Recreational Climbing and Scrambling

4

Chapter Summary

In this chapter, the types of climbing are defined and numbers involved are estimated. The effects of traditional summer climbing on cliff vegetation and other biota, like gastropods, are evaluated. This includes "gardening," footpath erosion up to the crags, at the tops, and a decrease in rare and endangered species and tree damage from abseiling and belaying. The effects of cliff micro-topography and climbers' preferences are discussed with regard to the vegetation distribution and the fact that not all effects are negative. The impacts on bird populations are evaluated, and the damage to the rock by ropes, chalk, protection, and the creation of rock polish is discussed. Other environmental effects from bouldering, winter, and mixed climbing are evaluated. The management to counteract these impacts such as management plans, memorandums of understanding, liaison groups, closures, seasonal restrictions, star systems in guides, permits, and outreach and education, including codes of conduct, are discussed and evaluated

4.1 Introduction

Climbers cannot deny that their sport causes some ecological damage. It can disturb birds and particularly their breeding, it clears vegetation from the cliff face and specific routes, and it erodes tracks to and from the route. However, climbers often argue that the damage caused is insignificant to that of other outdoor activities, and it is true when one considers other major land-use activities. As Hearn (1994) stated when considering the effects of nature conservation and cliff climbing in Cornwall (UK), "Nationally the effect of climbing, or any other recreational pursuit, is minor when compared with agriculture, pollution, development and other major land-use activities." Conservationists could hold the view that the path climbers leave behind is a scar on the landscape, for example, the paths leading up to Dinas Cromlech in Snowdonia. Would they argue so strongly if the damage had been caused by rockfall? Would attempts be made to repair the damage, and would it even be an issue if there was not a road so ideally placed from which to view it from? A climbers' attitude might be to argue that what they create is a part of the natural environment. However, this is far from the truth, and climbers can damage a specialised environmental niche. Cliffs can be scarce compared with other ecosystems, and the species that have adapted to live there are often rare. So, for example, Raven and Walters (1956) suggested that whole communities of plants, containing many characteristic mountain plants, are in Britain represented by the merest fragments clinging to relatively inaccessible ledges where the most ubiquitous of sheep cannot penetrate. Wyatt (1988) stated that "A crag is not just a rock.

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It is a living community of plants and animals. Who decides to climb it becomes part of it. He or she must judge how much of that community of which they are a part must die to satisfy their Adventure." Is the answer none of it, some of it, or all of it? Before considering some of these issues, we have to realise that there are several activities under the umbrella term "climbing."

4.2 Types of Climbing

Traditional climbing or summer climbing takes place on inland cliffs or on coastal cliffs (Fig. 4.1).

This can include instructional cliffs where low technical ability is required, but there may be high numbers involved on some of these cliffs. The climbers ascend rock walls and cliffs that are protected with gear; they have to insert artificial safety equipment, such as wedges or cams which are jammed into cracks in the cliffs and which can often erode the rock. This gear is both placed and removed by the climbers and is considered to have least impact on the rock as a climbing team leaves no trace. The protection that developed differed from country to country and ranged from slings, pegs, and pitons to chocks and camming devices. On the soft Bohemian sandstone, removable jammed knots prevented damage to the rock. It has been suggested that this type of climbing should be called adventure climbing (UIAA 2014). It is largely environmentally friendly. Bouldering is a shorter, power-driven ascent of difficult problems where there are no ropes involved and the routes are usually under 5 m high on boulders or small cliffs (Fig. 4.2). As a discipline it dates from 1993 when Black Diamond sold the first commercially available crash pad which is needed at the cliff base to cushion any falls and make a safer landing if there are falls. Winter climbing might involve snow gullies, ice climbing on waterfalls or glaciers, or mixed climbing on a combination of snow, ice, and rock. Dry tooling is a form of climbing taking place on outdoor crags and indoor climbing walls using ice axes and crampons. Dry tooling on outdoor crags in "summer conditions" typically occurs on overhanging quarried rock or on rock faces which are generally unsuitable for

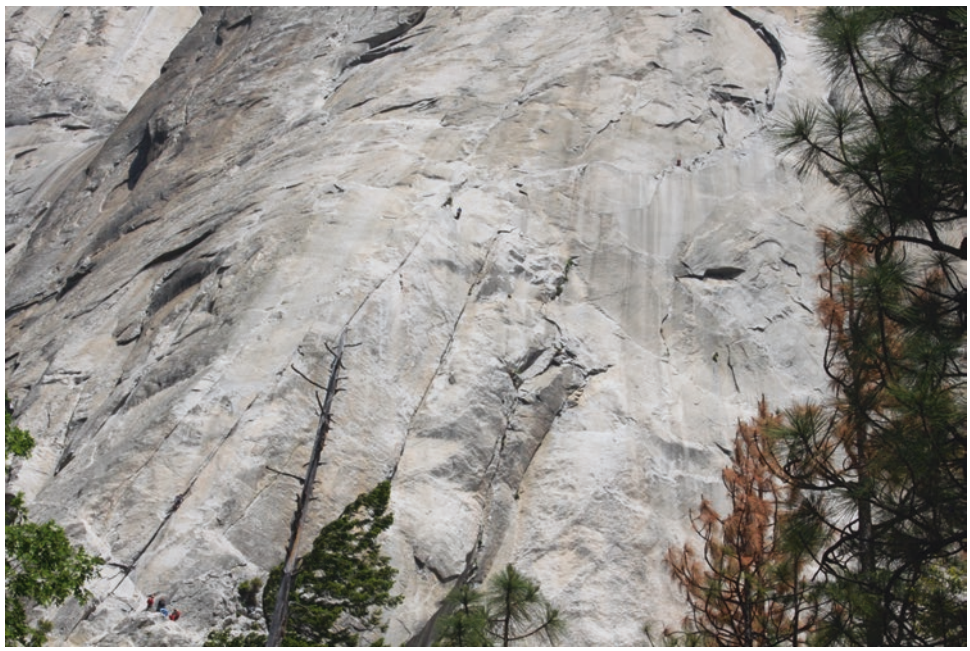

Fig. 4.1 Big wall climbing, El Capitan southeast face, Yosemite. Photo by D. Huddart

Fig. 4.2 Erosion at base of crags, Harrison's Rocks, South East England. Photo by D. Huddart

conventional rock climbing, and it usually involves the use of fixed equipment and drilled/manufactured axe and crampon placements. The British Mountaineering Council (BMC 2014) has acknowledged it has a place in British climbing, but it is not considered an acceptable practice on established rock climbs. The BMC states that the suitability of individual sites for dry tooling should be considered on a case-by-case basis by the relevant BMC area meeting. Unfortunately it has already caused noticeable, irreparable damage to high-quality rock climbs in the Lake District (UK) with scratch marks and damage to crucial gear placements or handholds. Free soloing requires no safety or aid equipment allowing the climber to ascend a route using no safety equipment and so is the least invasive form of climbing. Sport climbing involves participants setting their own route, using a rope, and can take place either on cliffs or indoor climbing walls. The routes are pre-bolted by the first ascent party who drill the rock and place a bolt, and therefore this eliminates the need for safety equipment. A bolt hanger is used for clipping a carabiner to the bolt. Speed climbing is where the route and the handholds

are standardised, and the participants are timed over the route. The latter two types have increased in popularity as we will see from the next section and are important if it can be shown that they lead to the increased popularity of outdoor climbing. Top rope climbing is where a safety rope is always anchored above the climber either in scaling cliffs or artificial walls. A top rope route is set up by a climber either leading a sport or traditional route from the base to a set of anchors, where the rope is attached with locking carabiners. Aid climbing is where climbers ascend steep rock faces with the use of specialised climbing equipment that allows mechanical upward progress rather than free climbing. Climbers can place pitons, cams, and nuts to attach the rope and themselves to as they climb upwards. Scrambling is where easy rock faces and ridges are climbed, usually in mountains, either with or without a rope. It requires basic climbing skills using hands and feet and belaying, descending, and abseiling. So we can see that there are several types of climbing, and logically they can have different environmental and ecological impacts.

4.3 Numbers Involved in Climbing

The numbers involved in the activities may illustrate the relative impact potential either in total number of climbers or the relative importance of the types, although we will see that the impacts vary between types. However, because climbers often just carry out their activities in small independent groups or a pair, are not members of clubs, and may not figure in the surveys that have been carried out, it is extremely difficult to estimate realistically the numbers involved in the activities.

This is especially the case when the types of climbing are grouped in different categories of activity. However, in general there has been a growth worldwide in climbing as a series of recreation pursuits, although climbing did not appear in the top twelve recreation activities in six European countries, Canada, and the USA in the 1990s and 2000s (Bell et al. 2007) and it did not appear to be measured or in the forecast changes up to 2050 in the USA (Cordell et al. 1997; NSRE 2003; Cordell 2004). Cordell (2008, 2012) suggested climbing was the fastest-growing nature-based activity in the USA in the period 2000–2007, with a growth from 7.5 million in 1994–1995, to 9.0 million in 1999–2001, 8.7 million in 2007 to 9.8 million between 2005 and 2009. This was a percentage increase of 9.5% from 1994–1995 to 2009, 8% growth in the period 1980–1984, and a 12% growth in the period 1985–1989. Total number of days of participation increased by 23.8% in the period 2000–2007, up to 0.1 B. However, the Outdoor Foundation, Topline Survey (2017) suggested in the USA a growth of 6% for traditional and ice climbing between 2013 and 2016, with a 20.3% growth between 2006 and 2016 from 1.586 million to 2.79 million. However, in the same period, there was a growth of 3.4% in sport/indoor and bouldering from 4.728 million to 4.905 million. Unfortunately in Bowker et al. (2012), in a survey of potential changes up to 2060, rock climbing was included in backcountry activities, which also included mountain climbing and caving. The total for 2008 was 25 million, and the range for 2060 was estimated to be 38–48 million, with an increase of participation days from 121 million days in 2008 to be between an estimated figure of 178 and 219 million days by 2060. The figures quoted in a report for Colorado (2013) stated that climbing (which included sport, indoor, and bouldering) was the 23rd most popular outdoor recreation activity in the USA with numbers of 4.592 million, 1.5% of the US population, whilst in Colorado it was ranked 21st, carried out by 12.5% of the population, with 3.912 million activity days in total. This illustrates the regional variation within the USA as might be expected, and the numbers had increased from an estimated half a million to over 1 million from 2006 (Climbing Management Guide 2008).

In the UK the BMC membership rose from 25,000 in 1990 to 82,000 currently, and individual membership rose from 25,000 in 2000 to 55,000 in 2015. National Trust figures for rock climbers estimated 1.35 million casual climbers and 150,000 active climbers which illustrates the great difference. In the late 1990s, it was thought that there

had been an increase of 140% of active summer climbers in the previous 15 years. The estimated increase in winter climbers had been 20% of the summer climbers in the same time period. Technology had brought about the pushing of climbing limits which has caused new routes to be put up on existing crags, the continued search for new routes, and the development of winter routes that follow summer rock lines and have been climbed using winter tools under winter conditions. Until recently, with the more obvious impact of global warming, the popularity of winter climbing was seen from the number of new routes that have been put up. For example, from October 1996 to the New Year of 1997, 60 new routes were reported in *High* magazine (no.170), and in the same magazine (No.172), another reason for expanded climbing in the mixed scene was restricted resources in the UK and the need to find new ground and to diversify new ascents. In the UK Gordon et al. (2015) suggested that 14% of 8.96 million people who were active in the outdoors participated in mountaineering, abseiling, and climbing on a weekly basis. This figure was 93,000 which was an increase in 16,000 compared to 2014. According to Adventure Participatory Survey Adventure Sports (APS) in 2013–2014, once a week participation in rock climbing age over 14 was 61,300, whilst 28,900 climbed at an indoor wall.

Sport climbing (which includes sport, bouldering, and indoor) has grown tremendously recently. Between 2007 and 2014 the number of people participating grew by 18,732 in the USA, while from 2014 to 2015 the number grew by 148,287 to 4.6 million, which was 70th from a list of the top 111 outdoor activities. In the same country, the Outdoor Industry Association puts the total participation in bouldering at between 4.7 and 6.9 million people. This is also shown by Eastern Mountains Sports who state that its sales of crash pads for bouldering had grown by 15% in the last year (2017), sales of rock shoes had grown by 70% over the last five years, and ropes and other gear by 40%. The International Federation of Sport Climbing echoes this boom and now has over 87 member federations over five continents and claims over 25 million people climb regularly. In England, for example, the number of young people taking part in the BMC Youth Climbing Series has risen by 50% in the last five years, whilst in Austria the number of members and member clubs in 2008 was 23,170 in 141 clubs, whilst in 2016 the figures were 61,140 members in 176 clubs. In 2010 the BMC Climbing Wall Survey to over 3000 members had over 5 million climbing wall user visits each year at 350 walls listed in the BMC Wall Directory. One of the crucial statistics was that over 75% of the respondents said they climbed at both indoor walls and outdoor crags. This boom in sport climbing can only escalate much further as the activity has been added to the 2020 Summer Olympics in Tokyo.

Despite the difficulties of obtaining accurate numbers and the variation in figures put forward, we can establish that the numbers of climbers of all types have increased, as have the number of climbing participation days, and so it is no surprise that there is an increase in noticeable and measurable ecological effects on the crag ecosystems.

4.4 How Do Climbers Affect Crag Ecosystems?

We need to itemise what climbers need from their crags and then look at what plants need and see if the two are compatible. Climbers need good aspect, usually south-facing crags; the rock needs to be clean and free from vegetation; the rock needs to be dry and steep; the rock needs to be good and solid; the faces need to be of a reasonable height, and there needs to be interesting route diversity. Plants need to be protected from grazing and competition. They need available water with nutrient leaching from above a useful bonus; the slope angle should not be too steep or the soil will not build up and support plant life; a southerly aspect is useful; the rock type can be important as base-rich rock tends to support a wider species range than acidic rock. Looking at the needs, it might appear that the rock that is climbed on the most often is the type not suitable for plants to live on and suggests no great conflict of interests. However, this is not so because the

cliffs that are climbed on now have been extensively stripped of their vegetation, cleaned, and "gardened" in the past. As an example in the UK climbers tend to affect the arctic-alpine group of plants which are linked to past cold climates and which are increasingly rare and likely to be on the verge of extinction under global warming; there are woodland species which can survive because of high humidity and damp hollows, meadow and flush species which can survive on ledges, and specialised plants where water pours down a rock face or gully, such as the range of mosses and liverworts and the rock pioneer species, the lichens. There are also moorland species characteristic of peaty, acidic soils and the upland grasses and heath species which would be expected in the general area of the higher crags but are selectively grazed by sheep on the UK crags.

4.5 Effects of Climbing on Cliff Vegetation and Other Biota

4.5.1 Traditional Summer Climber Impacts on the Vegetated Crag Environment

Climbing can impact in the following ways (for an excellent overview on Cliff Resource Impacts, see Marion et al. (2011), pp. 105–112):

- Development of new routes where the vegetation and loose rock are gardened, either accidently or on purpose. This gardening sanitises the intended route line, leaving barren rock. Soil can be mechanically scraped from the rock face by using a wire brush, toothbrush, or trowel as the soil and/or loose rock can hinder a climber's ability to ascend a cliff safely. They need a clean surface so that their hands and feet are able to grip the micro-topographical features of the rock. Trundling can take place where the loose, unstable rock and soil can be removed from a climb. This extracted loosened rock means that future climbers will not injure themselves or the person on belay will not be hurt by falling rock. In some areas a few climbers have resorted to chiselling the rock to create handholds. So cliffs are often modified so that the climber may have better traction with the rock.
- Climbing established routes which might need placement of protection in cracks and clean routes and belays is often taken on ledges which are suitable for plant colonisation, and so standing on these ledges will result in erosion. In this way colonisation by plants is prevented, scraping away mosses and lichen which escaped the initial gardening, exposed rock becomes progressively more polished, and rockfall becomes more likely. However, the National Trust illustrated that a recent survey at Avon Gorge (Bristol area, UK) showed that climbers actually had a beneficial effect by keeping paths and belay ledges open and trodden which is exactly the kind of habitat preferred by such plant rarities as the Bristol rock cress, (*Arabis scabra*) which needs open ground for germination.

Access to the base of established routes at the base of the cliff can cause damage. Ascending steep terrain to the crag has sometimes ill-defined, access routes which cause climbers to unknowingly take several paths to the same destination. For example, the 22 climbing sites in the Pinnacles National Monument, California (USA), were reported to have access leading to them, but in a short period of time, steep secondary trails appeared which began to divert water, causing soil loss, trenching, the development of shortcuts, and vegetation loss. The result is increased footpath erosion as at Harrison's Rocks (South East England) and Stanage (Peak District) and damage to areas such as delicate scree slopes with accelerated erosion (e.g. World's End screes at Llangollen, North Wales). If a wider view is taken, then there could be a greater number of cars, car parking problems, sometimes on vegetation, damage to gates and fences, and perhaps disruption to livestock. Better access often leads to more climbers, and a vicious circle can occur. There is also damage to cliff-top vegetation by trampling around abseil points or from footpaths along the crag top. At Harrison's Rocks, Baker (2005) found that ground levels had been lowered by more than 1 m in some places due to intense foot traffic at the crag base (Fig. 4.2).

- At Harrison's Rocks photos of the outcrops in the early 1950s show dense vegetation cover around the rocks, and 50 years later, the position had greatly deteriorated. At Stanage where there are over 8500 graded climbs, with many regional classics and a few of national classic status, Smith (1997) found a variation in crag foot erosion depending on the crag use. At buttresses, like crags 1–3, where there was no climber use, there was little, if any, bare ground at the immediate crag foot, and there was a moorland ecosystem composed of heather, bilberry, bracken, and wavy hair grass. On the other hand, at the buttresses of high popularity, like Tippler Buttress, Flying Buttress, and Mississippi Buttress, the bare ground width averaged between 7 and 10 m, and around 50% of the surveyed area was bare ground. Heath species like heather and bilberry were all but eradicated from the crag base, and those plants that remain lie at 15–20 m from the crag. There are now large areas of bare ground and grassland in an area of heather moorland. The popular buttresses have long since exceeded their carrying capacity in this area.
- Carr (2007) also measured the environmental impact of climbs in the Red River Geological Area of the Daniel Boone National Forest, a world-class climbing destination in Kentucky (USA). He used bare ground as a surrogate for environmental impact, and climbing impacts the ground in a concentrated use area at the base of climbs, an area called a climbsite (with analogy to a campsite). The climbers also impact the ground on the access trails which may either be along the cliff base between climbsites or the access trail from the parking area to the cliff base. The most important factor in determining the amount of impact was found to be the type of climb, whether a sport climb or a traditional climb. Sport climbs were found to have three times as much impact. As the difficulty of a traditional climb increased, the impact reduced. Similarly as the access to the climb gets more difficult either in trail quality (sport climbs) or length (traditional climb), the impact is reduced. Better climbs and more quality stars lead to more impact with traditional climbs. The ground impacted due to climbing was estimated to be 2.8 acres out of a total area of 29,000 acres, which is only 0.01%. The length of cliffline base impacted was estimated to be 0.9 miles out of a total of 254 miles which is only 0.04%. So using these measures of environmental impact, climbing in this area has a limited impact. Moreover Walendziak (2015) measured the environmental area of impact at eight climbing areas in the same area over a six-year period from 2007 to 2013 to determine the impact trends. He found that the total mean area of impact did not change significantly and climbsites remained stable and seem to have reached an area of impact maturity rather like what Cole (2013) found for campsites.
- Retreat from the top of routes can cause erosion on descent footpaths.
- There can be tree damage from abseiling points and belaying from trees. This can cause damage to the bark by friction and abrasion, with the most severe damage caused by friction from ropes being pulled down after abseiling. This friction wears the tree bark and with repeated use can lead to ring barking of the tree. Where there is the removal of a complete ring of bark around the tree trunk, this can lead to disease caused by fresh-wound parasites which can cause cankers, decay, and other diseases and lead to loss of tree strength. Damage to trees is evident in two stages: stress which is a reversible condition where energy or other survival factors become limiting and the tree or one of its parts or processes begins to operate near its limits through root or bark damage. Stress can be reversed. However, if nothing is done about the problem causing stress, a tree can die, or the affected part is severely affected. Once damaged a tree will attempt to self-repair. An example is where Scots pine responded to the removal of 50% of their bark at the base of the trunk by increasing the production of resin acids. Two and a half times the normal concentration of acids was found in the bark adjacent to the wounds and includes dehydroabietic acid, which may be a deterrent to larval feeding and

provide increased decay resistance against white-rot and brown-rot fungi (Liddle 1997). For example, Richards (1997) reported damage from abseiling at Craig Bwlch y Moch, Tremadog (North Wales), and Webber (2002) showed the damage caused by abseil anchors from trees at Clogwyn Cyrau, near Betws-y-Coed (Snowdonia, North Wales). Webber (2002) conducted simulated abseils from three species of tree known to be used by climbers using two 50 m, 9-mm thick ropes, tied together and tied round the tree base. The simulation was carried out 100 times and the depth of any rope groove recorded. The results are illustrated in Table 4.1. The trees were on private land and were already marked for felling. Although the overall final rope groove depth was hardly different, the smoother, thin barked holly was damaged quicker than those species with thicker, rougher, flaky bark like the oak and the Scots pine. This suggests that other smooth-barked trees located at other climbing venues in North Wales, like the rowan and silver birch, will be susceptible to rope damage.

However, a final point worth making is that at the top of Craig Bwlch y Moch (Tremadog), there are young oak trees stripped of bark by sheep, and there are no trees in the agricultural land where sheep ensure no woodland regeneration takes place. So it is worth remembering that it is not only climbers that cause tree damage.

Table 4.1 Simulated abseils (all trees were of maturity class 4) (after Webber 2002)

No. of abseils	Depth of any rope groove in mm: sessile oak (*Quercus petraea*)	Depth of any rope groove in mm: Holly (*Ilex aquifolium*)	Depth of any rope groove in mm: Scots pine (*Pinus sylvestris*)
10	No groove, moss removed	0.5	No groove, some bark smoothing
20	No groove but beginning to smooth	0.8	No groove, more smoothing
30	0.5	1.2	0.5
40	1.0	1.4	0.6
50	1.2	1.5	0.8
60	1.5	1.8	1.1
70	1.6	1.9	1.5
80	1.8	1.9	1.7
90	2.0	2.0	2.0
100	2.1	2.2	2.4

- An example from North America looked at the Eastern white cedar (*Thuja occidentalis*), tree density and age structure that have been shown to be affected by climbing (Kelly and Larson 1997). The authors compared four climbed and three unclimbed sites on the Niagara Escarpment, near Milton (Ontario). The results showed that living tree density on the cliff face was lower in the climbed areas. The age structure of these forests show that the numbers of older and younger age classes have been reduced on the climbed cliff faces. A high percentage of the trees on the climbed cliff faces showed evidence of damage.
- There are positive results too as the National Trust in the UK has shown that climbers have assisted with vegetation clearance in some areas which have difficult access, for example, the clearing of rhododendron on Lundy Island, their assistance with botanical cliff survey, the provision of advice on cliff stability and dangers, and the undertaking of bird-ringing projects, such as the peregrine falcon in the Lake District and choughs in Pembrokeshire (south-west Wales). The presence of climbers can help deter egg thieves as has been demonstrated from the sandstone cliffs at Helsby (Cheshire).
- Rock climbing significantly reduces the vascular and non-vascular vegetation cover on cliffs according to Ruby (2015), although as we will see, not all researchers agree. There must be damage to lichens on crag faces by removal and wear as it might be expected that the pioneer species on rock faces, the lichens, must be affected by climbing. Adams and Zaniewski (2012) evaluated the lichen community composition for both cover and richness on a cliff face commonly used for climbing on a sandstone outcrop on the Sibley Peninsula on the north shore of Lake Superior. They found that both the richness and cover were significantly lower on the climbing cliff

sections compared with the unclimbed sections. Regression models indicated significant relationships with cover and richness to environmental response variables and the climbing treatment. There was major lichen community group separation between climbed and unclimbed areas, and they thought that this was linked to both aspect of the measured plots and the climbing treatment. Baur et al. (2007) assessed the lichen species diversity and cover on climbed and unclimbed areas of ten isolated cliffs in the northern Swiss Jura Mountains. A total of 38 calcicolous lichen species, three bryophyte species, and one alga were found on the rock faces. Climbed and unclimbed rock areas did not differ in the total number of lichen species, species density (the number of species/100 cm^2), or total lichen cover. However, the frequency of occurrence of epilithic lichens (those that grow on top of rock without penetrating the rock substrate) was lower along climbing routes than in unclimbed areas. The lichen community composition of climbed areas differed from that of unclimbed areas, and the dissimilarity increased with increasing climbing intensity on the focal route in climbed areas but not with the age of the climbing route. Nuzzo (1996) on exposed dolomitic cliffs in Illinois (USA) had suggested that climbing had apparently significantly reduced the lichen cover and lichen species density by 50% from 13.7% cover and 2.4 species/0.25^2 on unclimbed areas to 6.7% cover and 1.2 species/0.25 m^2 on climbed cliffs. However, although the climbed cliffs had lower lichen cover, the distribution of community groups was similar on both sets of cliffs, which indicated to the author that environmental and physical variables were the primary determinants of cliff flora on the vertical exposed cliffs. This was because climbing too did not have an apparent effect on the vascular plants, which ranged from 2.74% to 10.62% cover on individual cliffs. Studlar et al. (2015) used a simple force meter to measure the adherence of bryophytes and lichens to try and understand the vulnerability to removal by both climbing route preparation (cleaning) and accidental dislodging. They did this on the Pottsville conglomerate caprock at Coopers Rock and at the New River Gorge National River in West Virginia (USA). They found that lantern moss (*Andreaea rothii*) is held relatively tightly, probably benefitting the more weakly attached species such as the liverwort (*Diplophyllum apiculatum*) which commonly grows epiphytically on *A. rothii*. The umbilicate lichens, the smooth rock tripe (*Umbilicaria mammulata*), and common toadskin (*Lasallia papulosa*) were more tenacious than the lantern moss, but the loss of extensive smooth rock tripe colonies was found to be one of the most visible climbing consequences. However, they recommended long-term studies with different experimental disturbance regimes to more fully evaluate climbing impacts on bryophyte-lichen communities.

- Camp and Knight (1998) showed that in the Joshua Tree National Park (California), six cliffs with no climbing, moderate climbing, and intensive climbing were sampled for plant diversity and community structure. Results showed that the number of individual plants decreased with increased climbing use both on and off the cliff face. Similarly Farris (1998) showed that on three Minnesota cliff systems, the frequencies of most plant taxa were lower in the climbed areas (Table 4.2).

Table 4.2 Mean number of taxa per plot in three climbed and unclimbed areas

From Farris (1998) from Minnesota State Parks					
Blue mounds		Interstate		Shovel point	
Climbed	Unclimbed	Climbed	Unclimbed	Climbed	Unclimbed
2.88 ± 0.24	3.98 ± 0.35	0.88 ± 0.17	4.35 ± 0.29	6.97 ± 0.39	10.18 ± 0.44
$n = 48$	$n = 45$	$n = 48$	$n = 48$	$n = 33$	$n = 27$

There are significant differences between climbed and unclimbed plots at all three locations

However, the total plant cover was significantly lower in the climbed plots. Fragile forms such as the umbilicate and fruticose lichens were especially sensitive. It was found that the microtopography of the rock had a significant impact on both the amount of vegetation present and the use of a cliff area by climbers. It was suggested that the identification of causal links between climbers and vegetation structure must include a careful assessment of the geological and environmental factors that strongly influence both the climbing use and the vegetation dynamics. We will return to this later.

- McMillan and Larson (2002) evaluated the effects of climbing on the heavily climbed limestone cliffs of the Niagara Escarpment, which have the most ancient forest east of the Rocky Mountains, with Eastern white cedar that are over 1000 years old. They compared the vegetation on three parts: the top edge (plateau), the cliff face, and base (talus) of both climbed and unclimbed cliffs. The climbed faces had only 4% as many vascular plant species as those that were unclimbed. The diversity of bryophytes and lichens in climbed areas was 30–40%, respectively, of the unclimbed areas. There was a decreased vegetation cover on the cliffs, and for vascular plants the cover on climbed plateau and talus was around 60% of the unclimbed areas. For bryophytes the cover on the climbed areas was about 20% of unclimbed areas. While climbing did not affect the extent of lichen cover, it did change the types of species that grew on the cliffs. The delicate lichens were replaced by tough species. In the climbed areas, the proportion of non-native plants in the climbed areas was three times higher (81% compared to 27%).
- Climbing reduces the plant density which increases the number of sites where non-native plants can grow. Climbers can introduce seeds and living non-native plants via their boots, clothing, and equipment, but it is not only non-native species or alien species which can colonise but weed species and disturbance-indicator species as well.
- Baur (2004) and Rusterholz et al. (2004) have shown that the exposed cliffs of the Swiss Jura also harbour a highly diverse flora with many rare and endangered species. They examined the impact of rock climbing on the vascular plants in the lower part of four cliffs of the Gerstelflue (NW Switzerland) by comparing the vegetation of climbed and unclimbed areas. In the climbed areas, the plant cover and species diversity was reduced, and the density of forbs (any herbaceous plants but not grasses) and shrubs decreased, whilst the density of ferns tended to increase. The climbing also caused a significant shift in plant species composition and altered the proportions of different plant life-forms. These authors considered that rock climbing can be a threat to sensitive plants of this limestone cliff community. Müller et al. (2004) in the Northern Swiss Jura studied the ecological effects of climbing on the vascular plants at the cliff base and on the cliff face by assessing the plant cover and species density at various distances from the frequently used climbing routes. The plant cover was found to be significantly reduced at the base of the climbing routes, as was the species density too. The plant cover and species density at the cliff face tended to increase with distance from the route. When the vegetation of five frequently climbed cliffs was compared with that of seven unclimbed cliffs, the climbing significantly altered the plant composition. Specialised rock species occurred less frequently on the climbed compared with the unclimbed cliffs.
- It has also been claimed that climbing leads to a decrease in rare and endangered species because some of these are arctic-alpine species that live on high mountain and cliff ecosystems. They are relicts from the last cold Pleistocene phase, and others are endemic to certain restricted areas. We will discuss two examples here. The cliff goldenrod (*Solidago sciaphila*) is an endemic species restricted to dolomitic or sandstone cliffs in or near the driftless region of the upper Midwest USA. A demographic study of 544 genets (a colony of plants that come from a single genetic source)

on currently climbed, previously climbed, and unclimbed dolomite cliffs in north-west Illinois indicates that the position on the cliff face was the most significant factor affecting growth.70% of all plants grew within 3 m of the cliff top, and this was only 18% of the cliff face (Nuzzo 1995). Within the upper cliff zone, climbing significantly reduced Solidago density. The cliffs that were actively climbed had few genets in the upper 3 m, averaging 3.2/m^2, whilst unclimbed cliffs and cliffs not climbed for two years supported 14.2/m^2 and 12.0/m^2, respectively. The basal area/m^2 and the plant production/m^2 were significantly lower and the inflorescence length non-significantly lower on currently climbed cliffs due to the lower genet density. In the lower cliff face (over 3 m from the top), genet density was low (0.2–2.1 m^2) on all cliffs regardless of the climbing intensity. Two years after cessation of climbing, Solidago in the upper zone of the previously climbed cliffs had similarly high density, basal area, plant production, and inflorescence production as on the unclimbed cliffs. So this suggests a quick recovery of this species.

- A second example is that of the effect of climbing on the yellow whitlow grass (*Draba aizoides*) and the alpine saxifrage (*Saxifraga paniculata*) which occurs on the limestone cliffs of the Swabian Jura in Southern Germany. Both are rare and endangered species, particularly where climbing is allowed. Wezel (2005) measured the following: the number of cushions/cliff, the number of rosettes per cushion, and the aspect and the inclination of the sites. *Saxifraga paniculata* was found on 75% of the cliffs, whilst *D. aizoides* only on 30%. In cliff areas where climbing took place, *S. paniculata* was only found in relatively uninfluenced parts of the cliffs. In contrast *D. aizoides* was found with a significantly higher frequency on climbed cliffs and at the foot of the cliffs which means that climbing even increased the numbers of this plant. This was explained by climbers spreading the seeds, and when cleaning the climbs, cushions and rosettes fell to the talus slope and were re-established because they can put down adventitious roots. This was backed up by the work of Vogler and Reisch (2011) in the Franconian Jura and the Swabian Alb where they compared the number and distribution of *D. aizoides* plants on eight cliffs that had been climbed for the last 50 years with eight pristine, unclimbed cliffs of similar size and aspect. They also collected plants for DNA analysis. This plant was known to be highly sensitive to climbing disturbance (Herter 1996) and is a cushion plant of low competitive ability, highly adapted to the limestone cliff habitat, and very sensitive to trampling or sideways shearing forces. The climbed cliff faces had smaller and fewer plants when compared with the pristine, unclimbed cliffs. On plateau sites species occurred unaffected by climbing. They were significantly less frequent on the cliff faces but more frequent on the talus of climbed in comparison with unclimbed cliffs. The reasons were those suggested first by Wezel (2005). The DNA analysis showed that compared with the climbed cliffs, there were greater genetic differences between plants living at different heights on the unclimbed cliffs. This was attributed to the displacement of plants by climbers who move rosettes down the cliff, displacing genes in the process. This shift in turn reduces the genetic differentiation between the upper and lower subpopulations. This may affect the long-term fitness of this plant species to survive in an environment to which it has become adapted since the beginning of the postglacial period after thousands of years of natural selection.
- Clark and Hessl (2015) from the New River Gorge National River in West Virginia (USA) compared species richness, abundance, and composition of vascular plants, bryophytes, and lichens on 79 pre-established climbing sites and 32 unclimbed control sites across the potential climbing-use intensity and the cliff structure. Differences in species richness and abundance associated with potential climbing-use intensity and cliff structure were variable across the taxonomic groups. Linear models

indicated that cliff angle was the strongest explanatory variable of species richness and abundance for all three taxonomic groups. Potential climbing-use intensity had a small but negative effect on species richness and abundance of vascular plants, no effect on bryophytes, and a substantial effect on lichens. Cliff angle and canopy height and aspect were the primary drivers of species composition. They observed no change in community composition due to climbing, and the fundamental control on cliff vegetation was cliff angle.

- Many researchers as we have seen report that climbing has significant negative effects on the cliff biota, but most of the previous work has not been controlled for variation in micro-site characteristics when comparing sites with and without climbing. Most researchers did not identify either the style or difficulty level of the climbing routes. However, Kuntz and Larson (2006) tried to solve these problems by sampling climbing areas used by advanced sports climbers and quantified differences in micro-topography between climbed and control cliffs. They determined whether differences in vegetation existed between pristine and sport-climbed cliffs when micro-site factors were not controlled. Then they determined the relative influence of the climbing, cliff-face micro-topography, local physical factors, and regional geography on the richness, abundance, and community composition of cliff-face vascular plants, bryophytes, and lichens. When they did not control for micro-site differences among cliffs, the results were consistent with the majority of prior work on impacts of climbing: that is, the sport-climbed cliffs supported a lower mean richness of vascular plants and bryophytes and significant different frequencies of individual species when compared with pristine cliff faces. When the relative influences of micro-topography and climbing disturbance were taken into account, however, the differences in vegetation were not related to climbing disturbance but rather to the selection by sport climbers of cliff faces with micro-site characteristics that support less vegetation. Climbed sites had not diverged towards a separate vegetation community, but they supported a subset of species found on the pristine cliff faces. Marion et al. (2011) also suggest that it is clear that the correlation between fewer plants and climbing impacts does not automatically mean recreation has caused the reduction in plants. They suggest that micro-topographical differences and the climbers' preferences must also be factors.
- In the Baetic mountain range (SE Spain) on limestone, Lorite et al. (2017) studied three climbing sites to look at the influence of a range of qualitative categories of climbing frequency impacting on the vegetation. They looked at low frequency (intermittent climbing), medium frequency (high frequency without overcrowding), and high frequency (high frequency with overcrowding). Within each site climbing routes and adjacent areas free of climbing were selected and sampled by photo-plots obtained by abseiling. The images were then analysed to calculate species cover, richness, and total cover. It was found that climbing negatively affected the cliff vegetation community at all sites. There was a significant decrease in plant cover, species richness, and a shift in community composition recorded, with the cover the variable most sensitive to climbing. The impact observed related to the frequency: low-frequency sites with usually more specialised climbers underwent only mild damage, whereas at the high-frequency sites, the impact was severe, and they suggested that the conservation of the species, especially the rare ones, was jeopardised.

4.5.2 Impacts on Gastropods

When we look at other biota on cliffs affected by climbing, we find impacts too. Baur et al. (2007) in the Northern Swiss Jura found that five out of the eleven snail species were specialised lichen-feeders, and plots along climbing routes had fewer snail species than plots in unclimbed areas. Total snail abundance was positively correlated with lichen species richness, but there was no correlation between snail species richness found. The results show that frequent climbing can change the

lichen community and reduce the snail community on limestone cliffs. A climbing-related reduction of snail abundance may also alter the lichen-herbivore interaction and indirectly change the competitive interaction among lichen species. Ten years later Baur et al. (2017) reported a diverse gastropod community with some rare species in the similar mountain area. They examined the effects of sports climbing and micro-topographical features of the rock faces on the terrestrial gastropods by assessing species diversity and abundance on climbing routes and in unclimbed areas of seven isolated cliffs. They considered exclusively living individuals attached to rock faces. A total of 19 gastropod species were recorded. Six of them were specialised rock-dwelling species whose individuals spend their entire lives on rock faces, feeding on algae and lichens. Plots along climbing routes showed fewer species of rock-dwelling snails as well as other gastropod species than plots in unclimbed control areas. Similarly both the density of individuals and the frequency of occurrence in the climbing route plots were reduced in both groups of snails. This work indicates that terrestrial snail diversity and abundance are suitable indicators for impact assessment.

4.5.3 Climbing Effects on Bird Populations, Particularly Raptors

Cliffs provide nesting sites for some bird species, and disturbance from climbers who are on routes close to nests on both inland and sea cliffs can affect breeding success. However, climbers sometimes cannot avoid birds on cliffs, although one view is that the cliffs are the birds' home, and climbers could be looked upon as trespassers on the birds' territory simply to achieve their quest for adventure. Generally though climbers can coexist without detriment to a bird's breeding success, and it is often stated that it is egg collectors, unscrupulous gamekeepers, overzealous birdwatchers, and photographers who can cause the greatest harm. Climbers are therefore not the only cause of bird disturbance or failure to breed, and sometimes the issues are complex. Hearn (1994) suggested that "climbing probably contributes to the disturbance of sea birds," but we know that there are effects of marine oil pollution and climate change, which might be affecting food supplies. Recreation however can have many documented effects on bird populations, and these are illustrated, for example, in reviews by Buckley (2004) and Steven et al. (2011). These can range from the physiology to immediate behaviour that can be affected, including changes in temperature, heart rate, or stress hormone secretion; changes in foraging, vigilance, and evasion; and changes in reproductive success and/or the number or density of birds where there can be reduced number of nests built and eggs laid—a prospecting bird will not establish a nesting territory at a site which is noisy and disturbed. If continually frustrated, it may abandon the cliff resulting in a total loss of that bird. Climbers can also disturb nesting birds on the way to crags as not all endangered species are cliff nesting but nest on moorland or breed around small water bodies (see Table 4.3).

There have been conflicts concerning birds and climbers, and undoubtedly climbers have affected some birds; there have been documented incidents but relatively few, and climbing restrictions have been placed on many crags during breeding seasons (see the BMC Regional Access Database, the Green Guide to the Uplands, and the excellent traffic light system on the Mountaineering Scotland website which informs climbers which crags had nesting raptors and which crags were safe to climb, and all that climbers need to do is check websites before they

Table 4.3 Birds at risk from climbing disturbance in the UK

Sea cliffs	Cliff nesting	On the way to crags
Auk species, for example:	Chough	Dotterel
Puffin	Peregrine falcon	Fieldfare
Razorbill[a]	Golden eagle	Harriers
Guillemot	White-tailed eagle	Hobby
Kittiwake	Raven	Divers
		Grebes
		Greenshank
		Curlew

[a]80% of the West European razorbill population

go climbing and then change their plans if they spot a nesting raptor whilst climbing; Advice on Disturbance of Birds and Nesting). Nevertheless the climbing restriction system which is in place in the UK and a similar system in the USA seem to work well. Examples will now be discussed using the relationship between the peregrine falcon (*Falco peregrinus*) and climbers in the UK and the USA.

In the UK during the Second World War, the British Air Ministry ordered the destruction of peregrine falcons to protect against losing domestic carrier pigeons. Before 1939 the populations stood at approximately 1050 pairs, and wartime killings resulted in a 13% decrease, but by 1955 the population was restored to 95% of the pre-war figure. However, due to an increase in deaths of homing pigeons, a Peregrine Enquiry was set up in 1960. Instead of finding an abundance of peregrines, the enquiry found a serious decline in numbers. This was due to the use of organochlorines, particularly DDT, and then cyclodiene compounds such as dieldrin and because the peregrine was one of the most seriously affected as it was at the top of the food chain. By 1967 the population had declined to 44%, but there were voluntary and then legally enforced bans on these chemicals by the 1980s. The peregrine is classed as a Schedule 1 species which means it is a rare or endangered species protected by special penalties, and it is a Red Data species, along with the razorbill, chough, and guillemot. Birds can be included in the Red Data Book if the population is internationally significant, a scarce breeder in the UK, restricted in distribution, and vulnerable or of special concern (BMC 1995). By this time the peregrine population was at least 1300 pairs, with the greatest concentration in the Lake District, and currently that area is thought to have the highest density of breeding peregrines in the world. A report by King (1991) was produced for the BMC because it became obvious the birds were nesting in areas that were being climbed and there could be conflicts. In this report 56 occupied crag sites used by climbers were identified in England and Wales which represented between 5 and 10% of the UK peregrine population. At least half of these sites had access restrictions or wardens which minimised disturbance. Only five disturbance incidents had been traced over a number of years, and therefore probably under 1% of the UK peregrine population had been disturbed. Various guidelines though were recommended which we will refer to later. Some of the nesting sites were in the Yorkshire Dales, and this area is popular for climbing on the limestone. There are seasonal climbing bans during the breeding season on several crags, and the use of crag names in guidebooks where peregrines are nesting are only used once the birds have established and restrictions are in place, but certain peregrine sites are not advertised. Guides and BMC restrictions of course give information for egg collectors. Smith (1995) looked at the relationship between climbers and the peregrine falcon in the Yorkshire Dales by means of a questionnaire to 78 climbers. There were some disturbing conclusions outlined: there are restrictions at Malham, Blue Scar, and Great Close Scar, but only 46% of the climbers knew of the Malham restrictions, 38% at Blue Scar, and only 10% at Great Close Scar; some crags that do not have restrictions were thought to have them, so there was confusion related to the knowledge of climbing restrictions; 53% of climbers could not identify the peregrine falcon from bird silhouettes, and the climbers' source of restriction information came from magazines and guidebooks. A good indicator though was 78% of the climbers thought that the restrictions are generally adhered to, but how accurate this figure is in the light of the answers to some of the questions is debateable. Also there were six observations of climbers on restricted routes, and three climbers stated that they had disturbed peregrines in the Dales. Generally though a Yorkshire Naturalists Union representative thought that the climbing restrictions were working well and that climbers have a good attitude towards the restrictions and hinted that some of the birdwatchers were more of a problem. Disturbing a peregrine from the nest can have varying possible effects: eggs and their young are particularly prone to chilling and

dehydration if the parents are kept away from the nest while feathered young, which are not yet ready to fly, can be scared out of the nest prematurely. Time off the nest can be the most dangerous as egg cooling can have a disastrous effect and the distressed birds may not return to the nests at all. 91% of the climbers had a good idea of the harm that disturbances can cause. However, the general conclusion was that more education is needed for climbers with regard to their potential effect on bird populations.

In Southern Europe, Brambilla et al. (2004) noted that breeding success and productivity were lower for peregrine pairs that co-existed alternatively with ravens or climbers, compared to undisturbed pairs. Pairs settled at cliffs simultaneously occupied by ravens and frequented by climbers did not fledge any young which suggested that raven predation on peregrine eggs or chicks may be predisposed by human disturbance. Clearly what was needed was a seasonal ban on climbing.

In the USA the peregrine falcon has been protected as an endangered species under state and federal laws. In New York State, certain climbing routes have been closed by the Department of Environmental Conservation (DEC) during the breeding season in the Adirondacks. It is illegal to climb these routes as falcons are very territorial and will use their razor-sharp talons in defence of their territory, including attacks on humans. Just like in the UK with the banning of DDT, in New York in 1971, efforts began to re-establish a breeding population within the state. The Peregrine Fund initiated this reintroduction programme in 1974 which ended in 1988 with 159 peregrines released. The actual areas of cliffs quarantined have to represent a balance between the recreational climbing interests and the need to protect the nesting and breeding activities, although the priority is to protect an endangered species whilst maximising climbing opportunities at the same time. So individual climbing routes rather than whole cliffs are closed. Climbers have helped by providing Department of Environmental Conservation (DEC) with peregrine sightings which are hopefully accurate and by helping to identify climbing routes which should be closed to protect the birds. The closure of routes is based on a number of factors, and a specific distance from the nest site cannot be used to make a closure determination. At the beginning of the breeding season, DEC closes whole sections, or large portions, of the cliff where peregrines have regularly nested. This allows them to choose a nesting site without being affected by climbers. They often chose a site quickly and begin nesting earlier than when the cliffs were subject to climbing. Climbers benefit because an earlier nesting start results in an earlier fledging of the young, and the closed routes are reopened sooner. At the Devil's Tower in Nevada, 45 climbing routes are affected by closures, and there is also the prairie falcon (*Falco mexicanus*) which occupies a similar niche. At Zion National Park, 13 different routes are closed to protect the peregrine, but the cliffs that do not have nest sites are opened sometimes in late April to early May, and cliffs with nests remain closed until the chicks fledge usually in late July. At the Pinnacles National Park in California, there are peregrines, prairie falcons, and golden eagles. In 2016 there were thirteen pairs of peregrines in the region, eight pairs actively nested, and six nests fledged twenty-two chicks. The failures are not usually due to climbers but are caused by egg predation, often by ravens. In Yosemite there are 14 pairs of peregrines. The peregrine was delisted from the Federal Endangered Species List in 1998, and part of the recovery has been due to the respect that climbers have shown to the nesting sites and the nesting restrictions (Fig. 4.3).

4.5.4 Unusual Potential Impacts on Mammals

The pine marten, which is a rare mammal species in the UK, built a den at the top of a crag on May Rock, near Inverness in Scotland. In April 2015 this resulted in the closure of the *Ephemeral Artery* and *Venus Return* routes on that crag. This was because it is an offence to harm pine marten or their dens. This was an extremely unusual closure for a mammal species.

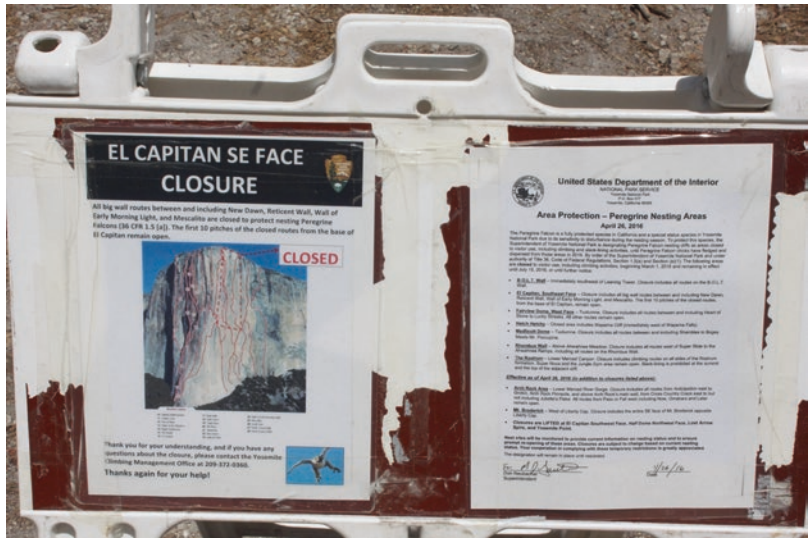

Fig. 4.3 El Capitan (Yosemite) SE face closures due to peregrine nesting areas. Photo by D. Huddart

4.5.5 Overview of the Climbing Impacts on Cliff Biotic Diversity

In a critical review of whether climbing affects and threatens cliff biotic diversity, Holzschuh (2016) indicated that the majority of the published results into these issues may be thwarted by systematic abiotic differences between climbed and unclimbed cliffs. The lack of proper controls may have led to an overestimation of the negative effects of climbing on biodiversity. She suggests that the evidence for the impact of climbing for most taxa is inconclusive. Studies on lichens and vascular plants have described evidence for negative, positive, and no effects as we have illustrated. Gastropod biodiversity seems negatively affected, whilst the evidence for the impact on birds is still lacking. Bryophytes are generally unaffected. She thinks that further research is urgently needed because of the mixed results from previous studies that do not allow final conclusions. Future studies need to select comparable controls for biodiversity comparisons, widen the focus to further cliff-associated taxa, such as micro-invertebrates, and investigate how any climbing effects vary with climbing intensity. This is needed to facilitate improved management of climbing areas that are rich in biodiversity and which contain rare and threatened species. However, it seems extremely difficult to study climbing's potential impacts on the biodiversity as the biggest challenge is to find appropriate unclimbed cliffs to compare with the climbed ones. Cliffs that share characteristics such as slope angle, the amount of sunlight a face gets, the minor geological and geomorphological differences, and so forth are difficult to find. Often all cliffs in a region that are attractive for climbers are climbed, and only cliffs that do not resemble the climbed cliffs in all abiotic characteristics remained unclimbed. If this is the case, then no reliable study can be carried out. The other obvious issue is that there are a limited number of scientists who have the climbing skills necessary to conduct this type of research.

4.5.6 Damage to the Rock

This can occur by chipping and other mechanical wears such as polishing; the impact of chocks, pitons, and bolts; increased rockfall rate; and mainly aesthetic damage caused by chalk and rope wear on relatively soft rocks, like the Wealden sandstones in South East England

Fig. 4.4 Rope damage to Sandstone, Zion National Park, Utah. Photo by D. Huddart

(Fig. 4.4). There are other types of damage which may be considered as acts of vandalism, where graffiti, or what the perpetrators would consider artwork, is painted on crags. This can be removed but with considerable effort and potential damage to the rock.

4.5.6.1 Chalk

Most climbers use white chalk ($MgCO_3$) to dry their hands whilst climbing, but its use is controversial, and it is banned in some climbing areas like the Garden of the Gods and Red Rock Canyon Open Space in Colorado Springs and at the Arches National Park in Utah. This is because its long-term use is thought to damage the rock surface, particularly on porous sandstone cliffs. It is aesthetically unsightly too as it can cause white blobs, blemishes, and stains on darker rock if porous, such as sandstone or some types of limestone. The effects of chalk on plants, lichens, and liverworts still needs further study. It is thought that, although it may change the pH, chalk use generally does not harm the cliff environment. The aesthetic impact can be lessened by either using coloured chalk to match the rock colour or no chalk at all whenever possible. Liquid chalk or other types of drying agent that do not leave a colour because they leave no trace on the rock could be used. One type is Metolius Eco Ball which is a non-marking substitute for climbing chalk as it leaves no visible marks on the rock and has a chalk feel. Many climbers ignore the rules in some areas, and it is difficult to clean white chalk from the sandstone surface, especially since cleaners and solvents may damage the rock and should not be used, and any brushes used should have soft bristles. Some local climber's organisations like the Pikes Peak Climber's Alliance schedule chalk cleaning days every year at Garden of the Gods to scrub the white blotches off the sandstone.

4.5.6.2 Effects of Protection

In traditional and aid climbing, it has been suggested that the placement of protection like nuts causes no damage to the rock (Long 2004), but it seems logical to suggest that this is unlikely to be the case and that climbing does have a weathering effect on the cracks where the protection is placed (Fig. 4.5).

A general rule is to use the largest nut that will fit the crack as it is more secure than a smaller one. Using the largest size that will fit appropriately will exert less pressure on the rock surface. The smaller pieces of gear will concentrate the force on a tiny area making the rock more susceptible to splintering and weathering. The smaller

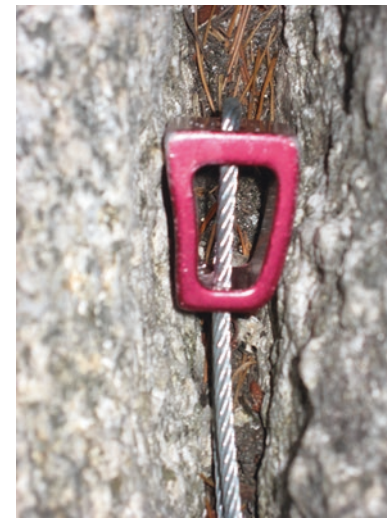

Fig. 4.5 Nut placement. Source: Iwona Erskine-Kellie, Vancouver, British Columbia, Canada

nut will affect a lesser surface area but should put more pressure on it thus eroding the rock surface more, although the larger nut, whilst exerting less pressure, will affect a larger surface area. To try to measure the impact of such protection, Hamilton (2004) adopted an experimental approach but in the field. These experiments occurred on the Fahan Grit on the climbing area known as Rubonid Point on Dunmore Head and on Thur Sandstone on Thur Mountain in County Cavan, both in Ireland. It was found that after 100 repetitions of placing "Wild Country" size 1 and 10 nuts into cracks, weathering did occur. How much weathering occurred depended on several factors that included the type of rock, the rock strength, grain size, and the size and shape of the crack used. Nut movement within the cracks varied between distances of 4 and 127 mm, and the amount of debris displaced from the mechanical action of the nut placement was between 1.66 and 2.19 gm. Additional findings were that there was significant wear to the nuts used and that additional weathering was caused by the swaged cable that had replaced the spectra cord which was originally strung to the chocks. The advantage of this stiff cable is that it allows for easier placement of the nuts.

Aid climbing has resulted in the actual cracks on routes from the placement of pitons becoming eroded, and the climbs have become easier in nature. The original pitons were made of soft iron, and because removal could ruin them, they were usually left fixed in the crack. However, since then the almost indestructible chrome-molybdenum steel pitons have been used. Owing to their repeated placement and removal, the cracks have become brutalised and have ruined more than one climb, leaving large and unsightly scars. Every classic climb in Yosemite was destined to become a string of piton scars, for example, Serenity Crack, until nuts replaced pitons as the common means of protection. The same occurred in the UK and, for example, on Idwal Slabs in Snowdonia where the easy-angled, easy-grade multi-pitch climbs have numerous scars where climbers have used the same placements for running belays and main belays while protecting themselves on classic routes, such as "Faith," "Hope," and "Tennis Shoe." Repeated use of the same placements has in some cases widened the crack and changed the size of the protection that had originally fitted at that location. There were also distinct changes in colour of the rock at the placements to white from beige colour of the rest of the crag. At Idwal Slabs they are very prominent at the bottom of the crag where instructors and belayers have practiced placing nut protection into the convenient vertical cracks (Fig. 4.6A). Here natural weathering morphology can also be seen which seems to have a bigger effect on the dolerite rock than the effects of the climbers (Fig. 4.6B).

There has been a major ethical debate over many years particularly in the USA and the UK over the use of bolts and fixed anchors and how best to create a compromise between the adventure climbers on the one hand and the sport climbers on the other. In some parts of Europe, it is difficult to find natural rock and routes which are unbolted, like in Hungary and Poland. This debate is summarised well in Richards (1997), Achey (2013), and UIAA (2014). It has been argued that bolts prevent cliff-top erosion and tree damage at popular belay stances as we have seen from Tremadog in North Wales, although if it is recommended that descent paths are used, it will create more footpath erosion, and if these are not maintained to a high standard, the climbers will abseil from trees or bolts. It has also been suggested that by following lines of bolts, this can steer climbers away from more vulnerable areas, although this has not been proved. It has been shown too that bolting has increased the attraction of an area like in the Red River Gorge (Kentucky) which has world-class sport climbs.

Within the UK there are policies which govern the installation of bolts and other fixed protections on cliffs. The BMC's position on bolting was restated in 2014. There are crags in the UK which are traditionally bolt-free like the Pembrokeshire and Cornish sea cliffs, the mountain crags of Snowdonia, and the gritstone edges of the Peak District. However, there are many crags across the country where sport climbing is agreed and accepted and even some crags where

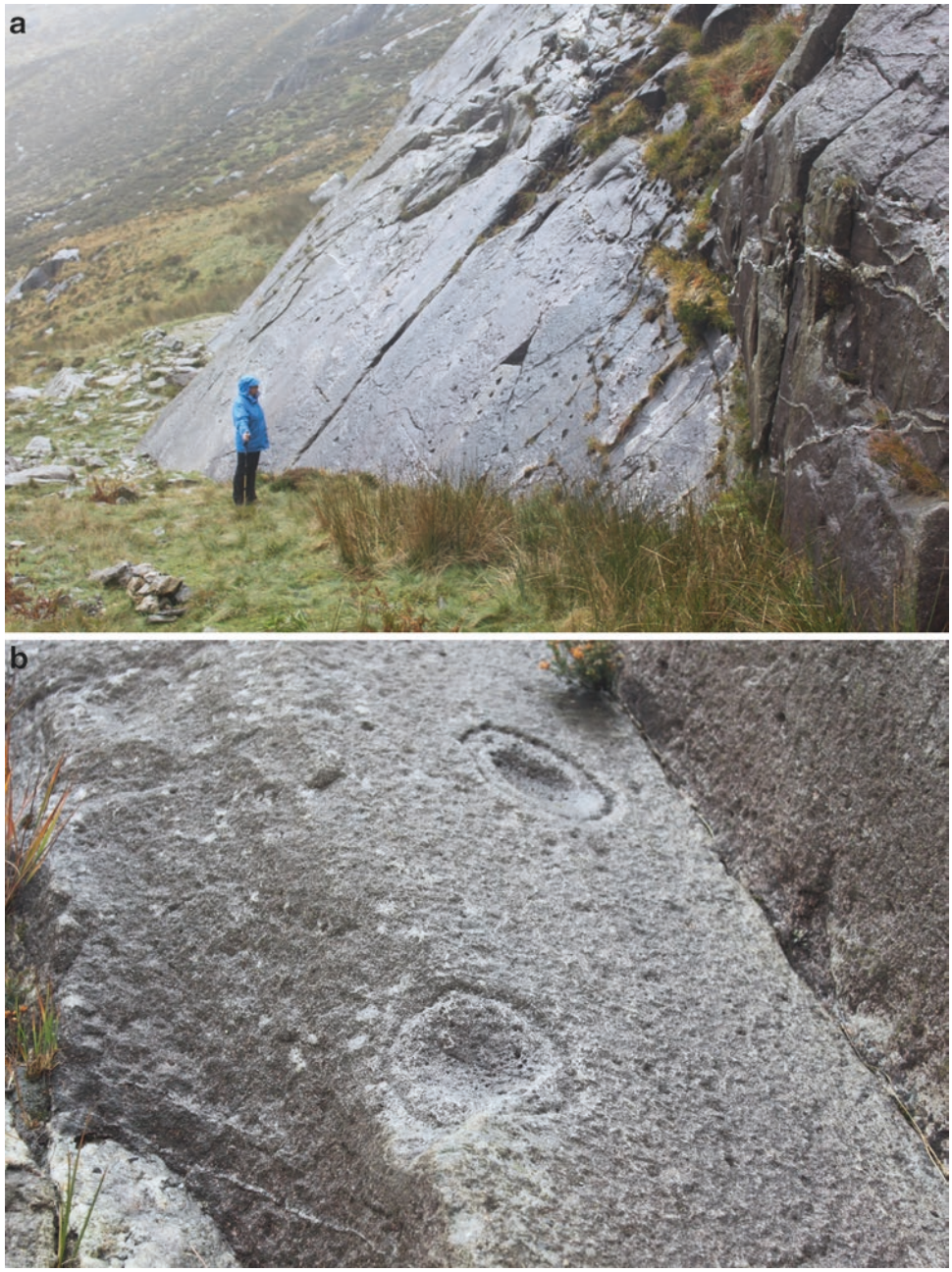

Fig. 4.6 (A) Idwal Slabs (Snowdonia): erosion at base of crag, oblique and vertical jointing, and weathering holes. Photo by D. Huddart. (B) Weathering pits in dolerite, Idwal Slabs, Snowdonia. Photo by D. Huddart

both climbing approaches co-exist. Site-specific regional drilled equipment agreements and proposed change to those agreements must be debated and agreed by climbers at open meetings arranged by the BMC. Proposed revisions to drilled equipment policies and/or retro-bolting proposals should be widely publicised prior to discussion and agreed on a consensus basis. In the case of substantive and potentially controversial proposals to use drilled equipment, wider

consultation should be carried out through the National Council, the BMC area structure, and the BMC's media outlets prior to agreement. In the 1990s the BMC supported some projects on the grounds of "exceptional access and conservation circumstances," such as on Pen Trwyn, Marine Drive, the Great Orme (North Wales 1991), where to reduce the risk to public safety from loose rock on the exits of climbs, over 300 lower-off points were installed as an alternative to a climbing ban from the council. At Wintour's Leap on GO Wall in the Wye Valley (1994), abseil stations were installed as the landowner specified that unless an alternative means of exit from the cliff could be found, instead of the owner's back garden, there would be access restrictions from April to September when family members required full privacy. A final example comes from Stone Farm Rocks, Sussex, where fixed anchor points to be used as belay points were installed because on the very soft sandstone, there was a lack of suitable belay anchors and the rock showed severe grooves caused by rope cutting into the rock in badly positioned belay systems.

4.5.6.3 Rock Damage by Ropes

Where the rock is extremely soft sandstone like the Ardingly Sandstone of the Weald in South East England and the demand for climbing on natural rock is high as the area is close to London, there are bound to be problems related to erosion of the rock caused by climbing. The Southern Sandstone as it is called is probably the most fragile climbing area in the UK and possibly the busiest area, and the ongoing erosion means that holds are constantly changing, routes are in flux, and repairs have to take place on a regular basis to protect the area. The main problem is that the hardened outer surface crust of the sandstone, which is 2–3 mm thick, gets easily eroded by any weighted rope moving over the sandstone which causes a sawing effect, rock groove formation, and permanent damage. At the crag top, this is most obvious as moving top ropes belayed to trees and tree roots well back from the crag edge. Once this crust has been eroded, the underlying sand grains are further eroded by climbing, and some climbers have chipped handholds which are easy to do in this soft rock where the grains are easily detached by minimal pressure. The rock is far too friable and unsuitable for conventional leader-placed protection, so climbs are carried out using a top rope or by soloing, and careful positioning of ropes is necessary. Belay anchors have been installed at the top of most climbs at Bowles, Harrisons' Rocks, Stone Farm, Bulls Hollow, and the Hut Boulder at High Rocks. An interesting ethical conundrum is that at these sandstone crags, natural weathering has produced honeycomb weathering, and there is differential weathering along bedding planes and vertical joints in the rock, and as we will see later in a section discussing management issues, the methods to try and rectify these anthropogenic erosional problems may well be unsuccessful.

4.5.6.4 Rock Polish

This is a rock feature which is widely recognised by climbers and is often quoted in guidebooks. For example, Jones (1993) in the Ogwen Valley in North Wales suggested that on p. 47 "An obvious line which only just manages to attain the grade due to the polished nature of the rock," and the BMC (1996) highlights the polishing of holds on popular routes as a problem at climbing sites. Although climbers tend to favour the more solid rock types which resist erosion, Bunce (1985) believed that geomorphological damage on stronger rock types may occur if crag use intensified which it has in subsequent years, and he quoted the very polished and dangerous rock on Broad Stand (Scafell). However, limited research has been carried out as to its nature. Curry (1997) looked at the impact of climbing on dolerite at Little Tryfan (Tryfan Fach), a crag 50 m high and 200 m long. Generally it is thought that rock polish is characterised by smoothness and glossiness of the rock surface in relation to the surrounding rock surface and edges may also be rounded. It leads to a loss of friction due to the surface becoming smooth. However, Curry (1997) found that there is smoothness but the surface does not necessarily become glossy, but it can be characterised by discolouration of the rock. However, there is no obvious consistency in this colour change, and it must be affected by the original

rock character, but there is rounding off of the polished feature. There also seems to be a gradual reduction in the size of the grains on the polished rock surface. As rock surface weathering usually leads to an increase in surface roughness, it is clear that climbers cause this phenomenon.

4.6 Bouldering and Its Environmental Impacts

There seems to have been a lack of research on any impact of bouldering, but this is strange because this type of climbing involves many of the same types of potential impacts as traditional and sport climbing, such as removal of vegetation and soil, crag base trampling and therefore lowered vegetation diversity, possible effects on gastropods, creation of rock polish, and chipping of the rock. The sport has been growing in popularity, and it is no longer just used as a training regime for climbers, but it is a mainstream recreation activity. However, Tessler and Clark (2016) sampled sites in the Shawangunks (New York). They implemented a paired climbed-unclimbed research design that successfully removed any potentially confounding environmental variation, and so bouldering appeared to have caused the observed differences in vegetation between pairs. Climbed boulders have a lower species richness and cover, with the greatest reduction found on mid-height boulder faces where most climbing seems to occur. Community composition and species frequency did not differ between pairs. This impact is weaker than that reported in most cliff-climbing studies, but the number of climbers and usage at the studied sites is lower.

In some bouldering areas, climbers have modified the rock to create finger or footholds (chipping) or have used epoxy adhesive to prevent friable flakes or lips of rock from breaking off (gluing) and making a problem easier, more difficult, or even impossible. These practices are very uncommon but should be universally condemned by all climbers as it degrades the climbing resource and eliminates challenges for future generations.

The Access Fund (2004) outlines further environmental impacts created by bouldering: paths gradually appear to the individual boulders, and if boulder use is heavy in a popular boulder area, then a weblike trail may link boulders as the boulderers move from one to another. There can be obvious impacts to the base of the boulders, and the soils and vegetation can quickly become compressed; if flat, the vegetation can be eroded, and if on a slope, erosion may occur. Crash pads, whilst they may reduce erosion by distributing and absorbing the force of falls, may damage the vegetation. Bigger issues may occur where there are archaeological remains and particularly rock art on faces. Some federal lands in the USA maintain a 50-foot buffer zone between rock art and climbing/bouldering, but at Hueco Tanks State Historical Park in Texas, there is no minimum linear distance established between rock art panels and climbing routes. Climbing here is simply prohibited directly on, above, and adjacent to these panels.

4.7 Winter Climbing and Its Environmental Impacts

First there needs to be clarification of some of the terms and techniques used in the broad definition of winter climbing. As the name suggests, it involves the use of ice in order to climb inclined, steep terrain, although it is not always the case that winter climbing relies purely on the use of ice for upward progress. It is common that during an ascent of a winter climb, areas that are totally free of ice are climbed; such areas might include snow fields, snow gullies, rock buttresses, frozen vegetation, or a combination of all of these. Generally though, it refers to roped or protected climbing of icefalls and glaciers, frozen waterfalls, and cliffs and rock slabs covered with ice refrozen from water flows. There are two types: alpine ice is frozen precipitation formed in a mountain environment and that usually requires an approach to reach, and water ice is formed from frozen liquid water usually found on a cliff or slab beneath water flows. Mixed climbing is an ascent involving both ice and rock climbing. Progress is made easier by the use of specialist equipment: boots that take crampons,

usually plastic, ice axes for each hand, and crampons and protection equipment like pitons and ice screws. It has the potential to be far more environmentally damaging than other types of climbing because the tools and crampons have the potential to damage rock and vegetation far more than rock boots and chalk.

The climbing techniques used vary according to the type of climbing. Where climbing occurs on snow, climbers step kick combined with the use of the ice axe for support or arrest if the feet slip. Front pointing commonly occurs whilst climbing ice, but in the case of mixed climbing, the techniques are more complex, and there is a combination of techniques, including those from summer climbing. However, there is group of techniques which have developed which are unique to mixed climbing and where most of the environmental damage can occur: (a) torquing is where parts of the ice axe are wedged into cracks by a turning force being applied to them after they have been inserted in the crack. This can cause scratching, widening, and the pulling out of any soil and vegetation from inside the crack. Climbers can chip the rock to make the hold that much more secure. (b) Hooking is where the pick of the ice axe is hooked over an edge or spike of rock which can cause scratching and vegetation damage. (c) Turf placement is where the ice axe pick is driven into frozen soil or vegetation in order to gain some purchase. This frozen vegetation is considered the perfect placement. This has been called tufting where low temperatures cause the soil moisture to freeze and so provides an ideal medium for ice axe placements. Many routes can only be climbed in winter because of the amount of turf on the route line.

Other techniques for protecting climbs and setting up belays are slightly different to those used in summer, for example, many icefalls in the Alps use bolts in the rock at the side of the icefall which can be unsightly especially with tapes and slings attached.

The difficulty and insecurity of winter climbing enhance the potential for the climber to commit acts of environmental damage that they would not dream of in summer: the placement of pegs, pitons, and warthogs (all forms of protection) can cause environmental damage as they have to be hammered in and the effect on the crack is to widen it; the removal of a peg also can cause further widening or extra impact on the rock surface because it requires multidirectional hits with a hammer; they can also be left in situ because they will not come out and are unsightly; crampon scratches on rock and stances are more likely to be potential plant habitats which due to the amount of traffic, even in good conditions, are liable to heavy erosion. Damage potential of front pointing is less in good conditions but can be high, for example, an 80 kg person will apply around 100 kg/mm ^{2} on each of their front points, and this can cause smearing and the production of deep scratches that look unnatural. For example, an account of a new route records the damage done on a single ascent of a new line by Garthwaite and Clarke in December 1993 when they ascended Punster's Crack on the Cobbler, a recognised summer route in Scotland. The ascent left much damage on the soft mica schist. Further damage can be seen on hillwalking paths which regularly become iced or covered in snow in the winter months. An example is the massive scratching and erosion through the Devil's Kitchen in Cwm Idwal (Snowdonia). There are also deep and long scratches on winter ascents of rock climbing classics such as First Pinnacle Rib and Grooved Arête on the east face of Tryfan (Snowdonia). Yet it must be stated that not many kilometres away in Llyn Llydaw, there are many striations and chatter marks caused by ice erosion, and the visual impact is surely not that different. The climbs tend to be on less steep rock which are more likely to have vegetation and in wetter areas like gullies and even on crags that would be ignored in summer, for example, in the Devil's Kitchen. The problems can occur because of the condition of the routes. Where there is plenty of snow and ice, there are no real problems for the flora as all the plants are frozen under a thick snow cover. However, marginal conditions can prove disastrous to sensitive plants, often arctic-alpine rarities which tend to grow best on north-facing slopes where snow lies longest. Also mixed climbing can be undertaken when ice climbs in the same area are out of condition. This

is because it often takes a long period of freeze-thaw for ice climbs to come into condition and ice formation can be unpredictable. All that is needed for mixed climbing is that the turf is frozen, there is snow on the ledges, and there is enough hoar frost (rime) on the walls to give a wintery atmosphere and prevent climbing without crampons. From this it can be seen that mixed climbing may cause considerable damage to vegetation and the soil, considerably more so than snow and ice climbing which theoretically should not be damaging. The route up on ice climbs should cause minimal environmental impact, but the route down can be very different and abseiling down can cause crampon scratching on the rock.

Even when there is good ice, it has been suggested that on busier routes, pick marks can spoil the appearance of the ice which is obvious but cannot be permanent and is just aesthetic in nature. However, it has been suggested that some climbers are upset at the appearance of the route that is made more obvious, and they know that they are not the first up the route as they had perhaps hoped.

As an example of the effects of winter climbing, Thompson (1992) conducted a short experiment on a frozen watercourse on the flanks of Clogwyn Du'r Arddu (Snowdonia) on 9 December 1991. The site chosen was not of any great botanical interest, there was no obvious previous disturbance, and the site is of a similar grade to that climbed by most people and of such difficulty and character that it may be disturbed by the techniques described before in mixed climbing (Grade IV); the climb was only ascended, and the climb was in moderate to poor condition at the start of the experiment and deteriorated to poor after six tramples/climbs. The observations during the experiment were as follows: little disturbance during the initial trample, damage to vegetation/soil significantly increased with successive tramples (the climb's condition was becoming poorer), removal of ice tools caused significantly more disturbance than placement, vegetation incorporated in the ice was disturbed, and pieces of this vegetation and soil were removed. One of the significant factors that will affect the degree to which damage will occur will be the amount of pressure that the climber puts upon the climb, and it is likely that a confident and skilful climber will put less pressure on a climb than a climber of lesser ability. When nervous, there is a tendency to drive the picks in deeper and to kick the front points in harder to create more security, but this results in more pressure, and the climb comes into poorer condition faster and with greater disturbance. Climbers who are pushing in terms of difficulty may cause considerably more damage than climbers who are climbing well within their ability. Three control sites were surveyed immediately adjacent to the trample site and were of a similar nature. The changes that were observed after trampling were that chunks of vegetation/soil were found on ledges, some vegetation was detached from the rock but had not fallen off completely, some areas of vegetation had been disturbed in that the soil was extremely loose and more susceptible to any further shearing in comparison to undisturbed areas, small scratch marks were visible on the rock, and soil/vegetation had been removed from cracks. The lycopodium and sphagnum moss species seemed particularly affected. These were species that grew in drier areas and hence might have been less protected by the formation of ice, and their resistance to shear was less. Future potential damage might be far greater as it is possible that upon subsequent climbing, the effect will be greater than if the area had not been disturbed at all. In addition due to the weakened soil and vegetation, it is more likely that natural erosion will be greater during rapid thaw and high rainfall. If the vegetation could recover is uncertain, but the time scale would be considerable. This crag too has rare arctic-alpine species like the Snowdon lily (Fig. 4.7), which may be in danger due to effects of winter climbing in poor conditions.

A questionnaire survey of 100 winter climbers (Thompson 1992) suggested some interesting results: 81% of the climbers would attempt a route in poor conditions provided that there was no excessive danger suggesting that the climbers were unaware of the possibility of environmental damage or were not concerned by it; 52% suggested

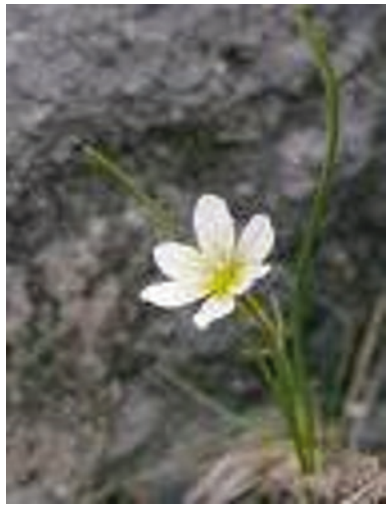

Fig. 4.7 Snowdon lily (*Lloydia serotina*), Clogwyn Du'r Arddu, Snowdonia. Photo by D. Huddart

that they would only climb in good conditions; the 41% who indicated that they would continue as normal but with extra care is a little unrealistic, so despite their good intentions, it may be of little help; 7% would climb regardless. If damage is shown to be occurring as a result of winter climbing, most climbers would modify their activities which may be environmentally good news.

4.8 Management of Climbing

In many parts of the world, there are well-developed voluntary systems to manage climbing activities so that the recreation activity can be maximised whilst the environmental impacts are minimised. For example, the Access Fund in the USA, formed in 1991, exists on a mission to protect climbing access and the integrity of America's climbing areas and represents climber's interests and values. They suggest that 60% of climbing areas are on public land and that these lands are currently being covertly dismantled by Congress and the President and that one in five climbing areas in the USA is threatened by an access issue. The organisation maintains a broad network of partnerships within the climbing community and the outdoors industry and other like-minded advocacy groups. It exists to keep climbing areas open and has bought 52 acquisitions through the Access Fund Climbing Preservation Grant Program and the Access Fund Land Conservation Campaign which has helped preserve over 15,500 acres of land for climbing. In the UK the BMC formed in 1944 is the national representative body for England and Wales existing to protect the freedoms and promote the interests of climbers, hill-walkers, and mountaineers. Mountaineering Scotland is the national representative body and membership organisation for those who live in Scotland or enjoy Scotland's mountains. It encourages participation and progression in the mountain activities we have discussed and promotes safety and skills, campaigns to safeguard access rights and responsibilities, and seeks to protect Scotland's mountain landscapes from insensitive development. As can be seen, there are political dimensions too and many government organisations manage much of the climbing areas in the USA, so there has to be liaison between all these organisations and the climbers.

4.8.1 Management Plans

In the USA this has resulted in the management of climbing through management plans, like the New River Gorge National River in West Virginia (NPS 2005). This centres on over 1600 climbing routes along extensive cliffs and is one of the largest climbing locations in the Eastern USA. This plan was published in 2005 because of increasing popularity of climbing in this area, the more obvious impacts, and the conflicts between commercial use groups, non-profit groups like scouts, and individual climbers. The purpose was to present a strategy that protected the natural and cultural resources whilst continuing to provide opportunities for a high-quality climbing experience. The plan was to meet the following objectives:

1. To create a management tool to adequately address resource protection and visitor use issues related to climbing.
2. To build partnerships with climbers, climbing groups, and commercial organisations in managing climbing.

3. To provide guidance on managing commercial groups.
4. To maximise input from the public and the climbing community throughout the planning process.
5. To provide a forum for public involvement and collaboration—this was a crucial aim. The National Park Service (NPS) considers the long-term partnership with climbers and other interested parties to be a crucial component of an effective climbing management plan. The plan gave three alternatives for climbing management: the alternative (A) or the no-action alternative would continue with the existing management; the alternative (B) which is the preferred NPS option would involve climbing management, including education and outreach efforts, improvements to facilities, and the use of new and existing trails; the alternative (C) is similar to (B), but concession contracts would be required for commercial use, and there would be a more restrictive, pre-emptive closure for peregrine falcon nesting on Endless Wall. A detailed inventory of the environmental consequences and their intensity with the three alternatives is discussed. There are several appendices and one on ethics and education which is excellent and another on various aspects of research. There were opportunities for individuals and organisations to respond to the plan.

Early example of the way in which the NPS established the management direction and actions was the Devils Tower National Monument Final Climbing Management Plan (1995, updated 2006) which was a precedent-setting management plan between the NPS, climbers, and Native Americans. At least six Northern Plains Indian tribes had long considered the site to be a sacred place for meditation, offerings, sweat lodges, and ceremonies, particularly important in June, and they would have liked a complete climbing ban. The 1995 plan aimed to preserve cultural values and climbing opportunities by establishing a "voluntary closure" to climbing during June each year which was a compromise with climbers (see the detailed background to the case in Cross and Brennenan 1997). Although climbing has been reduced by about 85% in June since the adoption of the plan, there has been a recent increase in June, and if climbers do not respect this partial closure, it is feared that there well may be a total ban eventually. The current plan also provides direction for management of resource impacts associated with climbing, including fixed anchors, trails, chalk, slings/webbing, and restrictions to protect wildlife.

The Wichita Mountains Wildlife Refuge produced a Final Environmental Assessment for Technical Rock Climbing (1995) which gave a general appraisal of environmental effects in a climbing area and evaluation in relation to impacts from other recreation types. It provided a model for dealing with fixed anchors, permissions for new routes, and fixed anchor replacements in a USFW refuge. The Chickamauga and Chattanooga National Military Park Final Climbing Management Plan (1998) was an early example which closed some routes, authorised placement of bolt top anchors below the rim of mountains to protect summit vegetation and soils, set group size limits, directed park staff to analyse the potential for use fees, urged voluntary trailhead registration by climbers for monitoring purposes, and prohibited new fixed anchors and the use of power drills without NPS approval. Other examples of climbing management within planning documents are the Joshua Tree National Park (2000), Rocky Mountain National Park (2001), Denali National Park and Preserve (2006), and Zion National Park plans (2007). In the Arches National Park, there was a combined Canyoning and Climbing Plan (2013b). Within the Shenandoah National Park plan (NPS 2010), there was a set of climbing guidelines, but for all the national parks in the USA, guidance is given in Managing Climbing Activities in Wilderness (NPS Reference Manual # 41, 2013a). Over the years there has been much discussion over the use of bolts, anchors (see the United States Forest Service policy for anchors and the heated discussion that this generated), drilling, dry tooling, and the impact of sport climbing in both the USA and UK, and

the ethics of climbing seems to have gradually changed from the original traditional climbing ethics to a more liberal and environmentally insensitive set of ethics based around sport climbing. In the light of increasing bans of fixed climbing anchors in American parks, Jones (2004) examined the visual impacts of rock climbing in the Rock Canyon Park, Provo (Utah). Using photos he examined the views of both climbers and non-climbers and found there were no significant differences between anchors only, anchors and chalk excluded factors, the chalk only factor, or between climbers and non-climbers. This seemed consistent with the results of Schuster et al. (2001) who found that the traditional sport climbers perceived that managers had little understanding of climbing as an activity and that resources were often micro-managed as a result.

4.8.2 Memorandums of Understanding or Agreements

In the USA there have been several examples of memorandums of understanding or agreements which are written frameworks that establish cooperative relationships between two or more parties that define the common interests that parties share and define the way they will work together to reach common goals. A good example is the MOU between the Wichita Mountains Climbers' Coalition and the Department of the Interior US Fish and Wildlife Service, Wichita Mountains Wildlife Refuge. Here the Climbers' Coalition will provide volunteer assistance through an advisory bolting committee; educate and inform the climbing community about conservation issues, resource protection, leave-no-trace ethics, and stewardship philosophy; assist refuge managers in monitoring the effectiveness of the FWS rock climbing management plan; maintain all climbing areas free of rubbish or abandoned equipment; remove excess chalk from the rock as needed; and work in partnership with the FWS.

4.8.3 Liaison Groups

In the UK there have been established liaison groups for various climbing areas with representatives of all the interested parties, for example, landowners, local clubs, the BMC, guidebook writers, and Natural England so that management can be integrated. There are regular meetings so that there can be a discussion of all relevant issues.

4.8.4 Closures

There have been closures of some climbing cliffs and routes, for example, on the famous arch landforms in the Arches National Park (Fig. 4.8), in Monument Valley, and Canyon de Chelly in Arizona. The latter two have been for cultural reasons, and there has been a complete ban on climbing on Cave Rock in Nevada from 2007 which is a sacred site for the Washoe tribe, and all the bolts were removed by 2009 (see a detailed discussion of this case in Makley and Makley 2010).

4.8.5 Seasonal Restrictions

There have been many seasonal restrictions in the USA, mainly for raptor breeding which are well publicised and generally well respected by climbers. In the UK the BMC has excellent relationships with many conservation and countryside organisations, and it supports reasonable restrictions and recognises the great importance of certain cliff and mountain areas for bird breeding. In the UK, there are well over 160 individual sites in England and Wales that have restrictions to protect sensitive species. Access agreements depend on the species, numbers, and distribution of birds present, but most apply between February and mid-August, but there are variable restrictions at some sites, and some restrictions are lifted if birds do not nest on certain crags. These types of restriction are best because they offer protection for birds but a greater freedom and flexibility for climbers. An example of the restrictions can be given from the island of Lundy where restrictions are in place between 1

Fig. 4.8 Landscape Arch, Arches National Park, Utah. Closure of all climbing routes in this national park on arches. Photo by D. Huddart

April and 31 July, but of the over 100 climbing areas listed in the guide, only 71 have climbing restrictions in this time period and many cliffs are unrestricted. A number of classic climbs have been left open even though they are near to bird colonies, and it is important that there is no encroaching onto nearby restricted climbs or doing anything that causes disturbance to breeding birds. Sometimes because of late fledging, climbs can be closed after 31 July, and checks have to be made with the warden. Care has to be taken that access routes to open climbs do not go through restricted areas. In the UK too, climbers need to be aware of the Wildlife and Countryside Act (1981) and the Nature Conservation Act (Scotland) (2004); the Conservation Regulations (1994) implements the Council Directive 79/409/EEC on the conservation of wild birds (the "birds directive") and the Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna (the "habitats directive"). Climbers need to know that it is an offence to interfere with the nest of any wild bird or obstruct a bird from using it and that certain birds which are rare or endangered have increased levels of protection and penalties for abusing them. This Schedule 1 status means it is an offence to disturb these birds whilst they are building a nest, are near a nest containing young or dependent young, and even when they are away from the nest. It is also an offence to uproot any wild plant, and on National Trust, land digging, cutting, injuring, or taking any soil or plant is against by-laws. In some areas like in National Trust in Cornwall, seasonal restrictions operate in the vicinity of all known seal pupping caves in September and October.

4.8.6 "Remote Areas"

Some areas of cliff could be designated or scheduled as "remote areas" as in the National Trust policy for Pembrokeshire and in Cornwall. This means minimal recreation use, no facilities like car parks, and no promotion, although climbers will be welcome to find and use these areas by their own initiatives, but with the extensive use of the internet and social media, it is doubtful if this lack

of promotion is very successful in deterring climbing. No promotion means no publication in guidebooks, so close liaison is required with editors and writers.

4.8.7 Rerouting

There can be management of the descent routes from crags down the gullies which can be temporarily closed for recovery; the routes can be rationalised and rerouted as appropriate or feasible, for example, erosion control was carried out by the BMC at Harrison's Rocks, Stone Farm and Cadshaw Rocks in 1996, and at Stanage more recently.

4.8.8 Use of a Star System in Guidebooks

It is possible that climbs which have been badly damaged could be closed so that recovery if it occurs could be studied and new climbs might not be publicised without reference to the liaison group, but this type of policy has not really taken place. Use of certain climbs though could be discouraged by some agreed means like the star system could be taken out of guides, climbs could be taken out of the next guidebook edition, or some explanatory text could be included in certain areas which have been identified as vulnerable, like Gurnard's Head, Cornwall, or there is a need for a strong conservation message. The Climbers Club took the controversial decision at the time to omit the star-rating system from the new Tremadog guide, arguing that the three-star routes were eroding too quickly. An argument from James and Wightman (2003) from the Rockfax guides was that the principle of attaching a single star to any climb that is worthwhile was a useful principle. This is because it in turn provided 75–85% of the routes at a crag with stars and therefore attracted climbers to that percentage of routes and so may spread the rock weathering load. These arguments related to stars in guidebooks, and whether they are useful in controlling rock damage and erosion seems a little irrelevant because it is likely that there are many reasons why climbers chose to climb where they do, not just guidebook information.

4.8.9 Booking or Permit System

There may well be limits imposed where there is overcrowding or damage is occurring. This could be a booking or permit system for both individuals and groups. For commercial use there could be a charge for group use and an annual licence system in place. Car park management can play an important role in limiting numbers. Certain crags might be regarded as sacrificial crags, used especially for beginners, group use, like with the scouts and the army, and for commercial groups, for example, Idwal Slabs in Snowdonia.

4.8.10 Outreach and Education

Generally as part of a management plan and policy, there has been an important role for outreach and education, not only to the general public but in this case to the individual climbers, climbing clubs, and other organisations. This may be through close liaison where climbers have been involved in close partnerships with land managers, often to the mutual benefit of both parties. In the Potomac Gorge final report, Marion et al. (2011) suggested that in some instances, it may be possible to alter climbing routes to avoid impact to rare plants. The removal or addition of anchor bolts and/or alteration of climbing guides, which include descriptions and photos or diagrams of each climbing route, can accomplish this. While most climbers own and consult climbing guides, on-site signage may also be necessary to inform all climbers of climbing route changes. Attarian and Keith (2008) note that the strategic placement of fixed anchors on the cliff face can also be used to protect trees or vegetation communities by diverting use away from them. For example, this was done in North Carolina state parks and at Sunset Rocks, Tennessee, in the NPS Chickamauga and Chattanooga National Military Park. They also suggest targeted outreach on species recognition

and avoidance practices and individual climbing route restrictions. Collaborations with climbers and the authors of climbing guides are critical to the successful application of this strategy.

Within the Potomac Gorge, climbers have generally used natural anchors rather than fixed protection. However, Marion et al.'s (2011) survey did reveal the presence of older pitons, top and face bolts, and other mostly historic artefacts. Cliff-top trees are numerous and provide the most commonly used anchor. While abrasions to tree bark and small limb cutting are common, their use as anchors rarely causes damage that is more deleterious (but see earlier in this chapter). Nevertheless, if trees are used, one recommended low-impact practice is to install webbing slings around trees to avoid trampling damage and impacts from the repeated wrapping and unwrapping of ropes around the base of trees. If used, periodic inspections are necessary to replace webbing that has deteriorated from exposure to the sun.

The trampling and loss of ground vegetation and organic litter cover and soil around trees used as anchors are perhaps more significant forms of visitor impact. Such impacts could affect rare plants, and the removal of vegetation and organic litter substantially increases the rate of soil drying and loss and may increase tree mortality during severe droughts. The installation of bolt anchors just below the cliff top is an effective management practice that avoids impacts to trees and adjacent vegetation and soils. According to Attarian and Keith (2008), strategic bolt placement is increasingly being used by land managers to protect sensitive resources such as cliff-edge vegetation, soils, and specimen cliff trees.

Another low-impact practice is the placement of permanent bolt anchors at carefully selected, impact-resistant abseiling stations, allowing climbers to descend the cliff without using steep descent trails (which often have vegetation and easily eroded substrates). Substituting an abseil station in a location with naturally barren rock at the top, bottom, and along the intervening cliff face will result in less environmental damage than the same traffic on a descent trail, which generally has soils and vegetation. One abseil station can generally service a cluster of climbing routes. Such stations have been successfully implemented at the New River Gorge National River, WV; Shiprock, NC; and other areas (Attarian and Keith 2008). Alternately, descent trails can be stabilised by rockwork, which can also channel traffic around vegetation.

4.8.10.1 Provision of Information

There have been many attempts to produce leaflets, booklets, guides, codes of conduct, advice through websites, signage (Fig. 4.9), and recently from 2015 the Rock Project Tours to help reduce environmental impacts related to climbing and to promote climbers who are stewards for the climbing resources and responsible users of those resources. The biggest problem is the lack of research to indicate which methods of education and outreach can be most successful in these attempts.

BMC's Tread Lightly Booklet

An early attempt in the UK was the BMC's Tread Lightly booklet *Conserving Britain's Mountains and Crags* (1988), published with the financial support from the Nature Conservancy Council. It was thought that much of the damage and disturbance can be reduced by encouraging a minimum-impact approach to recreation: to climb the rocks and wander the hills yet leave no trace of our passing; that should be the aim. With regard to climbing, it was suggested that climbers should find out about and respect any restrictions placed on climbing for the protection of birds, animals, and plants; always keep gardening to an absolute minimum, especially when opening up new crags; be particularly careful not to damage vegetation when climbing in gills and gullies and keep to the gully floor where possible; try to minimise impact on the rock with no paint or scratched routes and leave no graffiti; not chip handholds; avoid placing pegs or bolts whenever possible (do not remove in situ belay pegs or bolts); avoid leaving any slings hanging from the crag; try to keep chalk use to the minimum; and, when climbing in winter, keep to well-frozen routes and avoid climbing at the start of a general thaw.

Fig. 4.9 Signage at Harrisons Rocks, South East England: information related to climbing etiquette. Photo by D. Huddart

Green Guides

The Green Guide was compiled by the BMC, the National Trust, English Nature, and the Land's End Climbing Club. These groups represent a wide range of interests with different issues that can affect the cliff environment, and possibly this means a more workable and balanced strategy for conservation. The following quote is taken from the Chair Ladder guide to Cornwall (Hannigan 1992), and this type of guidance needs to be more widespread if our natural environments are to be preserved. The attitudes promoted and specific information regarding the protection of particular species are publicised in the Green Guide, and it needs to be written into all guides concerning outdoor recreation: "Individual climbers, instructors and climbing schools are asked to react positively and helpfully to the aims of the National Trust in these matters. Response should include making personal judgements about whether or not to climb established routes in obviously eroded areas, on in fragile plant and bird habitats. Climbers wishing to establish new climbs should also think seriously about the impact of gardening, excessive rock removal and intrusion on ecologically vulnerable sites." Such responses should extend to all cliff areas whether or not they are owned by the National Trust (Hannigan 1992). The BMC has published Green Guides to the Lake District (Green Climbing guide) and the Yorkshire Dales, the Green Guide to the Uplands (2009), the Green Guide to Groups of Climbers (2015), and the Crag and Habitat Management Green Guide, all of which can be downloaded from the BMC website. The BMC have also established the Cwm Idwal Winter Climbing Information Project (2013) which gives live information on winter conditions on the BMC website from the Devil's Kitchen and Clogwyn Du'r Arddu. A remote sensing station was installed at a rock bluff below the cliffs of the Devil's Kitchen, and this generates live data and records the air temperature and the temperature of the ground at 5, 15, and 30 cm in the turf. This complements the BMC's North Wales White Guide (2011) which can be downloaded from the BMC website. Further live information on Lake District winter conditions can be obtained at Great End that is monitored at 750 m in a similar way. This information complements the Lake District winter conditions guide (2015).

Leave No Trace

The Leave No Trace Centre for Outdoor Ethics strives to educate all those who enjoy the outdoors about the nature of their recreation impacts as well as techniques to minimise such impacts. It is best understood as an ethical and educational programme not as a set of rules and regulations. It was created in the 1960s by the US Forest Service and became increasingly necessary as land managers witnessed the biophysical effects of increasing use. By the mid-1980s, the Forest Service had a formal "no-trace" programme emphasising wilderness ethics and sustainable travel and camping practices. The success of this programme led to cooperation between the Forest Service, NPS, and Bureau of Land Management (BLM)'s authorship of a pamphlet called "Leave No Trace Land Ethics." In the early 1990s, the Forest Service worked with the National Outdoor Leadership School (NOLS) to develop hands-on, science-based minimum-impact education training for non-motorised recreation activities. An outdoor recreation summit in 1993 created an independent, non-profit organisation called Leave No Trace Inc. (now the Centre). In 1994 the Centre entered into a series of MOUs with four federal land management agencies, and in 2007 the National Association of State Parks Directors developed a formal affiliate partnership to expand the possible use of the Leave No Trace programme on state park lands. Major programme development has taken place focusing on providing quality Leave No Trace education whilst broadening the programme's reach by including a Travelling Trainer Program consisting of mobile educators that travel throughout the USA teaching Leave No Trace and providing support at the local level. In 2007 a mobile summer educational programme called the "e-tour" was added to the educational offering, and in 2011 a seasonal team for Colorado was added; added also are a youth programme called PEAK (Promoting Environmental Awareness in Kids) that reaches over 150,000 annually with direct programming, frontcountry and urban-based Leave No Trace programmes and training for state and city natural areas and parks, community-based initiatives, including local and regional educational events, and volunteer opportunities coordinated by a State Advocate Network. Lots of educational materials have been produced, like the skills and ethics booklets *101 Ways to Teach Leave No Trace* and Marion's (2014) book *Leave No Trace in the Outdoor*, and courses like the Leave No Trace Youth Program Accreditation and five-day master educator course and workshops that run from one hour to two days.

Access Fund Projects

The Rock Project Tour is part of the Access Fund's mission to keep outdoor rock climbing areas open and protected. They do this by working to engage the climbing community and activate positive social norms, backed by consistent educational content, messaging, and programming that are specific to regional access issues and environmental concerns. It is ultimately climbers that are stewards and responsible users of the outdoor climbing resources, and they have to promote a positive identity for themselves and climbers as a whole group of recreationalists, mitigating the threats to access. The Rock Project is at the centre of this movement. To achieve this, climbers will be presented with the Climbers Pact which is a promise or covenant between climbers to practice a set of responsible outdoor ethics that protect climbing access. The pact outlines ten responsible outdoor behaviours in order to protect climbing access: commit to your fellow climbers to be considerate to other users; park and camp in designated areas; dispose of human waste properly; stay on trails wherever possible; place gear and pads on durable surfaces; respect wildlife, sensitive plants, soils, and cultural resources; clean up chalk and tick marks; minimise group size and noise; pack out all trash, crash pads, and gear; learn the local ethics for the places you climb; respect regulations and closures; and use, install, and replace bolts and fixed anchors responsibly. This is a national programme to encourage and inspire responsible outdoor climbing knowledge to protect the places they climb through responsible, low-impact climbing behaviours; be an upstander, not a bystander. The Access Fund

will work closely with Black Diamond and other leaders in the climbing community to build and distribute educational content through a web-based tool box that aggregates existing and newly developed educational materials, programming, templates, exemplar case studies, and community contacts.

Codes of Conduct

There have also been educational resources published by climbing organisations to act as codes of conduct in special circumstances like the Southern Sandstone Code of Practice (BMC) to try and prevent erosion of the soft sandstone (Table 4.4).

Bouldering and Climbing Conservation Codes

There are several bouldering and climbing conservation codes published by the BMC, such as A Code for Winter Climbers (n.d.-a), the Lake District Winter Climbing code (n.d.-b), the Sandstone Bouldering Ten Commandments (2017) which provide excellent advice to help preserve the rock and vegetation and are taken from Panton (2017). Other codes include the BMC's Crag Code (2007) which included "do not disturb livestock, wildlife or cliff vegetation, respect seasonal bird nesting restrictions"; the Mountaineers' Climbing Code (2014) included "behave at all times in a manner favour-

Table 4.4 Southern Sandstone Code of Practice (after the BMC)

Setting up a belay
At Bowles, Harrison's, Stone Farm, and Bulls Hollow, belay anchors have been installed at the top of most climbs. Do not thread the climbing rope through these, but set up a non-stretch belay. Use a static belay rope of 11 mm diameter. A convenient length would be 5 m, and it is also useful to have a longer belay rope of 12 m when there is no anchor and you are using a tree some distance back from the top of the crag. Putting a permanent sleeve around the knot just above the karabiner helps to protect both the knot and the rock. Alternatively, tape slings can be used. Note: the bolts are only to be used for top-roping
When setting up a belay, adjust the height of the karabiner to hang far enough over the edge of the crag so that the climbing rope will not touch the rock. Moving or stretching ropes should never come into contact with the rock. The sawing action destroys the weathered crust and cuts deep grooves in the top of the crag
On an isolated buttress, the first member of a party will usually have to solo to the top. Do not throw a rope over the buttress from the ground
Footwear
Wear light soft-soled footwear. If you do not have specialist rock shoes, lightweight gym shoes are the best. Clean your shoes before starting each climb
Descending
Walk off after completing a climb, do not lower off or abseil. On isolated buttresses all members of a party except the last should down-climb on a slack rope, and the last member should solo down
Climbing style
Top-roping and soloing are the only acceptable methods. A non-stretch belay should be used. Do not use pitons, bolts, nuts, camming devices, or any sort of leader protection
Choose a climb of the right standard. Please do not spend a long time "working" a climb that is too hard
The preferred ethic is not to use chalk. Please keep the use of chalk to a minimum. Do not use resin powder. Avoid cleaning holds if possible, but if cleaning is essential, do it gently with a very soft brush
Sandstone is softer when wet, and climbers must exercise caution by avoiding sharp or fragile holds and ensuring good footwork. If it is wet, why not embrace the opportunity to explore the wonderful cracks and chimneys on offer
Never climb with axes and crampons, even on the rare occasions when ice forms on the rock
Camping
Do not camp, bivouac, light fires, barbecues, or stoves near the crags. There is a campsite next to the car park at Harrison's Rocks. There is a fire area and in situ BBQ at the car park
Additional notes for leaders of organised groups
Please avoid the most popular climbs at weekends, particularly Sundays. Limit the time your group occupies a climb or a section of the crag. Remove ropes when you have stopped using a climb. Choose climbs to suit the ability of the group. If members are having trouble on a climb, their feet will slip repeatedly causing rock erosion, and additionally a weighted rope is likely to cause damage to the rock. Try something easier

(continued)

Table 4.4 (continued)

Abseiling
Please do not abseil at any Southern Sandstone crag. The top of the crag fragile holds on the face will be damaged. Abseiling is not permitted by the owners of the major outcrops
Malicious damage
Unfortunately this still happens from time to time, for example, graffiti, chipping new holds, or enlarging existing holds. If you see anyone doing this, please stop them
Ground erosion
Use established descent paths. Step on rock rather than earth, and avoid treading on vegetation if possible
Trees and vegetation
If there is no belay anchor, it is usually necessary to belay to a tree. Tie the belay rope round the tree as low as possible to minimise leverage. Please do not cut down or prune trees. Do not use herbicides for clearing vegetation from the rock. Regrowth will occur, and it will be the commonest species that recolonise, the rare species being eliminated

ably upon mountaineering, including adherence to Leave No Trace principles and the erosion; respect our wild neighbours and follow our rock climbing ethics." If climbing clubs adopt a crag, then this helps the environment by cleaning up litter, graffiti, and chalk and imbues the correct crag stewardship that needs to be fostered in all climbers and models behaviour by taking the time to educate others (see Organising a Successful Adopt a Crag p5 Vertical Times volume 97, Access Fund 2013).

Concluding Remarks

One obvious conclusion is that instead of encouraging climbing in the mountain environment, we should continue to foster the recent trend where there has been an explosion of indoor climbing, artificial climbing competitions, and even artificial ice climbing. The latter is especially the case with global warming inevitably meaning a decline in resources outdoors for ice climbing and a search to higher and more northern regions for decent climbs in condition. For artificial ice climbing, there are currently indoor resources at, for example, Winona Ice Climbing Park at Sandstone, Minnesota; Lake City Ice Park, Colorado; Stone Gardens, Seattle; Spire Climbing Centre, Bozeman (Montana); Hukawai Glacier Centre in Franz Josef (New Zealand); O2 World in Seoul (South Korea); Ice Factor (Kinlochleven) and Snow Factor (Glasgow) in Scotland; and even Vertical Chill in the basement of Ellis Brigham's shop in Covent Garden, London, and Kong Adventure in Keswick (Lake District). It is even possible to use Nicros FoamIce panels which can allow ice climbing indoors on simulated ice. However, to get the best of both natural environments and guaranteed ice climbing, there is nothing to beat the Ouray Ice Park in the San Juan Mountains (Colorado) which opened in 1995, and each November until spring, ice farmers spray water down the canyon walls of the Uncompahgre Gorge and create over 150 man-made ice and mixed climbs in 11 distinct climbing areas. All the climbing is free and is very close to the town of Ouray. Of course there literally are now hundreds of artificial climbing walls, for example, Basecamp in Reno (Nevada) and Holdistic in Edmond (Oklahoma), to cater for the needs of sport and climbing wall enthusiasts.

Education and appropriate stewardship are the keys to conserve the climbing natural environment. We need much more further research and much more education for the public and the climbing community about the impact of this recreational activity and a restriction of access to the more pristine cliff communities which means better management of the activity

to the benefit of both conservationists and climbers. The more liaison there is between the climbing community and the land managers, the better will be the end product for both parties. However, Carr (2007) suggested that climbing areas have no avoidable impacts, rather the impacts are unavoidable, such as trampling and erosion, and that improvement efforts at climbing sites may have to focus more on site hardening and actions to spatially concentrate climbing activities. He thought there should be less emphasis on climber education. This generally is not an accepted view, and a combination of outreach, education, and site management is the way forward. Baur et al. (2017) suggested that any management plan should contain a comprehensive information campaign to show the potential impact of intensive climbing on the specialised flora and fauna with the aim of educating the climbers so as to increase their compliance with any management measures. There are doubts too as to how much damage climbers really cause the natural rock, and compared with natural processes such as slope processes like rockfall or glacial erosion, the impacts appear trivial. There have also been some doubts expressed related to the impact of climbers on natural vegetation, and more research is needed to establish the truth. Seasonal closures of climbs appear to have been successful for the breeding bird populations who use the cliffs, and climbers and other factors may well be having bigger impacts on seabird populations. It seems likely that the educational materials and outreach programmes that have been evident in the last ten years have helped enormously in producing a more environmentally aware climbing population who has a greater concern for the stewardship of the mountain and crag environment.

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