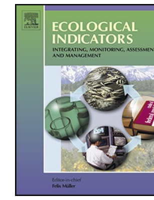
Ecological Indicators 72 (2017) 260–267

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



Impact assessment of intense sport climbing on limestone cliffs: Response of rock-dwelling land snails

Bruno Baur[a], Anette Baur[a], Dénes Schmera[a,b,*]

[a] Section of Conservation Biology, Department of Environmental Sciences, University of Basel, St. Johanns-Vorstadt 10, 4056 Basel, Switzerland
[b] MTA, Centre for Ecological Research, Balaton Limnological Institute, Klebelsberg Kuno 3, 8237 Tihany, Hungary

ARTICLE INFO

Article history:
Received 18 May 2016
Received in revised form 30 June 2016
Accepted 4 July 2016

Keywords:
Biodiversity
Climbing
Disturbance
Gastropod
Impact assessment

ABSTRACT

Exposed limestone cliffs in the Swiss Jura Mountains harbour a diverse gastropod community with some rare species. Sport climbing has recently increased in popularity on these cliffs. We examined the effects of sport climbing and microtopographical features of rock faces on terrestrial gastropods by assessing species diversity and abundance on climbing routes and in unclimbed areas of seven isolated cliffs in the Northern Swiss Jura Mountains. We considered exclusively living individuals resting attached to rock faces. In total, 19 gastropod species were recorded. Six of them were specialized rock-dwelling species, whose individuals spend their entire life on rock faces, feeding on algae and lichens. Plots along climbing routes harboured fewer species of rock-dwelling snails as well as other gastropod species (usually living in the leaf litter layer at the cliffs' base) than plots in unclimbed control areas. Similarly, both the density of individuals and frequency of occurrence in plots were reduced in both groups of snails on climbing routes. The complexity of the rock surface had little influence on the species richness and abundance of gastropods. *Pyramidula pusilla*, the species with the smallest shell and a preference to rest underneath overhangs, was less affected by sport climbing than snail species with larger shells and a preference to rest on exposed smooth rock surface. Our findings indicate land snail diversity and abundance are suitable indicators for impact assessment in rocky habitats. Future management plans and actions should therefore not only rely on plants; they ought to consider also gastropods and other invertebrates. Any management plan should include a comprehensive information campaign to show the potential impact of intensive sport climbing on the specialized flora and fauna with the aim of educating the climbers and increasing their compliance with such measures.

1. Introduction

Limestone cliffs are globally a rare habitat supporting highly specialized and distinct biotas including lichens, bryophytes, vascular plants, insects and gastropods (Larson et al., 2000; Schilthuizen et al., 2003). In contrast to large rocky areas of the Alps and other high-elevation mountains, the cliffs of the Jura Mountains in Switzerland are small and isolated, and mostly surrounded by beech forests or xerothermic oak forests, which have been partly cleared and subsequently used as pasture for some centuries (Moor, 1972; see also Fig. S1). In this landscape, the rocky habitats represent islands of special environmental conditions (Wilmanns, 1993). A variety of organisms living on these cliffs are inter- or post-glacial relics with a recent Mediterranean or Arctic–Alpine distribution (Walter and Straka, 1970). The high species richness, large number of rare species and rarity of the habitat type give limestone cliffs a high conservation value (Wassmer, 1998; Baur, 2003; Ursenbacher et al., 2010). The Fauna-Flora-Habitat guidelines of the European Union consider limestone cliffs as habitats of "European importance" (Council Directive 92/43/EEC, 1992).

During past decades, however, recreational activities including sport climbing, bouldering (a form of rock climbing on boulders), hiking, and mountain biking, are increasingly threatening the sensitive cliff biota. Rock climbing is popular in these mountain areas at low elevation, where this sport can be performed during the entire year (Hanemann, 2000). More than 2000 sport-climbing routes with fixed protection bolts have been installed on 48 rock cliffs of the Jura mountains in the region of Basel, Switzerland (Andrey et al., 1997). Approximately 70% of these sport-climbing routes were opened between 1985 and 1999 (Andrey et al., 1997). The enormous number of climbers has led to conflicts between the goals

* Corresponding author at: MTA, Centre for Ecological Research, Balaton Limnological Institute, Klebelsberg Kuno 3, 8237 Tihany, Hungary.
E-mail addresses: bruno.baur@unibas.ch (B. Baur), anette.baur@unibas.ch (A. Baur), schmera.denes@okologia.mta.hu (D. Schmera).

http://dx.doi.org/10.1016/j.ecolind.2016.07.003
1470-160X/

of nature conservation and recreation activities (Wassmer, 1998; Baur, 2003).

Damage to vascular plants and lichens due to rock climbing has been recorded on limestone cliffs of the Swiss Jura Mountains (Müller et al., 2004; Rusterholz et al., 2004; Baur et al., 2007), and on other types of rocky cliffs in Germany (Herter, 1993, 1996) and North America (Nuzzo, 1995, 1996; Kelly and Larson, 1997; Camp and Knight, 1998; Farris, 1998; McMillan and Larson, 2002; Clark and Hessl, 2015). Damage includes a reduction of vegetation cover, alterations in the composition of the plant community and local extinction of species sensitive to disturbance and of specialists adapted to these extreme habitats. Clearing of soil from crevices and erosion of the cliff edge and face have also been recorded (McMillan and Larson, 2002; Kuntz and Larson, 2006). Furthermore, human trampling reduced the aboveground vegetation cover at the base of cliffs and caused significant shifts in plant species composition (Rusterholz et al., 2011).

Climbing-related effects on invertebrate communities have received less attention. McMillan et al. (2003) examined living snails and empty shells in soil samples from climbed and unclimbed cliff sections at the edge, cliff face and talus of the Niagara escarpment. They did not distinguish between different groups of snails, but found that species richness and density of snails were lower along climbing routes than in unclimbed areas, and that snail community composition differed between climbed and unclimbed sites.

Limestone cliffs provide a variety of different microhabitats for snails, including xerothermic vegetation at the cliff edge and on ledges, accumulated rock and debris partly covered with vascular plants, bryophytes and decaying leaf litter at the talus and in fissures, solution pockets and shallow crevices in the rock face, and unstructured rock surface (Larson et al., 2000). Most snail species exhibit particular habitat requirements and thus occur only in certain microhabitats on rocky cliffs. Among them, a highly specialized group of snails exists exclusively on rock faces (i.e., rock-dwelling species). These snails are very resistant to drought and their specialized radulae enable them to graze epi- and endolithic lichens and cyanobacteria growing on rock faces (Baur et al., 1992, 1994, 2000; Fröberg et al., 2001, 2011). The snails are active during periods of high air humidity, otherwise they rest attached to the exposed rock surface or in small fissures (Neuckel, 1981; Baur and Baur, 1991). Attached to the rock surface, these snails are exposed to the risk of being crushed by climbers, which may result in a reduced snail density in climbed areas. Several other gastropod species occur in the leaf litter layer and ground vegetation at the cliffs' bases. In these species some individuals forage occasionally on algae on rock faces and may rest attached to the rock surface during periods of drought.

In our study, we examined whether intense sport climbing and microtopographical features of the rock face affect gastropod species richness and abundance on limestone cliffs. We used a design that considered different cliffs with multiple climbing routes and corresponding control areas. We exclusively considered living individuals resting attached to the rock faces avoiding any bias due to empty shells dislocated from other (micro-)habitats. We analysed species richness and abundance separately for true rock-dwelling species and for gastropod species whose individuals only occasionally occur on rock faces. In particular, we addressed the following questions:

1) Are species richness, species density and abundance of terrestrial gastropods on cliffs affected by intensive sport climbing activities and by the structure of the rock face?
2) Are different gastropod species differently influenced by sport climbing?
3) Do different gastropod species differ in their preferences for resting sites on rock faces and do these preferences differ between climbed and unclimbed rock faces?
4) Can rock-dwelling land snails be used as an indicator group for impact assessment?

2. Materials and methods

2.1. Study sites

The study was carried out in the lower parts of seven isolated limestone cliffs in the northern Swiss Jura mountains 10–15 km S–SE of Basel (47° 35′N, 7° 35′E; Fig. S1). The cliffs are situated at elevations ranging from 470 to 700 m above sea level and they are 1–13 km apart from each other (Table S1). They mainly consist of Jurassic coral chalks (Bitterli-Brunner, 1987). The characteristic plant community of the predominantly east- to south-facing cliffs belongs to the Potentillo-Hieracietum association (Wassmer, 1998). The cliff bases are covered by different stands of deciduous forests belonging to Fagetum and Tilietum associations (Burnand and Hasspacher, 1999). In this region, the annual temperature averages 9.6 °C and the annual precipitation is 1021 mm (MeteoSwiss, 2012).

2.2. Field survey

We recorded the number of individuals of each species in plots set up on sport-climbed cliff faces and on undisturbed rock faces (control areas) on the same cliffs in May–September 2005. We placed three 50 cm × 50 cm plots in a vertical line with an interplot distance of 20–30 cm in selected sport climbing routes (indicated by fixed protection bolts) at a height of 0.3–2.5 m (Fig. S2). Using the same spatial arrangement, we placed another three sampling plots at a horizontal distance of 10–30 m from each focal climbing route in an unclimbed part of the same cliff face (hereafter unclimbed control area). The following criteria were used to select the unclimbed control areas: (1) both the climbing route and control area had the same aspect, (2) they were situated within 10–30 m of each other, (3) received the same insolation, (4) did not differ in forest management at the cliff base, and (5) did not differ in rock surface complexity (see below). Five pairs of climbing routes and control areas were examined at each cliff and the same procedure was repeated at seven cliffs (Table S1) resulting in a total of 210 sampling plots (105 plots in climbing routes and 105 in the corresponding control areas).

In each plot, we carefully examined the rock surface, fissures and pockets for attached gastropods using a magnifying glass (3x). We surveyed plots only in dry weather and considered exclusively living snails resting attached to the rock surface (Figs. S3, S4). After species identification, we released the snails at the spot where they were found. Gastropod identification and nomenclature follows Kerney et al. (1983).

We used a compass to assess the aspect of the cliff face (in degrees from north) in each climbing route and control area. The elevation of the cliff's base was obtained from topographical maps. To assess the complexity of the rock surface we determined the number of fissures (narrow linear crevices or cracks extending into the rock surface), the number of ledges (any features extending out horizontally from the rock surface), and pockets (solution pockets consisting of circular cavities extending into the rock surface) in each plot. We used a semi-quantitative scale of cumulative scores to express rock surface complexity in each plot. The scores considered fissures: (0) no fissures present, (1) total fissure length ≤ 30 cm, (2) total fissure length > 30 cm; ledges: (0) no ledges present, (1) total ledge length ≤ 30 cm, (2) total ledge length > 30 cm, and pockets: