Following Shanas et al. (2006), baits (peanut snack) were used to attract rodents, and cotton balls were installed for insulation. At sunrise, the traps were checked, rodents identified and marked (first night only), then released. Estimated cloud cover, temperature and windspeed were recorded (see explanation in the bird section).

Scorpions were surveyed from beginning of July to end of September 2018. Each site was surveyed twice for scorpions. Surveys were conducted 1 h after sunset for 4 h every sampling night. Surveys consisted in active search of scorpions during 10 min with UV flashlight, without sampling in the same location twice. Scorpions were identified in the field and their activity was documented.

2.3. Social surveys

2.3.1. Campsite users field survey

We conducted a field survey of users of sign campsites in which we conducted the ecological surveys. Surveys were conducted on 17 different days from March 2018 to end of April 2019 (mostly during weekends and holidays), early morning (before users' departure) in 18 different sign campsites of varying intensity levels. Five trained experimenters approached campsite users and invited them to take part in the survey. Our time window to sample individuals was very narrow, as temperatures rise fast, thus we did not follow a strict sampling protocol, to maximize our sample size. Additionally, since low intensity campsites had very few visitors, more visitors in high intensity campsites were sampled than in low intensity ones and one campsite with very low intensity of use was excluded from the survey. In total, 288 campsite users participated in our survey, but 8 reported being under 18 years old and were thus removed from the dataset, resulting in a final sample size of 280 respondents.

We assessed respondents' nature relatedness using the 6-item version of the Nature Relatedness scale (NR) (Nisbet and Zelenski, 2013); participants rated their level of agreement to a list of 6 statements on a 5-point scale, from 1-strongly disagree to 5-strongly agree. Based on strong internal consistency (Cronbach alpha = 0.80), we derived a single measure of NR by averaging scores of the six items. We also measured environmental attitudes using the New Ecological Paradigm scale (Dunlap et al., 2000) and environmental behaviors following Cooper et al. (2015), as part of a larger survey, but do not present the results in this study. We explored expectations towards campsites by asking respondents to rate their level of agreement to a list of 18 items related to nature, comfort, setting or economic aspects, on a 5-point scale, from 1-strongly disagree to 5-strongly agree. We measured satisfaction regarding their night in the campsite by asking respondents to rate their level of agreement to a list of 9 items, related to general conditions, nature, access and setting, on a 5-point scale, from 1-strongly disagree to 5-strongly agree. Finally, we asked respondents to report their age, gender and the experimenter kept track of the campsite they were staying. An English version of the questionnaire can be found in supplementary material.

2.3.2. Online general public survey

We conducted an online survey of a representative sample of the adult population of Israel (Fig. S3), using a market-based company (iPanel) in winter 2019. In total, 322 adults participated in our survey. The questionnaire was designed to capture campsite users' profile, reasons for sleeping (or not) in campsites, and the attributes people desire in campsites. We first introduced the two types of campsites available in Israel using two representative images and text that explain the two types (sign and pay). Second, we asked respondents to report whether they have been in sign/pay campsites in the last five years, and if so, an approximation of the number of times. Then, for those who have been in either type of campsite, we asked them to indicate whether they go with their family, friends, organized group or other (several answers possible), and whether the purpose was to hike, socialize, go on a jeep tour or watch wildlife (several answers possible). After completing this section, we explained that our survey focused on sign campsites and that all the remaining questions were related to this type of campsite.

To explore reasons for sleeping (or not) in sign campsites, we provided respondents with a list of 12 items relating to nature (6 items; Cronbach alpha = 0.72), comfort (4 items; Cronbach alpha = 0.80) and economic (2 items; Cronbach alpha = 0.73) aspects, and asked them to report the extent to which they agree on each statement, from 1-strongly disagree to 5-strongly agree. We derived a single measure of each category by averaging item scores from the category.

We designed an image preference experiment to explore what attributes people prioritize in campsites. We presented respondents with options between different images of campsites and asked them to select the campsite they would choose to go in if they were to sleep in one. We showed 16 sets of choices to participants, which consisted in three pictures of campsites differing in levels of vegetation (0 no vegetation, 1 low level of vegetation, 2 high level of vegetation), toilets (0 absence, 1 presence), bins (0 absence, 1 presence) and access (0 difficult access, 1 easy access). We manipulated one picture of a campsite with no vegetation and digitally added vegetation using Adobe Illustrator CC 2017; below each picture, we presented pictograms indicating the presence/absence of toilets, bins, access (Fig. S4). We created all possible combinations of those four attributes, which resulted in 24 different images. The combinations of images for the choice sets were randomized, and each picture appeared twice in total of the 16 choice sets.

Finally, we recorded participants' gender, age, education level (elementary school, high school, professional diploma, bachelor degree, master degree and above), income level (from 0-below average, 5-average, to 10-above average; they were told the average household income in Israel is 15,700 NIS), region (Jerusalem region, Sharon region, Northern region, Southern region, Central region), family status (single, married or other), level of urbanization of place of residence and place of childhood (big city, medium-sized city, moshav or kibbutz) and nature relatedness (using the NR scale – see field survey for details; Cronbach alpha = 0.86). An English version of the questionnaire can be found in supplementary material.

2.4. Statistical analyses

2.4.1. Ecological surveys

We calculated the species richness, abundance and Shannon diversity of birds per visit per plot; for plants, we merged the observations from the different transects within a single plot to calculate a single measure of species richness, abundance and Shannon diversity of plants, respectively, per plot. Because each plot was only sampled twice for rodents and scorpions, we could not account for detectability; for each plot, we thus only retained the values (species richness and abundance) from the sampling day with maximum value for abundance to decrease variance in the models. We did not calculate diversity of scorpions, given the very low number of observations.

We conducted a first series of models testing differences in species richness, abundance and diversity between types of plot (campsite, control or ecological control). We used generalized linear mixed models with fitted negative binomial distribution (lme4 package; Bates et al., 2015) for birds and plants for species richness and abundance, and linear mixed models for diversity. For rodents and scorpions, we used zero inflated models fitted with Poisson distribution, since the distribution was largely skewed towards 0 (glmmTMB package; Mollie et al., 2017). We included the dependent variable (species richness, abundance or diversity of each taxa) and the type and size of plot as independent variable. In the birds' models, we also included temperature, wind intensity and cloud cover as independent variables. We then conducted a second series of models testing differences in species richness, abundance and diversity between intensity levels of campsites (low, medium and high, versus the associated control plot). We replicated the previous models with intensity levels of campsites instead of type of plot in the independent variables. In the rodents' and scorpions' models, we also added the boundary type in the campsite as independent variable. In the birds' models, we used the site and plot IDs as random factors to account for repeated visits in each plot. In the plants', rodents' and scorpions' models, we used the sites as random factor. For all models, we performed stepwise model selection based on AIC. We tested for collinearity using variance inflation factors and goodness of fits of models by checking that the deviances of the models are within the 95% confidence intervals of the distribution of the residuals.

Additionally, for birds only, we compared community composition between plot types, and between campsites intensity, as our models showed large differences. We used non-metric multidimensional scaling (NMDS) and permutational multivariable analysis of variance using Bray-Curtis distance matrices (vegan package) (Oksanen et al., 2017) with 100 iterations, and analysis of similarities with 999 permutations. We tested for homogeneity of variance with the *betadisper* (vegan package) test and for similarities across groups with the *anosim* function (vegan package).

2.4.2. Social surveys

Prior to our analyses, we used chi-square tests to compare the distribution of demographic variables between the survey populations (campsite users and general public) and their distribution in the adult population of Israel. For the field survey, we first used Kruskal-Wallis and chi-square tests to explore the differences in age, gender and nature relatedness between the three levels of intensity of use. We then used Spearman's Rank correlation coefficients to explore the correlations between satisfaction items, nature relatedness score, biodiversity measures (average abundance and richness of birds, total abundance and richness of plants, maximum abundance and richness of scorpions and rodents per campsite) and level of intensity of campsites.

For the online general public survey, we first explored the profile of campsite users and non-users for each type of campsite (demographics, previous experience in campsites, nature relatedness, motivations, reasons to sleep (or not) in a campsite). We explored correlations between several variables using Spearman coefficients. We then explored the importance of each campsite attribute in respondent's choice of a given campsite using a zero-inflated mixed model fitted with a binomial distribution, using the glmmTMB package (Mollie et al., 2017): we modelled respondent's picture choice (0/1) depending on low vegetation level (yes/no), high vegetation level (yes/no), bin presence/absence, toilets presence/absence, and access easy/difficult; we added nature-related reasons to sleep in campsite, comfort-related reasons to sleep in campsite, economic-related reasons to sleep in campsite, sociodemographic variables and platform used to fill the survey as co-variates. We also added the variable whether they have previously slept in a sign campsite before (yes/no) as co-variate, along with interaction terms with each attribute (low vegetation, high vegetation, bin, toilets and access). We added the individual and the choice set as random factors. We then repeated the model replacing the variable been in sign campsite by the variable been in pay campsite. We did a stepwise model selection based on AIC. For all analyses, we considered statistically significant results if *p*-values were below 0.05.

Statistical analyses were performed using R 3.6.0 (R Core Team, 2013).

2.5. Ethics statement

Permission for this study was granted by the Technion Social and Behavioral Sciences Institutional Review Board (approval number: 045–2019), and the research was performed in accordance with relevant guidelines and regulations. All participants were provided a brief description of the study and gave informed consent for study participation. All responses were anonymous.

3. Results

3.1. Ecological surveys

Bird species richness, abundance and diversity significantly differed between types of plots (Table 1; Fig. 1). Bird richness and diversity were significantly higher the ecological controls compared to both campsites and control plots (Table 1; Fig. 1b-c). We did not find any significant difference between campsites and controls (Table 1; Fig. 1a). We found a significant impact of campsite intensity for bird abundance, with higher abundance in high intensity campsites than in associated controls (Table 2; Fig. 1d). Bird community composition differed significantly between types of plots, with more local species in ecological controls towards more synanthropic species in campsites (ANOSIM; Global Rho $= 0.11$, $p = 0.001$; Fig. S5). This difference was even more important comparing high intensity campsites to associated controls and ecological controls (ANOSIM; Global Rho $= 0.16$, $p = 0.02$; Fig. S5). Bird community compositions did not differ between low intensity campsites and associated controls and ecological controls (ANOSIM; Global Rho $= -0.004$, $p = 0.49$).

Plant species richness, abundance and diversity were significantly lower in campsites than in ecological controls, and in controls compared to ecological controls (Table 1; Fig. 1b-c). Plant species richness and abundance were significantly lower in campsites than in controls (Table 1; Fig. 1a). Plant species richness and abundance were significantly lower in high intensity campsites than in controls and in low intensity campsites compared to controls (Table 2; Fig. 1d-e). We did not find any significant differences between types of plot for rodent richness, abundance and diversity (Table 1; Fig. 1a-c). Rodent abundance was significantly higher in high intensity campsites than in associated controls (Table 2; Fig. 1d); no significant difference was found between low and medium intensity campsites (Table 2; Fig. 1e-f). Scorpion abundance was significantly lower in campsites than in controls and ecological controls (Table 1; Fig. 1a-b). We did not find other difference between types of plot (Table 1; Fig. 1a-c). Scorpion abundance was lower (marginally significant) in high intensity campsites than in associated controls (Table 2; Fig. 1d).

3.2. Campsite users field survey

Respondents were mostly men (58.57%) and on average 36.8 ± 12.5 years old. The share of male, age groups 23–29 and 40–49 in the campsite users survey was higher than their prevalence in the Israeli adult population (Fig. S3). More respondents were surveyed in high intensity campsites (56.78%), than in low (26.78%) or medium (25.57%) intensity campsites. Gender proportion was similar across campsites of different intensity levels (Chi-square test; $\chi^2 = 2.16$, df $= 2$, $p = 0.33$). Respondents from low intensity campsites were older than respondents from other campsites (Kruskal-Wallis test; $\chi^2 = 13.61$,

Table 1
Summary statistics (estimate ± standard error and *p*-value) for each model looking at the differences between types of plots (campsite, control and ecological control) for birds, plants, rodents and scorpions. Empty cells are for variables omitted in model selection process. Values with p-value <0.05 are shown in bold characters.

			Richness		Abundance		Diversity	
			Estimate±SE	*p*	Estimate±SE	*p*	Estimate±SE	*p*
Birds	Intercept		**0.55 ± 0.15**	**<0.001**	**1.25 ± 0.22**	**<0.001**	**0.66 ± 0.10**	**<0.001**
	Type plot	Campsite (reference)	–	–	–	–	–	–
		Control	−0.10 ± 0.17	0.53	−0.34 ± 0.24	0.15	−0.05 ± 0.11	0.64
		Ecological Control	**0.42 ± 0.17**	**0.01**	0.41 ± 0.25	0.10	**0.29 ± 0.12**	**0.02**
	Temperature		**−0.22 ± 0.03**	**<0.001**	**−0.27 ± 0.05**	**<0.001**	**−0.17 ± 0.02**	**<0.001**
	Wind		**−0.15 ± 0.04**	**<0.001**	**−0.20 ± 0.05**	**<0.001**	**−0.12 ± 0.02**	**<0.001**
	Size		–	–	–	–	–	–
Plants	Intercept		**1.00 ± 0.19**	**<0.001**	1.59 ± 0.39	<0.001	0.57 ± 0.17	0.001
	Type plot	Campsite (reference)	–	–	–	–	–	–
		Control	**0.83 ± 0.24**	**<0.001**	**1.88 ± 0.42**	**<0.001**	**0.58 ± 0.23**	**0.01**
		Ecological Control	**1.61 ± 0.24**	**<0.001**	**3.02 ± 0.47**	**<0.001**	**1.66 ± 0.23**	**<0.001**
	Size		**0.21 ± 0.09**	**0.02**	**0.48 ± 0.18**	**0.008**	–	–
Rodents	Intercept		0.05 ± 0.22	0.81	**0.52 ± 0.22**	**0.01**	**−2.12 ± 0.74**	**0.004**
	Type plot	Campsite (reference)	–	–	–	–	–	–
		Control	−0.05 ± 0.33	0.87	−0.27 ± 0.26	0.30	0.01 ± 1.03	0.98
		Ecological Control	−0.05 ± 0.34	0.87	−0.13 ± 0.27	0.63	0.37 ± 0.93	0.69
	Size		–	–	–	–	–	–
Scorpions	Intercept		−0.40 ± 0.27	0.13	−0.16 ± 0.33	0.60		
	Type plot	Campsite (reference)	–	–	–	–		
		Control	0.29 ± 0.35	0.41	**1.41 ± 0.36**	**<0.001**		
		Ecological Control	0.40 ± 0.36	0.26	**1.19 ± 0.33**	**<0.001**		
	Size		**0.31 ± 0.12**	**0.01**	–	–		

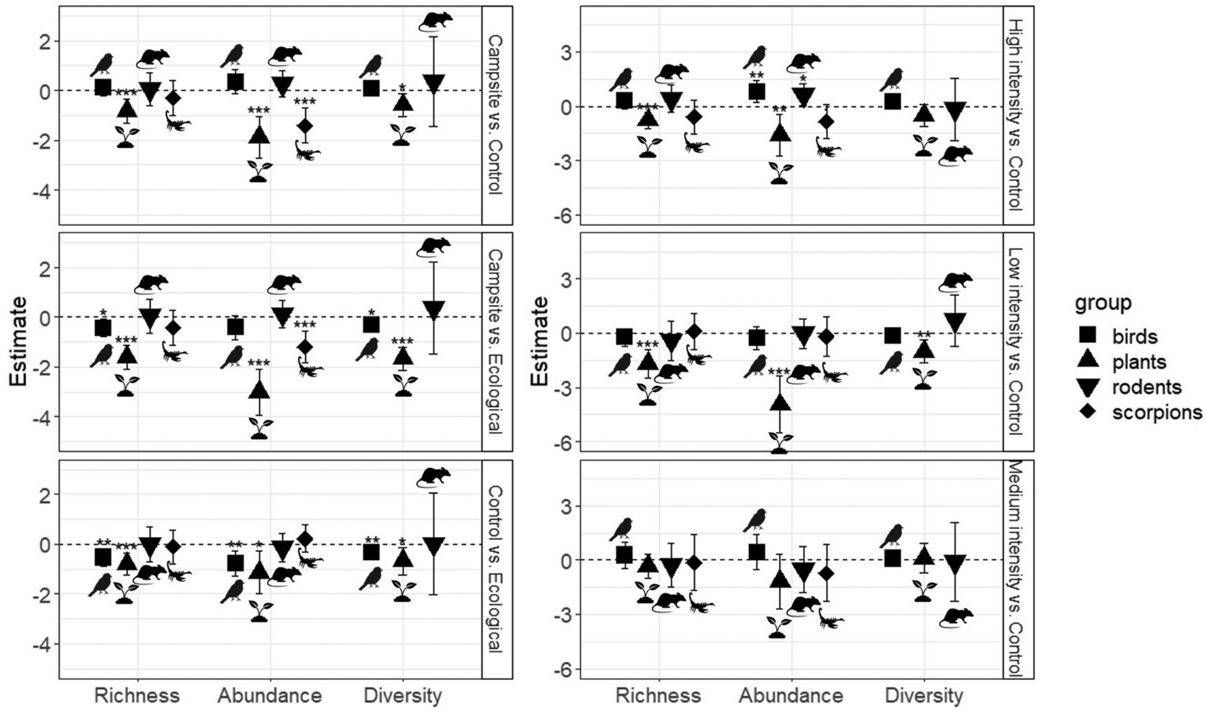

Fig. 1. Estimates of campsite practice on richness, abundance and diversity compared to controls (a) and ecological controls (b); estimates of controls compared to ecological controls (c); estimates of high intensity (d), low intensity (e), and medium intensity campsites (f) compared to controls (d), for each taxon (birds, plants, rodents and scorpions). All figures show estimates ± standard error, significant differences are based on multiple comparisons between types of plot. Significance levels: (***) $p < 0.001$, (**) $p < 0.01$, (*) $p < 0.05$, (.) $p < 0.1$. Positive values mean increased richness, abundance or diversity in the campsite compared to control or ecological control (a,b), in the control compared to ecological control (c), or in the campsites or varying intensity compared to controls (d, e, f).

Table 2
Summary statistics (estimate ± standard error and p-value) for each model looking at the differences between campsite intensity and controls for birds, plants, rodents and scorpions. Empty cells are for variables omitted in model selection process. Values with p-value <0.05 are shown in bold characters.

			Richness		Abundance		Diversity	
			Estimate±SE	*p*	Estimate±SE	*p*	Estimate±SE	*p*
Birds	Intercept		**0.39 ± 0.18**	**0.03**	**0.88 ± 0.24**	**<0.001**	**0.60 ± 0.11**	**<0.001**
	Intensity	Control (reference)	–	–	–	–	–	–
		Low	−0.23 ± 0.24	0.34	−0.28 ± 0.33	0.39	−0.14 ± 0.17	0.40
		Medium	0.26 ± 0.35	0.45	0.41 ± 0.49	0.39	0.07 ± 0.22	0.73
		High	0.29 ± 0.22	0.19	**0.80 ± 0.30**	**0.007**	0.22 ± 0.16	0.18
	Temperature		**−0.29 ± 0.04**	**<0.001**	**−0.35 ± 0.06**	**<0.001**	**−0.20 ± 0.03**	**<0.001**
	Wind		**−0.14 ± 0.05**	**0.008**	**−0.17 ± 0.06**	**0.01**	**−0.09 ± 0.03**	**0.002**
	Size		–	–	–	–	–	–
Plants	Intercept		**1.70 ± 0.18**	**<0.001**	**3.57 ± 0.32**	**<0.001**	1.15 ± 0.19	<0.001
	Intensity	Control (reference)	–	–	–	–	–	–
		Low	**−1.70 ± 0.40**	**<0.001**	**−3.95 ± 0.79**	**<0.001**	**−1.01 ± 0.32**	**0.005**
		Medium	−0.35 ± 0.33	0.29	−1.18 ± 0.78	0.12	0.09 ± 0.42	0.81
		High	**−0.77 ± 0.23**	**<0.001**	**−1.60 ± 0.59**	**0.007**	−0.52 ± 0.31	0.10
	Size		–	–	**0.46 ± 0.22**	**0.04**	–	–
Rodents	Intercept		−0.00 ± 0.25	1.00	0.29 ± 0.24	0.24	**−1.29 ± 0.47**	**0.006**
	Intensity	Control (reference)	–	–	–	–	–	–
		Low	−0.40 ± 0.55	0.46	−0.01 ± 0.41	0.96	0.70 ± 0.72	0.33
		Medium	−0.28 ± 0.62	0.64	−0.53 ± 0.65	0.41	−0.09 ± 1.10	0.93
		High	0.40 ± 0.38	0.28	**0.61 ± 0.31**	**0.04**	−0.16 ± 0.87	0.84
	Boundary type	None (reference)	–	–	–	–	–	–
		Bolder	–	–	–	–	–	–
		Soil	–	–	–	–	–	–
	Size		–	–	–	–	–	–
Scorpions	Intercept		−0.26 ± 0.28	0.35	0.52 ± 0.28	0.06		
	Intensity	Control (reference)	–	–	–	–		
		Low	0.09 ± 0.50	0.84	−0.18 ± 0.54	0.73		
		Medium	−0.13 ± 0.77	0.86	−0.71 ± 0.79	0.36		
		High	−0. 59 ± 0.48	0.22	−0.84 ± 0.48	0.08		
	Boundary type	None (reference)	–	–	–	–		
		Bolder	–	–	–	–		
		Soil	–	–	–	–		
	Size		**0.56 ± 0.16**	**<0.001**	**0.71 ± 0.15**	**<0.001**		

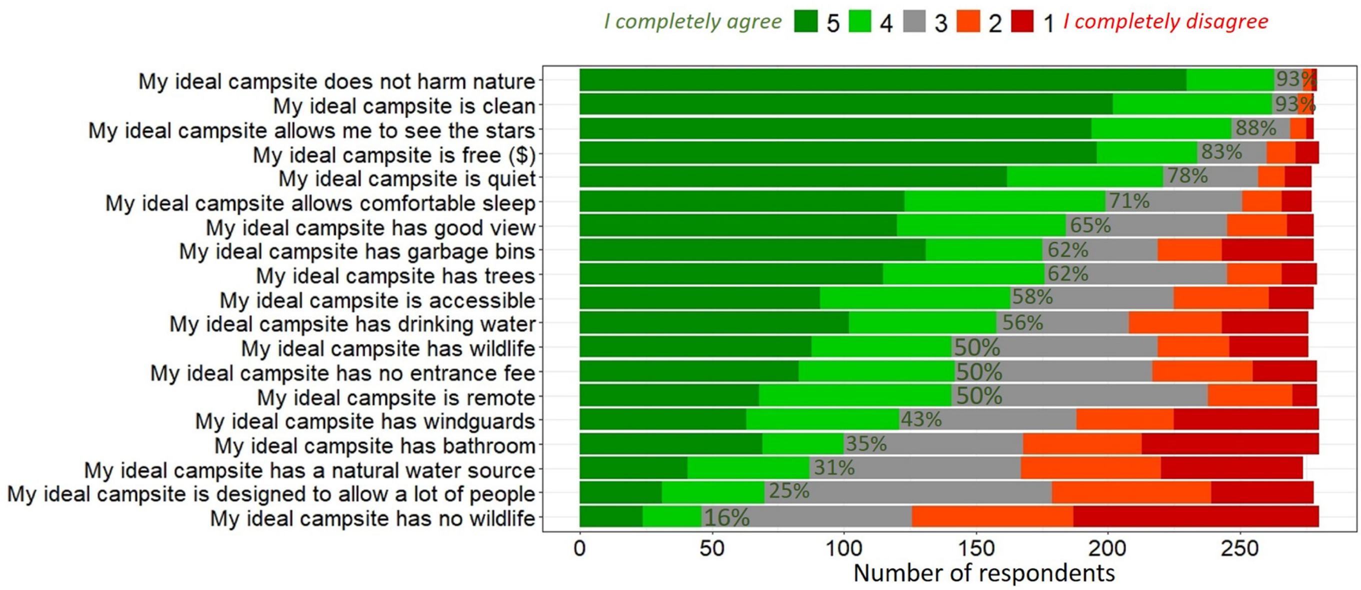

Fig. 2. Numbers of respondents from the field surveys agreeing with each statement on expectations towards campsites. Agreements are presented in variations of green and disagreements on variations of red. Proportions (%) of respondents completely agreeing (dark green bars) or agreeing (light green bars) are provided. The number of participants differ between questions due to missing data.

df = 2, $p = 0.001$). Nature relatedness was slightly higher among respondents from low intensity campsites (NR = 3.94 ± 0.70) than among respondents from medium (NR = 3.67 ± 0.94) and high intensity campsites (3.73 ± 0.78), although these differences were not significant (Kruskal-Wallis test; $\chi^2 = 3.41$, df = 2, $p = 0.18$).

Expectations towards campsites varied largely from 16% to 93% agreement: most respondents reported that for them, an ideal campsite does not harm nature (93% agreement), is clean (93%) and enables to see the stars (88%; Fig. 2). Slightly more than half of the respondents reported that an ideal campsite has garbage bins (62%) and trees (62%; Fig. 2). Only very few respondents reported that they expect no wildlife in their ideal campsite (16%; Fig. 2). Overall level of satisfaction was relatively high, on average 70.88% of respondents positively rated the nine satisfaction items. Respondents were particularly satisfied with cohabitation with animals (92%), campsite accessibility (85% and 80%), the location (76%) and conditions (70% and 65%) and nature experience (61%; Fig. 3). Respondents who reported sleeping in campsites more often tended to be less satisfied than those going to campsites less often. Finally, respondents were not very satisfied with the ability to find quiet spot in the campsite when it was crowded (Fig. 3).

Level of intensity of use was negatively and weakly correlated to respondents' satisfaction from the sleeping conditions ($r = -0.17$, $p < 0.001$; Table S1). Thus, campsites with low intensity of use were perceived to provide better sleeping conditions. While most biodiversity indicators did not correlate with satisfaction items, rodents max richness and abundance were negatively and weakly correlated with the statement "Animals did not bother me while I was staying in this campsite" ($r = -0.17$, $p < 0.001$; $r = -0.18$, $p = 0.02$; Table S1). People who slept in campsites with less rodents were less bothered by animals compared to those who slept in rodents' rich campsites. The level of nature relatedness was weakly and positively correlated to satisfaction items related to comfort, access, the view and location of the campsites ($0.11 < r < 0.22$; Table S1). Finally, we found positive correlations between the satisfaction items ($0.18 < r < 0.81$; Table S1).

3.3. Online general public survey

Respondents were on average 39.7 ± 14.8 years old, slightly more women (51.86%), mostly from high school or bachelor's degree levels (33.54% each), and mostly from Northern (30.12%), Haifa (26.39%) and

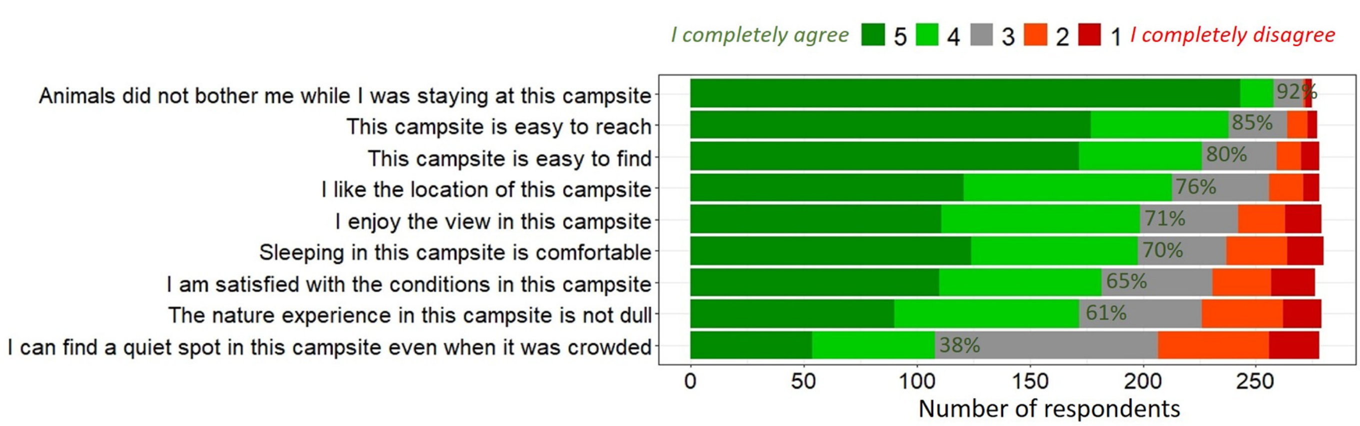

Fig. 3. Numbers of respondents from the field surveys agreeing with each statement on satisfaction following the overnight experience. Agreements are presented in variations of green and disagreements on variations of red. Proportions (%) of respondents completely agreeing (dark green bars) or agreeing (light green bars) are provided. The number of participants differ between questions due to missing data.

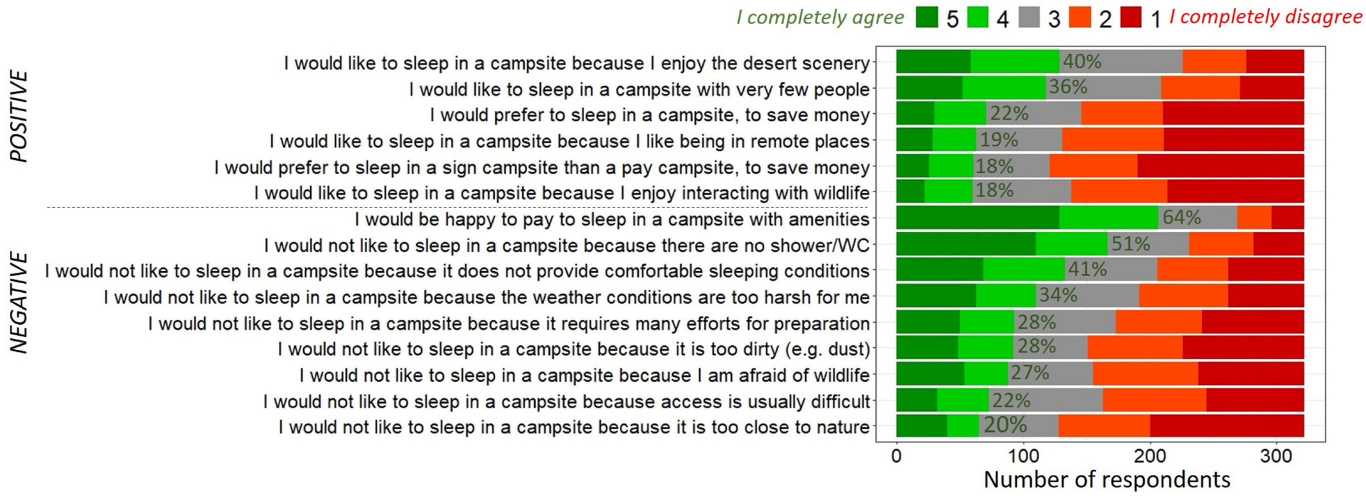

Fig. 4. Numbers of respondents from the online survey agreeing with each statement related to reasons to sleep (or not) in a campsite. Agreements are presented in variations of green and disagreements on variations of red. Reasons for which individuals would like to sleep in a campsite are presented first (6 statements), followed by reasons for which individuals would not like to sleep in a campsite (9 items). Proportions (%) of respondents completely agreeing (dark green bars) or agreeing (light green bars) are provided.

Southern (24.84) regions; respondents rated their income as average level (mean = 4.99 ± 2.34, on a scale from 0 to 10). Our sample of respondents was representative of the overall Israeli population (Fig. S3).

In our survey, 55.27% of respondents have slept in pay campsites within the last five years, and 37.26% reported having slept in sign campsites in the last five years. Respondents with previous experience in campsites were slightly younger ($Age_{PayCamp} = 37 \pm 14$; $Age_{SignCamp} = 35 \pm 14$) and reported a slightly lower relative income ($Income_{PayCamp} = 4.81 \pm 2.43$; $Income_{SignCamp} = 4.91 \pm 2.29$) than other respondents ($Age_{Pay/SignCamp} = 42 \pm 14$; $Income_{PayCamp} = 5.21 \pm 2.22$; $Income_{SignCamp} = 5.03 \pm 2.38$). Among those having previously slept in campsites, they reported having slept on average 5 times in campsites in the last five years, for both types of campsites; also, the main purposes of sleeping in campsites were hiking (31%) and socializing (36%), while jeep touring and wildlife watching purposes were relatively scarce (8% and 4%, respectively); finally, they reported going in campsites mostly with family (35%) or friends (33%), while organized group or other were less common (9% and 2%, respectively). Slightly more than half of respondents reported that they would be happy to pay to sleep in a campsite with amenities (e.g., toilets; 64%), and 51% reported that they would not sleep in a campsite because there are no shower or toilets (Fig. 4). Enjoying the desert scenery was a reason to sleep in a campsite for 40% of respondents; wildlife was neither a reason to sleep (18%) or not to sleep in a campsite (27%; Fig. 4). We found positive correlations between nature relatedness and previous experience of sign campsite (Spearman rho = 0.31, $p < 0.001$; $NR_{Camp} = 3.39 \pm 0.69$, $NR_{NoCamp} = 2.81 \pm 0.95$) and pay campsites (Spearman rho = 0.23, $p < 0.001$; $NR_{Camp} = 3.23 \pm 0.83$, $NR_{NoCamp} = 2.77 \pm 0.94$).

The preference experiment analysis revealed that on average campsites with toilets were chosen in more than 75% of the choice sets, easy access in about 70% of the choice sets, and presence of bins in about 60% of the choice sets; campsites with no vegetation were chosen in only 25% of the choice sets, while campsites with low or high vegetation levels were chosen in about 35% (each) of the choice sets (Fig. 5). More specifically, although each attribute presence was positively associated with the choice of the campsite to sleep in, the attribute toilets had a much stronger importance, followed by access, then bin, and finally by the two levels of vegetation (Table 3). However, for respondents who have already been in sign campsites, the effect of high vegetation was stronger, and the effect of toilets and bin weaker; the

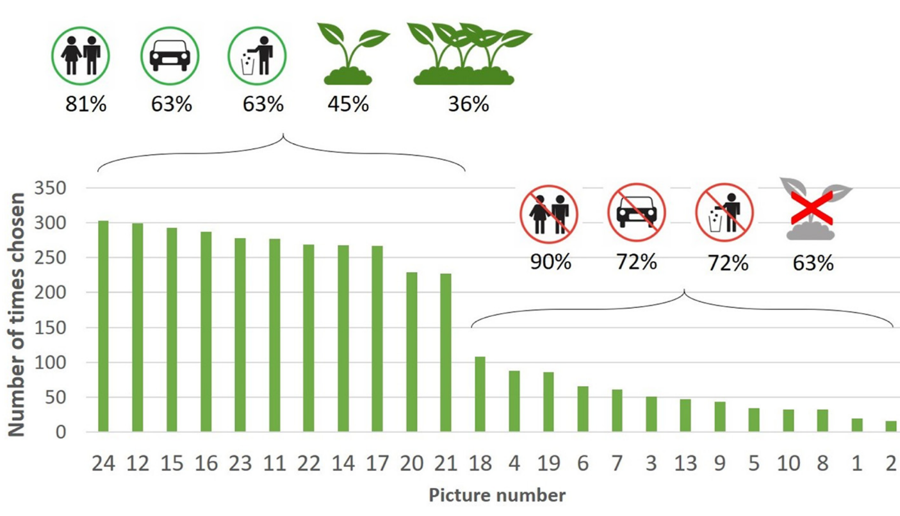

Fig. 5. Number of times each picture was chosen by respondents from the online survey. Each picture was shown twice in the total of 16 choice sets. Reported percentages are the proportions of pictures (from the sub-selection) with the attribute (i.e. bathroom, access, bins, and levels of vegetation); e.g. among the 11 most chosen pictures, 9 (81%) had bathrooms.

Table 3
Summary statistics of the most parsimonious models testing for effects of attributes on respondents' choice of campsites. BSC stands for 'Been in sign campsite', and BPC for 'Been in pay campsite'.

	Controlling for previous experience in sign campsites				Controlling for previous experience in pay campsites			
	Estimate	SE	Z value	P-value	Estimate	SE	Z value	P-value
Intercept	−6.45	0.44	−14.46	<0.001	−6.07	0.44	−13.81	<0.001
No vegetation (*reference*)	–	–	–	–	–	–	–	–
Low vegetation	0.52	0.06	7.73	<0.001	0.51	0.06	7.66	<0.001
High vegetation	1.11	0.07	14.34	<0.001	1.21	0.06	18.01	<0.001
Bathroom	4.06	0.08	50.54	<0.001	3.66	0.08	43.70	<0.001
Bin	1.93	0.07	26.86	<0.001	1.70	0.05	28.65	<0.001
Access	3.15	0.07	44.84	<0.001	3.11	0.06	44.66	<0.001
Been sign campsite (BSC)	0.90	0.10	8.82	<0.001				
BSC * High veg.	0.25	0.09	2.74	0.006				
BSC * Bathroom	−1.16	0.09	−12.03	<0.001				
BSC * Bin	−0.49	0.09	−5.36	<0.001				
Been pay campsite (BPC)					0.13	0.07	1.80	0.07
BPC * Bathroom					−0.21	0.09	−2.25	0.02

effect of toilets was also weaker for respondents who have already been in pay campsites (Table 3).

4. Discussion

Protected areas (PAs) are key conservation areas designed to limit the impacts of human activities on biodiversity (Gray et al., 2016; Shwartz et al., 2017). PAs also provide great opportunities for individuals to experience nature complexity (Cazalis and Prévot, 2019), especially in modern societies facing the so-called extinction of experience (Miller, 2005). Recreational activities in PAs could help restore an intimate relationship between humans and nature. These recreational activities however, can also have large deleterious effects on biodiversity (Monz et al., 2013) and identifying the right balance between promoting nature interactions and safeguarding biodiversity in PAs is challenging. To face this challenge, we need to better understand both the social value of specific recreational activity and its impacts on biodiversity. In this interdisciplinary study, we focused on one type of activity in PAs, camping, for which knowledge on biodiversity is still scarce (Larson et al., 2016). Only few studies have focused on the impact of campsites on biodiversity or surveyed campsite users (Garst et al., 2009), especially in desert ecosystems (Larson et al., 2016). Our results demonstrate that desert campsites located outside nature-rich areas (i.e. the wadis) have relatively moderate negative impact on biodiversity for three out of the four taxa studied (birds, scorpions and plants). Surprisingly, even when campsites were located in nature-poor areas, users' satisfaction was relatively high. In accordance, we also found that among the general public vegetation complexity (a measure of ecological quality) did not have strong influence on people's preferences of/for campsites and that biodiversity in the campsites was only weakly correlated to the level of satisfaction of campsite users. This study provides insights into conservation management strategies maximizing conservation and recreational values of desert campsites.

Recreational activities in PAs are increasingly popular (Balmford et al., 2009) and camping experiences appeal to many people (e.g., in Europe; European Commission, 2019). This suggests that the impacts of campsites on biodiversity in PAs can be potentially high and a broad understanding of those impacts is vital for safeguarding biodiversity. We found that high intensity desert campsites, even when located in ecologically poor areas, have negative impacts on biodiversity. Vegetation was the main taxa affected, with significantly lower levels of vegetation in campsites than in associated control and ecological control plots, a result that is consistent with previous studies (Cole, 2004; Eagleston and Marion, 2017; Pickering and Hill, 2007). Designing areas for camping often requires clearing of the vegetation to enable setting up of tents, and campsite uses induce vegetation trampling that ultimately reduce plant abundance and diversity over time.

Vegetation constitutes a vital resource for wildlife (e.g., nesting and foraging resources) (Henkhaus et al., 2020), although negative impacts on vegetation are likely to cascade to other taxa, we only found impacts of campsites on scorpions' abundance. Birds and rodents' abundances were even higher in high intensity campsites than in associated control plots. The bird communities in high intensity campsites were mostly composed of synanthropic species, compared to other campsites. This can explain the increase in bird abundance and highlight that the intensive activity can alter the structure of bird communities in areas which are species poor (like deserts). In accordance, Cole (1982) also found a positive correlation between intensity of campsites uses and ecological impacts. Campsite uses provide resources, notably food, and attracts synanthropic wildlife (Orams, 2002), as recorded in our study for birds and rodents. Thus, if all campsites are used intensively, their negative impact on biodiversity will likely be higher than what we have found here. Those campsites could become steppingstones for invasive and synanthropic species to enter the desert, which can ultimately endangers the native species, e.g. via biotic homogenization (Colléony and Shwartz, 2019). Results of our study highlight the importance of assessing impacts across several taxa, as the impacts may largely vary from a given taxa to another and the selection of optimal management strategies depends on this knowledge.

Selection of optimal management strategies for campsites in PAs also requires a broad understanding of users' attitudes and perceptions towards campsites. In line with previous studies we found that individuals primarily look for nature and social experiences when going camping (Brooker and Joppe, 2013; Garst et al., 2009). However, despite the desert campsites located in ecologically poor areas, we found that satisfaction of campsite users surveyed on site was relatively high regarding nature conditions as well as location and comfort. These results also reconcile with the fact that satisfaction items and even nature satisfaction items were not or weakly related to the level of sampled biodiversity in the campsites. Previous studies in urban and rural areas have shown similar results (reviewed by Pett et al., 2016). Under the extinction of experience, people demonstrated lower emotional connection to nature, reduced ecological knowledge and abilities to experience nature's complexity (Bashan et al., 2020; Dallimer et al., 2012; Shwartz et al., 2014). Thus, it may be that individuals do not perceive the difference in ecological conditions between campsites. This is concerning, as these trends suggest evidence for a shifting baseline syndrome, in which members of each new generation accept the situation in which they were raised as being normal (Soga and Gaston, 2018), which is likely to aggravate the biodiversity crisis.

The inconsistency between campsite users' desire for nature and high satisfaction in campsites of poor ecological conditions is striking. For only about half of the users in our field survey, having nature (wildlife and trees) seemed to be important, while many emphasized the importance of comfortable sleep. It is thus possible that campsites serve more as a "service", providing a sleeping spot facilitating another activity later on (e.g., hike, nature interactions the next day), rather than being directly for the purpose of interacting with nature. In that case, sleeping conditions would be an important aspect of the experience, while nature would not really matter. Garst et al. (2009) noted a shift in visitors uses from rustic campgrounds that provide only a tent pad and a fire ring to more developed facilities that offer a range of different amenities in the last decades. These trends can result from a growing preference for 'managed' and 'ordered' nature interactions in an environment perceived as safe, esthetic and comfortable (Clayton et al., 2017; Nassauer, 1995), which was also supported by our online general public preferences survey and experiment. More respondents declared they visited pay campsites compared to sign campsites in the last five year and campsites with toilets, easy access and bins were more important than having more complex vegetation in the campsites.

Campsites provide multiple recreational services. Expanding amenities could potentially help attract more diverse visitors to campsites who are less connected to nature and crave opportunities for meaningful interaction with nature (Richardson et al., 2020). One the one hand, this could increase intensity levels of campsites, but it may not necessarily impact satisfaction level, as we found no evidence of variations in satisfaction across intensity levels. On the other hand, under a considerable level of intensity of use, camping in PAs offers opportunities for meaningful interaction with wild nature. Such interactions are associated with enhanced well-being benefits and conservation behaviors (Colléony et al., 2020b; Prévot et al., 2018), which are different than experiences in "managed" nature or ecologically poor areas. Providing individuals with opportunities to experience nature complexity is vital for reconciling biodiversity conservation and well-being objectives and mitigate the biodiversity crisis (Clayton et al., 2017). PAs are the key destination for individuals to experience nature complexity as those areas have often richer biodiversity levels than non-protected areas (Shwartz et al., 2017). A recent study also showed the contribution of PAs for promoting pro-environmental behaviors, individuals living closer to PAs acting more pro-environmentally than individuals living farther (Cazalis and Prévot, 2019). Providing individuals with opportunities to experience nature complexity in campsites in desert PAs by ensuring that campsites are placed and designed to capture rich desert nature could thus contribute to averting the extinction of experience and help mitigate the biodiversity crisis. However, the costs of attracting more people to desert campsites on biodiversity should not outweigh the benefits for restoring affinity towards nature and well-being and careful balanced solutions are needed.

4.1. Management implications for campsites in desert protected areas

Our results have several implications for management of campsites in desert PAs and future research. They highlight the need of diversifying the types of campsites provided in desert PAs, to balance ecological impacts and recreational value of those sites. For instance, intensive campsites in close proximity to infrastructures could be designed for individuals seeking comfortable outdoor camping experience. Although these are intended for intensive use, we expect that the ecological impacts of such campsites will be limited, if the campsites will be located in ecologically poor areas and in close proximity to existing infrastructures (e.g. roads, visiting center of important nature sites). Given that the general public demonstrated strong preferences for amenities, such as toilets and bins, integrating some environmentally friendly amenities (e.g. dry ecological toilets and protected bins) can increase their popularity among the general public. We also suggest planting some native desert trees that can enhance nature experience and provide more diverse space than exposed desert land. Implementation of sanitation measures in the campsites, e.g. bins that safely contain food waste, is also important to limit attractiveness to synanthropic and invasive species in the desert.

Alternatively, extensive campsites located in more remote locations in the nature reserve and with no or limited development and capacity would benefit individuals seeking meaningful nature experiences. Thus, providing campsites in ecologically poor areas for most people could limit the extent of negative impacts on biodiversity, and designing few other campsites in ecologically richer locations could ensure meaningful experiences of nature for more nature-oriented individuals. Strategies can also be implemented to monitor campsite uses in PAs and restrictions applied to limit the number of visitors. Our study focused on the local impacts of campsites and further research effort should now investigate this at a larger scale and ensure that landscape scale design is not serving as steppingstones for synanthropic and invasive species to colonize the desert.

This is the first time, to our knowledge, that ecological impacts of camping are assessed across several taxa simultaneously and in the desert ecosystem. Caution should therefore be taken regarding generalizability of the results of this case study. In particular, the capture rate of rodents was very low, which may affect the overall results. It is also possible that capture rate was higher in poor sites because of lower resource availability, thus potentially biasing our results. It is worth noting that synanthropic birds usually come in large numbers (e.g. pigeons, sparrows), which could potentially explain their high abundance in high intensity campsites. Additionally, our sample of campsite users slightly differed from the representative sample of the Israeli population. The time window for sampling visitors of each camp (early morning before people leave the camp as temperatures rise fast) was very narrow, limiting our ability to follow a strict sampling protocol and reach a sufficient sample size. We believe our sample of respondents in sign campsites is representative of the visitors to sign campsites in general (which may not be representative of the Israeli population) as most individuals agreed to take part in our survey, although we cannot prove this and this represents a potential caveat to our work. However, our results from the field survey were consistent with those of the online survey, for which our sample of respondents was representative of the population. This further suggests that using crowd-sourced data could potentially be provide similar insights as field surveys while focusing on much larger sample sizes (Sinclair et al., 2020). Noteworthy, we mainly focused on sign campsites and it is possible that results could have differed in pay campsites. Future studies could expand our research and compare social value and ecological richness between paid and sign campsites.

We did not directly measure users' experience of nature in the campsites, and every individual's own experience in the campsite may have differed, thus potentially biasing our results, although respondents' answers were relatively homogeneous with some aspects (i.e. nature and comfort). Future studies should explore this further. For instance, comparing campsites located in ecologically poor areas to campsites in ecologically rich areas could be useful. The high proportion of satisfied campsite users may also be due to a sampling bias, with less satisfied campsite users avoiding campsites or camping elsewhere. Finally, the high proportion of respondents of the online survey who reported having previously slept in campsites may be due to the sampling method, as respondents receive incentives from answering the survey, which could thus bias our sample towards lower socio-economic status individuals, while wealthier individuals can afford hotels.

5. Conclusion

This interdisciplinary study provides important insights on desert campsites management strategies and highlights the importance of looking at both social and ecological aspects, and across several taxa, for guiding effective PAs management. Our results showed the overall complexity of balancing ecological and recreational aspects in PAs. Location of the campsites largely determines ecological impacts, as most differences we found where between campsites and ecological controls.

However, we found that when campsites were located in ecologically poor areas, their impact on biodiversity was moderate. In parallel, campsite users' satisfaction was high, but demand from the general public pointed towards more comfortable settings. We thus need to recognize that people's interest in nature varies and provide a variety of opportunities for nature experiences in PAs. This study further highlights the importance of combining social and ecological surveys to understand how to jointly achieve ecological and social benefits.

Credit author statement

Agathe Colléony: Data curation; Formal analysis; Investigation; Methodology; Writing – original draft; Writing – review & editing.

Gal Geisler: Data curation; Formal analysis; Investigation; Writing – original draft; Writing – review & editing.

Assaf Shwartz: Conceptualization; Funding acquisition; Methodology; Project administration; Supervision; Writing - original draft; Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.scitotenv.2021.145255.

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