*J. Mar. Biol. Ass. U.K.* (2005), **85**, 263–268
Printed in the United Kingdom

# The influence of visitors on intertidal biodiversity

Eunice H. Pinn*† and Michelle Rodgers

School of Conservation Sciences, Bournemouth University, Fern Barrow, Poole, Dorset, BH12 5BB, UK.
*Present address: Joint Nature Conservation Committee, Dunnet House, 7 Thistle Place, Aberdeen, AB10 1UZ, UK. †Corresponding author, e-mail: eunice.pinn@jncc.gov.uk

The Purbeck Marine Wildlife Reserve lies within the boundary of the Dorset and East Devon World Heritage Site on the south coast. This study investigated the influence of visitors on intertidal biodiversity at Kimmeridge Bay, the only accessible part of the reserve. The assemblages present on two rock ledges were compared: Washing Ledge, which is regularly visited and utilized by people, and Yellow Ledge, which is more isolated and visited much less regularly. At each ledge, three habitat types were investigated: open rock, rockpools and the fucoid zone. Multivariate statistical analysis revealed significant differences in assemblages between ledges and among habitat types. The differences observed in the communities of the two ledges can be explained to some extent by natural ecological processes, but human impacts were also detected. The most obvious contrast associated with trampling was a reduction in the larger, branching species of algae and an increase in ephemeral and crustose species in the more heavily utilized areas.

## INTRODUCTION

Tourism, educational visits, and other forms of recreation create disturbance and can damage rocky shore habitats. Paradoxically, in conservation areas where public access is encouraged to promote awareness of marine wildlife, these impacts can be particularly heavy (Fletcher & Frid, 1996). When people have been excluded from rocky intertidal shores, some of the changes recorded have been dramatic. For example, in Chile, there was an almost complete transformation of intertidal communities in only a few years from a monoculture of mussels to a more diverse community dominated by barnacles when people were excluded (Durán & Castilla, 1989). In general, the trampling of shores by humans has been found to reduce the abundance of organisms such as macroalgae, molluscs and barnacles (e.g. Ghazanshahi et al., 1983; Povey & Keough, 1991; Brosnan & Crumrine, 1994; Keough & Quinn, 1998; Eckrich & Holmquist, 2000; Jenkins et al., 2002).

On a global basis, the purposes of marine protected areas are extremely varied (Carr, 2000). These range from safeguarding nature, species protection and the protection of threatened environments to fisheries protection and tourism. There are often very few restrictions on human access within marine protected areas. The reserve or park status can also act as an attractor and may, therefore, lead to the degradation of the very resource it was set up to protect (Brosnan & Crumrine, 1994; Keough & Quinn, 1998).

### *Purbeck Marine Wildlife Reserve*

Purbeck Marine Wildlife Reserve is a voluntary marine nature reserve (VMNR) and has been described as the UK's 'flagship' VMNR. It was designated in 1978 and attracts over 100,000 visitors per year (Gubbay & Welton, 1995). Today, the reserve lies within the Dorset and East Devon World Heritage Site, designated in 2001.

The land surrounding and including Kimmeridge Bay is owned by the Smedmore Estate, a private family estate, which also owns the toll road leading to the bay. The western part of the reserve is controlled by the Ministry of Defence and is generally inaccessible to the public (Gubbay & Welton, 1995). Therefore, due to these landowners, the reserve is in a unique position as it has been protected from development over the years and is thus largely unspoilt. Kimmeridge Bay is the only easily accessed part of the reserve.

This study investigated the impact of visitors to Kimmeridge Bay on the intertidal species diversity through a comparison of two ledges. It was hypothesized that heavy use of one of the ledges for rockpooling, crabbing and other activities would have an impact on the epibenthic assemblages residing there. The second ledge was more isolated and therefore only rarely utilized by comparison.

## MATERIALS AND METHODS

Two sampling locations were chosen for this study: Washing Ledge is a heavily visited site within the confines of the bay whilst Yellow Ledge is a less well visited site to the east of the bay where relatively few visitors venture. Due to the structure of Kimmeridge Bay, it was not possible to have additional replicate ledges.

### *Visitor numbers and activities*

Visitor numbers and activities were monitored on each ledge at low tide over ten days including weekdays and a weekend. This monitoring was undertaken during school term time and therefore the numbers recorded are likely

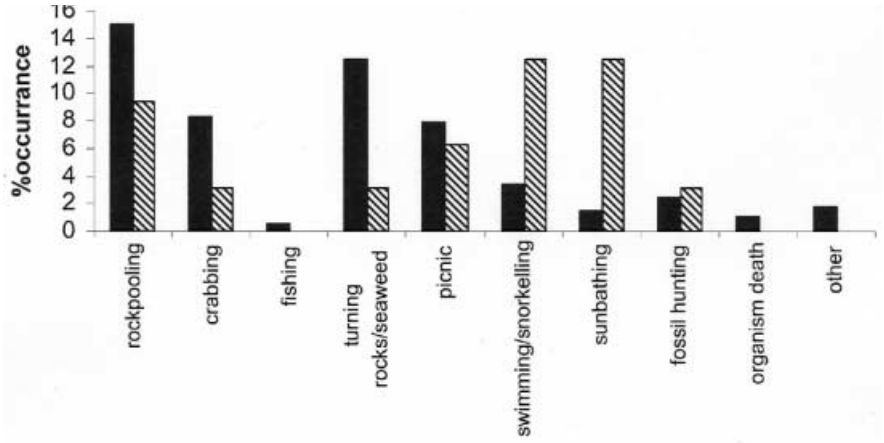


**Figure 1.** Visitor activity at Kimmeridge Bay (solid bar, Washing Ledge; striped bar, Yellow Ledge).

to be lower than would be expected during a holiday season. However, the monitoring did include seven school parties and was therefore considered to provide an adequate, although limited, representation of the numbers and types of activities that may be expected at each ledge.

### *Study area and assemblage surveys*

Due to the geology of the area, the ledges lie at a slant, both leaning downwards to the east, with the west side of both ledges being slightly higher above sea level. Because of the slanting nature of the ledges and variation in habitat use by visitors, three habitats were examined per ledge: the main open rock, the fucoid area and the rockpool area adjacent to the ledges.

The fieldwork was carried out between June and September of 2002. Each habitat type was surveyed using 20 randomly placed 0.25 $m^2$ quadrats with the abundance of all algae (as percentage cover) and all fauna (as numbers of individuals) being recorded. The data were analysed using standard multivariate techniques in PRIMER (Plymouth Routines In Multivariate Ecological Research). For cluster analysis and multidimensional scaling (MDS), the mean of all replicates was used. The Bray–Curtis similarity measure was used to calculate similarities using a 4th root transformation. Similarity percentages (SIMPER) were used to determine similarity (i.e. accounted for 80% of the similarity) and relative dissimarilities between assemblages.

### *Limpet populations*

In 1997, a voluntary closure of Washing Ledge was put in place due to the large number of visitors kicking limpets off the rocks and/or smashing their shells, which had significantly reduced the limpet population (P. Tinsley, personal communication). Limpet numbers and sizes were therefore recorded on both ledges to assess population recovery and effectiveness of the Washing Ledge closures. The differences in the population size distributions were examined statistically using a two sample Kolmogorov–Smirnov test.

## RESULTS

### *Visitor numbers and activities*

The visitor numbers to Washing Ledge (21.9 $h^{-1}$) were considerably greater than those at Yellow Ledge (0.8 $h^{-1}$). There was also a contrast in the type of visitor with families and/or children being concentrated on Washing Ledge and predominantly adults on Yellow Ledge (48.5%

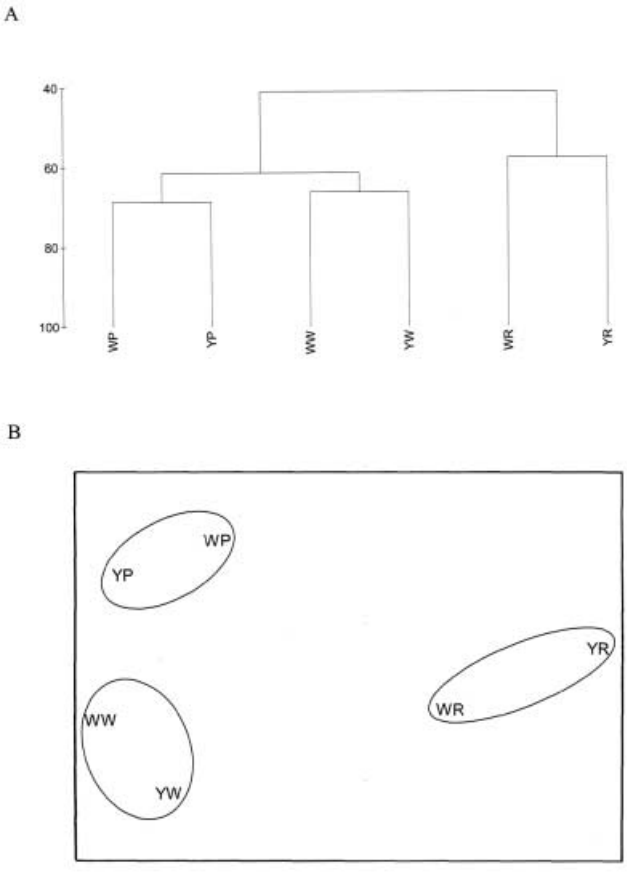


**Figure 2.** Cluster analysis (A) and multidimensional scaling ordination (B) of assemblage structure (W, Washing Ledge; Y, Yellow Ledge; R, open rock habitat; W, wrack habitat; P, rockpool habitat).



https://doi.org/10.1017/S0025315405011148h Published online by Cambridge University Press

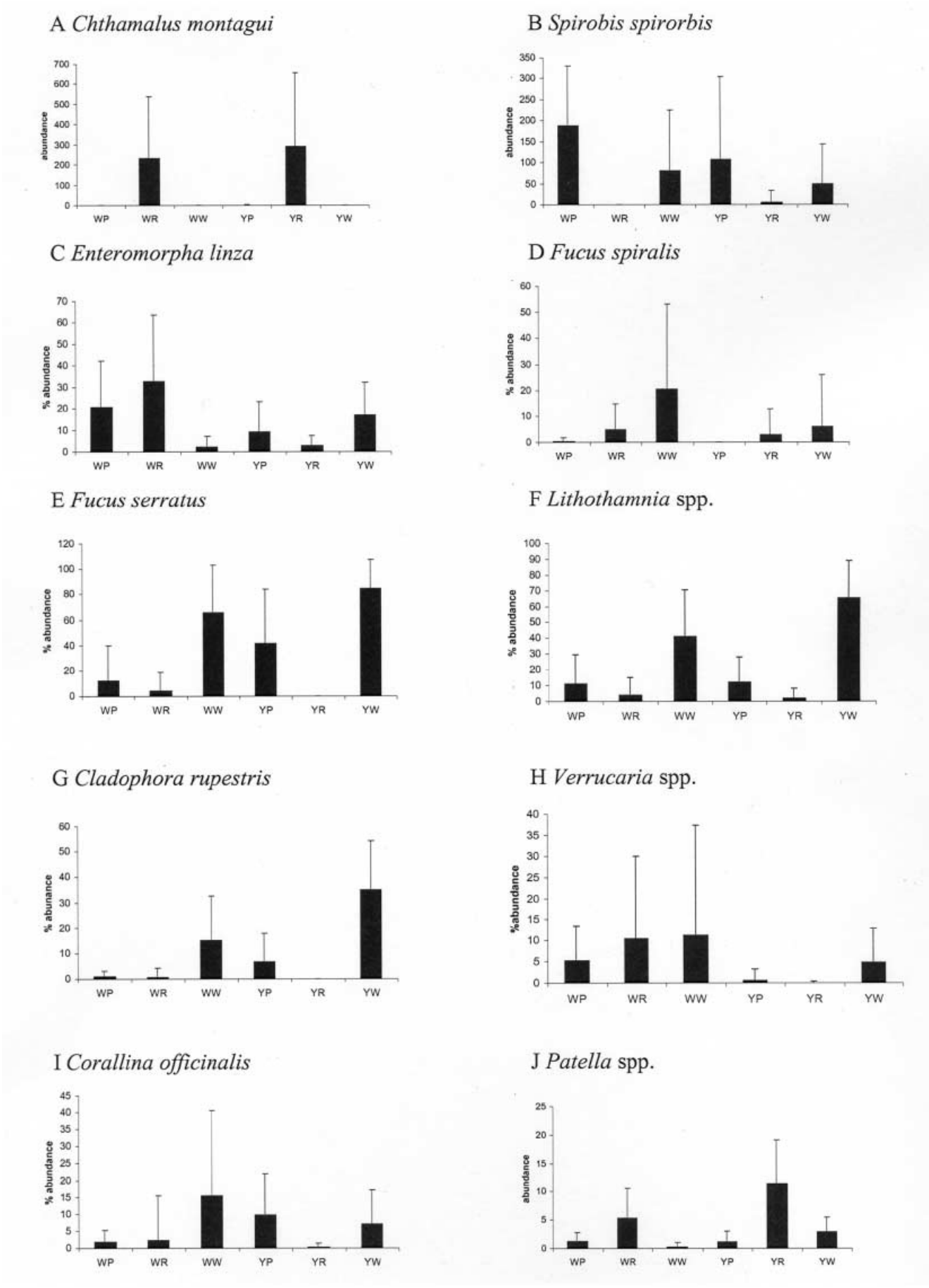


**Figure 3.** Abundance of individual taxa (W, Washing Ledge; Y, Yellow Ledge; R, open rock habitat; W, wrack habitat; P, rockpool habitat).



https://doi.org/10.1017/S0025315405011148h Published online by Cambridge University Press

**Figure 4.** Visitor damage to a limpet.

and 9%, respectively, were children). The most common activities observed at Washing Ledge were rockpooling, crabbing, turning rocks and rummaging in the seaweed and picnicking (Figure 1). On several occasions, limpets and sea anemones were observed being kicked off rocks. At Yellow Ledge, the most common activities were rockpooling, sunbathing and swimming/snorkelling (Figure 1).

### *Community results*

There was a considerable amount of variation in the assemblages observed in the different habitats and on the ledges. Mean species richness was similar for both sites (Washing Ledge: 8.0 ±2.8, N=85; Yellow Ledge: 8.4 ±3.5, N=99) but a greater total number of species were identified from the less heavily utilized site (Washing Ledge: 60 species; Yellow Ledge: 70 species). The differences between assemblages were greater between habitat types than between the ledges (Figure 2). The open rock habitat was characterized by the highest abundance of *Chthamalus montagui*, which was almost entirely absent from the other habitat types (Figure 3). The rockpool habitat was characterized by the highest abundance of *Spirorbis spirorbis* and *Enteromorpha linza* and lowest abundance of *Fucus spiralis* (Figure 3). The wrack habitat had the highest abundance of *Fucus serratus*, *Lithothamnia* spp., *Cladophora rupestris*, *Corallina officinalis* and *F. spiralis*, and the lowest abundance of *E. linza* (Figure 3). In general, Washing Ledge showed a reduction in the larger, branching species of algae and an increase in ephemeral and crustose species when compared with Yellow Ledge. For example, Washing Ledge was characterized by higher abundance of *E. linza*, *Verrucaria* spp. and *S. spirorbis*, and a lower abundance of *F. serratus*, *Lithothamnia* spp., *Cladophora rupestris* and *Chthamalus montagui* than Yellow Ledge (Figure 3).

### *Limpet populations*

In the summer of 1997, sections of Washing Ledge were closed on a voluntary basis and 'limpet protection zones' set up (P. Tinsley, personal communication). Although an educational campaign has generally reduced this activity, it was observed in the current survey (Figure 4).

*Patella* spp. were much more abundant on Yellow Ledge ($57.6\,m^{-2}$) than Washing Ledge ($22.2\,m^{-2}$) (Figure 3J). Sizes ranged from 0.4 to 6.0 cm on Yellow Ledge with a mean of 2.5 ±1.3 cm and from 0.4 to 6.2 cm with a mean of 2.6 ±1.3 cm on Washing Ledge. The size distribution of the two populations was not found to be significantly different ($P>0.05$, Z=0.029). However, it was noted that there were differences in their spatial distribution. On Yellow Ledge, the limpets were usually clumped together, whilst on Washing Ledge they were more widely spaced, with solitary individuals often being common.

## DISCUSSION

### *Effects of trampling on the intertidal community*

Despite the recent surge in outdoor recreation, we know surprisingly little about the most basic consequences of this increased usage (Eckrich & Holmquist, 2000). The present research has highlighted some differences in the communities, which can be attributed to human usage. In particular, the community of Washing Ledge, which is heavily



https://doi.org/10.1017/S0025315405011148h Published online by Cambridge University Press

utilized, is dominated by ephemeral and crustose species such as *Enteromorpha linza* and *Verrucaria* spp. In contrast, Yellow Ledge was dominated by larger branching species of algae such as *Fucus serratus* and *Cladophora rupestris*. In addition, barnacles were more abundant and limpets considerably more numerous on Yellow Ledge.

A wide variety of studies have been conducted on the impact of trampling on rocky shores. In general, a reduction in the abundance of larger, branching algal forms and an increase in turf and crustose species has regularly been recorded as a response to trampling (e.g. Fowler, 1981; Povey & Keough, 1991; Brosnan & Crumrine, 1994; Fletcher & Frid, 1996; Keough & Quinn, 1998; Jenkins et al., 2002). Ephemeral algal species also tend to be more abundant in heavily trampled areas (Fowler, 1981; Fletcher & Frid, 1996). Grazers, particularly limpets, invade heavily trampled areas (Povey & Keough, 1991; Keough & Quinn, 1998), although this has not been observed in all studies (Jenkins et al., 2002). Fowler (1981) actually observed a reduction in limpet abundance in more heavily utilized areas due to visitors kicking them off the rocks.

At Washing Ledge, voluntary 'limpet protection zones' were utilized in 1997 to help protect limpets and encourage population recovery (P. Tinsley, personal communication). Where limpet populations are reduced, their prey species, predominantly ephemeral algae, can flourish (Hawkins, 1981; Dye, 1995). Linked with this, *E. linza* and other ephemeral algal species are opportunistic species and will take advantage of newly opened spaces in the community created by disturbances such as trampling. Combined, these two factors are likely to account for the increased abundance of ephemeral algal species in the more heavily trampled areas.

The current study found that the limpet population of Washing Ledge was considerably lower in abundance than that found on Yellow Ledge. The population structure of both sites, however, was similar. Fowler (1981) found that the limpet population numbers were not only lower at Washing Ledge, but that larger individuals were also absent from the population. The contrasting results of the current study indicate that recovery of the limpet population is occurring at Washing Ledge and the larger individuals are now surviving. The 'limpet protection zones' and the associated public education have, therefore, had a successful effect. However, some visitors still persist in kicking limpets off rocks. This suggests a need for continued monitoring of the recovery. In fact, it was recently indicated that reinstallation of the voluntary 'limpet protection zones' is currently being considered (P. Tinsley, personal communication).

One interesting observation, although not tested statistically in the current study, was the aggregation of limpets at Yellow Ledge whilst those of Washing Ledge were more widely dispersed. Aggregation in limpets has been associated with exposure, food availability and predator defence (Morais et al., 2003; Coleman et al., 2004). For the purposes of this study, exposure is thought to be similar at both sites. The more random distribution of limpets at Washing Ledge may be associated with greater abundance of ephemeral algae and fewer natural predation events, e.g. by oystercatchers, due to the presence of visitors at the site. In contrast, at Yellow Ledge, the abundance of ephemeral algae was lower and the likelihood of natural predation events much higher, leading to an aggregation of the limpets.

### *Marine protected areas and human activity*

Management of the biodiversity and conservation of protected areas, whilst allowing access, is particularly difficult. From its conception, the Purbeck VMNR has always considered one of its primary roles to be education and management of people rather than the management of wildlife. The reserve represents a balance in the spectrum of tourist pressures: its relative inaccessibility versus its popularity. At Kimmeridge Bay, an emphasis is placed on encouraging exploration of marine life, but with a responsible and educated approach. Similar approaches have been shown to work well elsewhere (e.g. Ghazanshahi et al., 1983).

The findings of the current research suggest that variation is greater between habitat types than between the ledges. This indicates that although visitors do affect the biological communities of the ledges, environmental factors are probably more important in determining the species distribution on the shore.

### *Conclusions*

The species diversity at Washing Ledge was different from Yellow Ledge, suggesting that disturbance from human trampling is a contributing factor to the community make-up. The most obvious contrast was a reduction in the larger, branching species of algae and an increase in ephemeral and crustose species in the more heavily utilized areas. In addition, the limpet populations were severely impacted by trampling, leading to a reduction in abundance. Despite these effects, it is felt that Kimmeridge Bay must be maintained for public access and as an educational resource and that the impacts observed are acceptable in view of the size of the reserve. Kimmeridge Bay is the only accessible part of the reserve and represents only a fraction of the entire VMNR. It may therefore be considered 'sacrificial'. The educational work undertaken at Kimmeridge contributes significantly to marine conservation and this probably outweighs any impact visitors may have on this small part of the reserve. However, continued monitoring of the shore communities is advised to assess the long term impact of visitors.

We thank Peter Tinsley and Dan Williams, the warden and deputy warden at Kimmeridge Bay, for help and advice during fieldwork. Two anonymous referees provided very constructive comments on the manuscript.

## REFERENCES

Brosnan, D.M. & Crumrine, L.L., 1994. Effects of human trampling on marine rocky shore communities. *Journal of Experimental Marine Biology and Ecology*, **177**, 79–97.

Carr, M.H., 2000. Marine protected areas: challenges and opportunities for understanding and conserving coastal marine ecosystems. *Environmental Conservation*, **27**, 106–109.

Coleman, R.A., Underwood, A.J. & Chapman, M.G., 2004. Absence of costs of foraging excursions in relation to limpet aggregation. *Journal of Animal Ecology*, **73**, 577–584.

Durán, L.R. & Castilla, J.C., 1989. Variation and persistence of the middle rocky intertidal community of central Chile, with and without human harvesting. *Marine Biology*, **103**, 555–562.

Dye, A.H., 1995. The effects of excluding limpets from the lower balanoid zone of rocky shores in Transkei, South Africa. *South African Journal of Marine Science*, **15**, 9–15.

Eckrich, C.E. & Holmquist, J.G., 2000. Trampling in a seagrass assemblage: direct effects, response of associated fauna and the role of substrate characteristic. *Marine Ecology Progress Series*, **201**, 199–209.

Fletcher, H. & Frid, C.L.J., 1996. Impact and management of visitor pressure on rocky intertidal algal communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 287–297.

Fowler, S.L., 1981. *The ecological effects of visitor pressure in the rocky intertidal zone of the Purbeck Marine Wildlife Reserve, Dorset*. MSc thesis, University College London.

Ghazanshahi, J., Huchel, T.D. & Devinny, J.S., 1983. Alteration of Southern California rocky shore ecosystems by public recreational use. *Journal of Environmental Management*, **16**, 37–39.

Gubbay, S. & Welton, S., 1995. The voluntary approach to conservation of marine areas. In *Marine protected areas. Principles and techniques for management* (ed. S. Gubbay), pp. 199–227. London, UK: Chapman & Hall.

Hawkins, S.J., 1981. The influence of season and barnacles on the algal colonization of *Patella vulgata* exclusion areas. *Journal of the Marine Biological Association of the United Kingdom*, **61**, 1–15.

Jenkins, C., Haas, M.E., Olson, A. & Ruesink, J.L., 2002. Impacts of trampling on a rocky shoreline of San Juan Island, Washington, USA. *Natural Areas Journal*, **22**, 260–269.

Keough, M.J. & Quinn, G.P., 1998. Effects of periodic disturbances from trampling on rocky intertidal algal beds. *Ecological Applications*, **8**, 141–161.

Morais, S., Boaventura, D., Narciso, L., Ré, P. & Hawkins, S.J., 2003. Gonad development and fatty acid composition of *Patella depressa* Pennant (Gastropoda: Prosobranchia) populations with different patterns of spatial distribution, in exposed and sheltered sites. *Journal of Experimental Marine Biology and Ecology*, **294**, 61–80.

Povey, A. & Keough, M.J., 1991. Effects of trampling on plant and animal populations on rocky shores. *Oikos*, **61**, 355–368.

*Submitted 13 February 2004. Accepted 18 November 2004.*