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Vehicle damage caused by recreational use of coastal dune systems in a Special Area of Conservation (SAC) on the west coast of Ireland

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Abstract This study investigates the vehicle damage caused by recreational use on three coastal dune systems on the west coast of Ireland. Using aerial photographs taken in 1973, 2000, 2004 and 2006 in conjunction with ecological surveys, the impacts of recreational activities were assessed. The results show that the overall area of tracks increased more than threefold between 1973 and 2007 with the exception of one site where restricted access resulted in a subsequent reduction in the number of tracks. The study further shows that most recreational activities at the sites were water-based, with most traffic movement directed towards the shore and the highest density of tracks being within the first few hundred meters of the High Water Mark. The results of this study are discussed in the context of visitor management strategies for coastal conservation sites under recreational pressure.

Keywords Dune system · Habitat damage · Ireland · Machair · Recreation · Tracks · Recreation management

Abbreviations

cSAC	candidate Special Area of Conservation
EU	European Union
GIS	Geographical Information Systems
HWM	High Water Mark
JNCC	Joint Nature Conservation Committee
NPWS	National Parks and Wildlife Service
OSi	Ordnance Survey Ireland
SAC	Special Area of Conservation
SNH	Scottish Natural Heritage

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Introduction

The coast and particularly sand dune systems are under pressure from human activity, especially from recreation and tourism uses. While, in general, human infrastructure and development too close to the shore tend to worsen the process of coastal erosion (Wilcock 1977), utilization of the coast for recreational purposes, by both locals and residents, further exacerbate this by increasing the need for development on the shore including facilities such as hotels, caravan parks and golf courses (Cabot 1977; Quigley 1991; Catto 2002). These take up dune habitat and can interrupt the natural dynamics of the dune systems, such as dune movement or sand deposition patterns (Wilcock 1977; Curr et al. 2000). The impacts of these factors are further amplified by the fact that provision of facilities attracts visitors to the area, increasing the recreational pressure (McLeod et al. 2001).

However, even in the absence of facilities, beaches and dune systems are attractive recreation areas that are visited by many people every year as coastal recreation is popular with both locals and especially tourists. The overall issues in these dune systems in relation to recreational uses are trampling and erosion, resulting from activities like walking, pony trekking or driving (Quigley 1991; Curr et al. 2000; McLeod et al. 2001; Priskin 2003). The problem is that open access, lack of parking facilities and proximity to the beach attract increasing numbers of vehicles to the

flatter areas of dune systems, which cause damage to the dune habitats.

It has been shown that impacts and severity of impacts on habitats, especially on dune systems, depend on the use of the site. Extensive studies have been undertaken on the effects of trampling on vegetation and soils, especially in relation to sand dune systems. Liddle and Greig-Smith (1975a, b) surveyed tracks and paths in sand dune ecosystems in Anglesey, North Wales, with reference to effects of walking and vehicles on both soil and vegetation while Luckenbach and Bury (1983) studied effects of off-road vehicles on dune biota of the Algodones Dunes in California. In both cases it was found that the effects of vehicles were detrimental to plants causing loss of floral diversity. In Denmark, Andersen (1995) investigated the impacts of path creation due to human trampling on five coastal plant communities and came to the conclusion that for all five communities, total number of vascular plant species, species diversity and total vegetation cover were significantly reduced. Gremmen et al. (2003) concluded that for the vegetation of the Sub Antarctic Marion Island, human trampling resulted in reduced vegetation height, reduced total cover and reduced species richness of mires and feldmark, an exposed habitat, characterised by low plant cover, dominated by *Azorella selago* and cushion-forming mosses (Gremmen et al. 2003). Furthermore they noted that trampling effects differed between plant growth-forms which Burden and Randerson (1972) had previously observed. Hence, different habitats show different degrees of vulnerability according to the plant species composition (Hylgaard and Liddle 1981). Nonetheless, these and other studies demonstrate that the effects of trampling of any kind, human or vehicular, on vegetation but in particular sand dunes are detrimental to the vegetation and cause erosion of the soil (Liddle 1975; Westhoff 1967). Due to weight and type of motion, the damage caused by vehicles is more extensive than that caused by human trampling (Westhoff 1967). Schofield (1967) and Weaver and Dale (1978) further noted that repetitive use increased erosion, the former stating that 4,000 uses caused the exposure of sand and soil in grey dunes, and the latter stating that up to 1,000 repeated passages by motorbike increased track depth. However, this was also noted by Hylgaard and Liddle (1981), who concluded that more frequently used tracks wear down faster than those less frequently used and the intervals between use are also of importance in that repeated use over a short period of time can be more damaging than the same amount of repetitions taking place over a longer period of time.

The above indicates that trampling and the damage it causes should be seriously considered when dealing with the management of sand dune systems used for recreational purposes. With increased car ownership and the attraction of the coast and its beaches for recreational purposes, the pressure on coastal areas and dune systems has greatly increased. Careful management of coastal areas, especially those designated for conservation, for example Special Areas of Conservation (SACs) is required to ensure their protection. Therefore, when it come to management, it is essential to consider all impacts on a site under conservation.

Irish sand dune systems under recreational pressure

The Irish coast is under immense pressure from humans. Not only does Ireland's coastal area support 51% of the Irish population, but ever increasing numbers of people travel to the coast for recreational purposes (Cabot 1977; McLeod et al. 2001; Nairn 2005). The overall length of the Irish coastline is approximately 7,500 km (Marine Institute 1999), half of which is classified as soft coastline which includes sand dune systems (McLeod et al. 2001).

Irish sand dune systems include a number of different habitats, described in Fossitt (2000) as follows. From the high tide mark up, the first dunes encountered are small dunes, sparsely vegetated, less than one metre in height, so called embryonic dunes. These are followed further inland by marram dunes, which are semi-stabilized with an almost complete vegetation cover of *Ammophila arenaria*, which stabilises the dunes, traps further sand and helps the dunes to grow to heights of up to 15–20 m. Inland from the marram dunes are the more stable dunes, so called fixed dunes. These are stabilised hills or ridges with more or less complete vegetation cover, which occur where the amount of blown sand is decreased and humus has accumulated in the soil, increasing the retention of moisture in the sand (Nairn 2005; Fossitt 2000). These dunes have a more complete vegetation of herb-rich grasses or heath, characterised by Red Fescue (*Festuca rubra*) and Lady's Bedstraw (*Galium verum*). The fixed dune vegetation is usually rich in calcicole species (JNCC 2000). A rarer feature of the dune systems is the occurrence of dune slacks, found behind dunes and in hollows and depressions. These are low lying enriched wet areas which are at or close to the water table. They may be influenced by the tides as the water table lifts and falls with them. Their vegetation includes many aquatic and wetland species such as Silverweed (*Potentilla anserina*) and Water Mint (*Mentha aquatica*) (Fossitt 2000).

Machair

An Irish dune habitat of particular importance that occurs within the sites examined in this study is machair. It is one of the rarest habitats in Europe, found only on the western seaboard, where it is restricted to the coasts of Britain and Ireland. Most of this habitat is found on the west coast of

Scotland, almost half of all machair occurring in the Outer Hebrides (Angus and Elliott 1992; Love 2003). In Ireland, machair is limited to the northwest coasts of the country, from Galway Bay up to Malin Head in Donegal (Quigley 1991). Irish machair is a priority habitat according to the Habitats Directive (92/43/EEC) and as such is of special conservation importance. Scottish machair is not considered to be a priority habitat as it is much more intensively used for agriculture than Irish machair. Machairs, the name coming from Gaelic meaning flat or low-lying, are extensive, flat or gently sloping plains, vegetated with a wide variety of herbaceous species. Species typical of machair include Red Fescue (*Festuca rubra)*, Common Bird's-foot Trefoil (*Lotus corniculatus)*, White Clover (*Trifolium repens)*, Yarrow (*Achillea millefolium)*, Lady's Bedstraw (*Galium verum)*, Ribwort Plantain (*Plantago lanceolata)*, Eyebright (*Euphrasia officinalis)* and Daisy (*Bellis perennis)* (Fossitt 2000).

When it comes to coastal conservation, it is these habitats, contained within sand dune systems, that are under most pressure from human activity as they are the main focal points of recreational activities. The cumulative effects of pedestrians and vehicles, as well as activities such as camping, picnicking, walking and caravan use can cause severe damage to sand dunes and their vegetation (Tourism Policy Review Group 2003; Quigley 1991). These impacts are of major concern in all coastal dune systems, but they pose a particular problem in areas which are designated as conservation areas, especially when they contain habitats of special importance such as machair. In this study, the impacts of recreational activities are considered in relation to conservation sites designated as SACs according to the European Habitats Directive (92/43/EEC). To date, little research has been carried out in Ireland in relation to the impacts of recreational activities on sand dune systems. This study aims to assess these impacts on coastal SACs in Ireland and to consider the management of areas for conservation. Orams (1995) suggests that in relation to wildlife tourism there are four visitor management strategies: a) physical management: referring to the introduction of physical structures such as boardwalks; b) regulatory management: which refers to the introduction of rules and regulations; c) economic management: where charges are introduced for the use of an area; and d) educational management: also referred to as soft management. Although these different management strategies were drawn up in relation to wildlife tourism, they are applicable to any form of tourism or recreation in natural areas (I-Ling 2002). Hence all four management strategies should be considered as possible options in relation to the management of coastal SACs in Ireland.

The focus of this study is on a coastal SAC containing sand dune systems as these are fragile in nature but are also most attractive to tourists and recreationists, creating management challenges for the responsible conservation authorities. It has previously been shown that the impact of recreation on biodiversity is determined by the activities in which recreationists engage (Coombes and Jones 2010; Andrés-Abellán et al. 2005; Priskin 2003). This paper addresses the damage caused by recreationists in a particular SAC in the west of Ireland and to pinpoint what can be learned from this for management of coastal conservation areas elsewhere.

Study area

This study focuses on three coastal dune areas which are part of the Slyne Head peninsula candidate Special Area of Conservation (cSAC) (Fig. 1). The cSAC comprises a headland located 8 km southwest of the town of Clifden (population ~1,400) in Connemara, County Galway (OSi grid reference: L60 45).

Bordering the cSAC is the village of Ballyconneely, which provides services for the area such as a post office, two shops, a school, a church and a bar/restaurant. A rural bus stops in the village infrequently, providing a service on Wednesdays, Thursdays, Fridays and Sundays only, where the bus stops twice a day at the post office. Around Ballyconneely there are many holiday homes available to rent, as well as bed and breakfasts and a hotel providing accommodation for visitors to the area. The camp site at Aillebrack (Fig. 2) provides further possibilities of accommodation while the golf course is a draw for tourists.

The cSAC (23 km^2 approx.) encompasses a large number of different habitats from marine to terrestrial to freshwater, and it is fringed with rocky shores and sandy beaches. The site was designated as an cSAC due to the presence of priority habitats listed in Annex I of the EU Habitats Directive (92/43/EEC), primarily lagoons, machairs and orchid-rich grasslands. In relation to this study, machairs are of particular interest as the presence of a priority dune habitat was a selection criterion when selecting study sites. Machairs were chosen as these are of particular interest in an Irish context, being the only priority dune habitat to occur only in Ireland, in addition to the presence of the plant species *Petalophyllum ralfsii* (Petalwort) and *Najas flexilis* (Slender Naiad), both of which are listed in Annex II of the directive (92/43/EEC). Overall the peninsula is low-lying, with its highest point being 64 m above sea level. The underlying bedrock is mostly gneiss except for schist which runs along the northern shores of Mannin Bay (Fig. 2), a granite ridge running along the western side of the peninsula and a basalt outcrop which constitutes the peninsula's highest point (NPWS 2003).

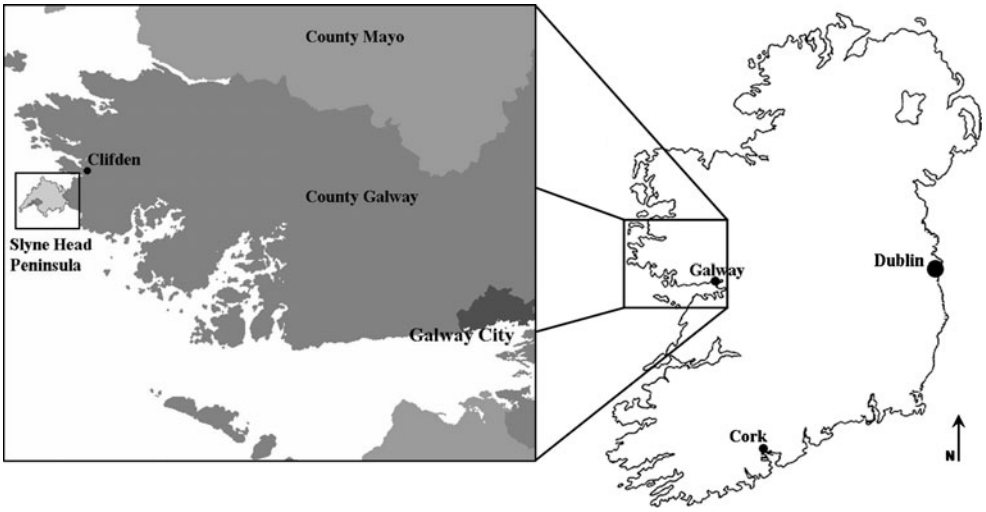

Fig. 1 Location of Slyne Head Peninsula cSAC within Ireland

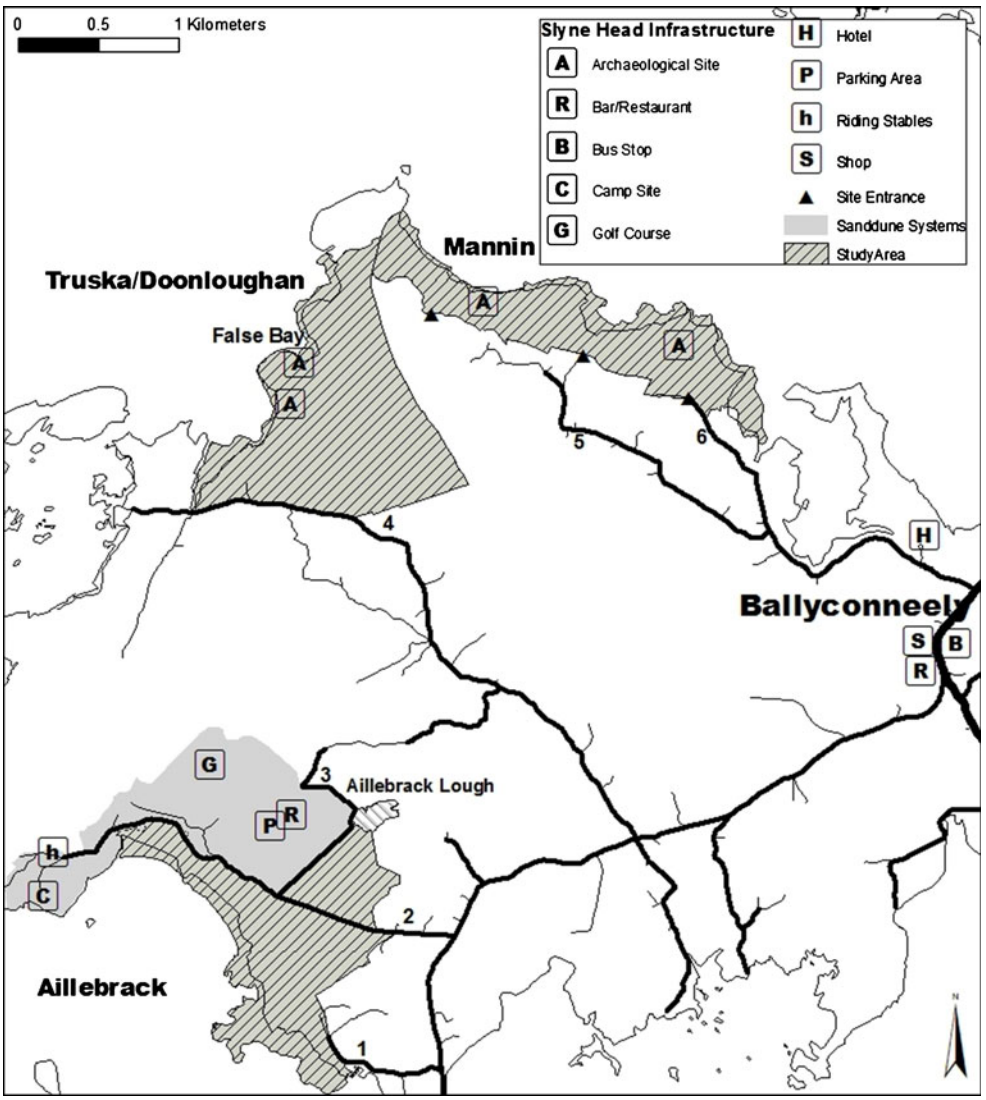

Fig. 2 Map showing all three study sites, Aillebrack, Truska/Doonloughan and Mannin, and further sand dune systems which were excluded from the study on the Slyne Head Peninsula as they were outside the cSAC borders (OSi 2000)

As one of the most westerly headlands in County Galway, the Slyne Head peninsula is exposed to the full force of the Atlantic Ocean. This not only results in the annual rainfalls of 1,200–1,400 mm (Met Éireann 2008), but also in strong westerly winds. It is these winds which are the force behind the creation of the sand dune systems on Slyne Head as they are a source of windblown calcareous sands which have an important influence on the habitats present, especially the sand dune systems and machairs in particular.

While there are a number of areas containing sandy beaches and sand dunes on the Slyne Head peninsula, machair occurs primarily in three coastal dune systems i.e. Aillebrack (1 km^2 approx.), Truska/Doonloughan (1.5 km^2 approx.) and Mannin (1 km^2 approx.), all of which are part of this study. All three coastal dune sites fulfilled the selection criteria for this study in that they are all part of a cSAC (the same cSAC in this case), they all contain a priority habitat (machair) and they are all subjected to recreational activity. In terms of site infrastructure, none of the sites have any major facilities. A summary of the three study sites is given in Table 1.

Aillebrack

Aillebrack is in the south of the Slyne Head peninsula. This site is unfenced and can be accessed directly from three roads (1, 2 & 3, Fig. 2). The site extends to both sides of road 2, the south western part being the larger area, abutting the coast, while the north eastern part of the site is the landward side, bordered by road 3. The site is grazed by cattle and Connemara ponies are raced here for one day each year in August when the site plays host to a Connemara pony race. The site also features two sets of goalposts, one of which is used frequently by the local community while the other is no longer in use (personal observation). There are two exclusions from the cSAC at this dune system, one is the 18-hole Connemara Golf Course, and the other is a caravan park at the western end of the site. Both existed before the cSAC was designated and they were excluded from the designation and hence from this study.

Truska/Doonloughan

Truska/Doonloughan lies to the Northwest of the peninsula. This site is not fenced and can be accessed anywhere along road 4 (Fig. 2). The coast on this site is west facing and exposed to strong prevailing westerly winds. A prominent sand ridge runs parallel to the coast, part of which is severely eroded. While up to approximately 15 years ago the site would have also been grazed by cattle and Connemara ponies, it is now only grazed by sheep (Crawford et al. 1996). In the past, landowners would have used the site as a supply of sand and a number of old extraction points remain, but these are no longer in use (O'Donnell, pers. comm. 2005). The site has a popular surfing beach in the Northwest of the site, False Bay (Fig. 2). The bay is also frequently used as a bathing beach despite the occurring undercurrents which create the waves ideal for surfing but make the bay unsafe for swimming. Further features are prominent kitchen middens which are located south of False Bay. These are prehistoric waste sites, heaps containing mostly shells but also other materials, and are remnants of settlements from the early Bronze Age (McCormick et al. 1996). Furthermore there is a Viking-age farmstead on the site, the only one on the Irish

Table 1 Overview of the three study sites, Aillebrack, Truska/Doonloughan and Mannin at Slyne Head, Ireland

	Aillebrack	Truska/Doonloughan	Mannin
Size	1 km^2	1.5 km^2	1 km^2
Aspect	Southwest	West/Northwest	North/Northeast
Ownership	Commonage, 12 shareholders	Commonage, 13 shareholders	Commonage, 20 shareholders
Landuse	Cattle grazing Pony racing (1 day)	Sheep grazing	Cattle & Sheep grazing
Access roads	1, 2, 3	4	5, 6
Access	Unfenced, access open from roads	Unfenced, access open from roads	Fenced, 3 access points, 2 public roads, 1 private
Tourism/Recreation	Caravan park & golf course within same dune system	Popular surfing beach	Unofficial campsite on site
Visitor numbers[a]			
Weekday	20–40	25–50	25–50
Weekend/Holiday	25–50	100–125	50–75
Special Features	2 playing pitches	archaeological sites, Annex II spp (*Petalophyllum ralfsii)*	Playing pitch, Archaeological sites

[a]As observed at site visits, approx 3 h each, in summer months 2005 during dry, warm weather

west coast, which can be found adjacent to False Bay (Gibbons and Kelly 2003). The site is also home to the largest Irish population of the liverwort *Petalophyllum ralfsii* (Petalwort) an Annex II species.

Mannin

Mannin is on the north side of the peninsula and a rock ridge running parallel to the coast leaves it more sheltered from the Atlantic winds than the other sites. This site, unlike the other two is fenced off from the road. There are three entry points into the site (Fig. 2). All entry points have gates, with the most easterly gate being directly by the side of road 6 (Fig. 2) while the central entrance is at the end of a narrow lane leading off road 5 and the most western entrance is to private grounds. The two public access points are used by landowners and visitors alike, with the most easterly one being the more popular with visitors. In 2001, one of the shareholders of the site placed large boulders in a row a few meters into the site to block vehicular traffic into the site. Some of these boulders have since been moved but most still remain in place today. The site is used by a number of landowners for grazing, for both sheep and cattle. In the past the site was used for sports and two sets of goalposts still stand on the site. These are occasionally used by visitors but no longer by locals (O'Flaherty, pers. comm. 2006). Between the two public entry points, towards the beaches, a number of caravans are located which remain there year-round. The camp site is not official and there are no facilities for campers on the site. The site also contains a number of archaeological remains, which include kitchen middens, shell heaps, created by settlers from the Bronze-Age to Medieval times (Gosling 1993).

Methods

Habitat mapping and damage assessment

In this study, habitats were identified in the field using 'A Guide to Irish Habitats' by Fossitt (2000). Fossitt operates on three levels with 11 broad habitat groups at level one, 30 habitat subgroups at level 2 and 117 habitats at level 3. With the guide come draft guidelines on its use (Heritage Council 2002). These guidelines suggest survey methods broadly comparable to the British Phase 1 Habitat Survey methodology (JNCC 2003).

Having carried out a pre-survey desk study of aerial photographs and other relevant materials such as six-inch maps (OSi 2003) and draft management plans of the area (NPWS 1998), field visits were undertaken to the study sites between April 2005 and June 2005 and again in August and September 2007. Using orthocorrected aerial photographs of the study area (OSi 2000, 2004, 2006), the habitats present at the three sample sites were identified. The Heritage Council guidelines recommend classifying and recording all habitats of 0.25 ha (50 m^2) in size and taking field notes in which to specify if further habitats, plants or features of interest are present. While this approach was taken in this study, some habitat patches, particularly sand blowouts, often smaller than 0.25 ha but still visible on the aerial photographs, were also mapped. During the habitat mapping process, special attention was paid to damage which was present in different habitats. Of the damage noted, tracks created by vehicles or through trampling were of particular interest and the severity of these tracks and trails was ranked. This was done according to a scale from one to three, one being the least and three being the most severely damaged (Table 2).

Following habitat classification and the damage assessment process, the data from the maps, aerial photographs and field notes were transferred to ArcGIS (edition 9.2) and digital habitat maps were produced. The habitat maps for 2007 and 2005 were based on aerial photographs and fieldwork data which was carried out in 2007 and 2005 respectively, while the maps for 2000 and 1973 were based on aerial photographs alone as the dates when the latter photographs were taken fall outside the time period of this study. These maps were produced to determine changes to the habitats of the sites over time due to tourism impacts. While the aerial photographs for 2000 were in colour and habitat identification could be based on comparisons with the more recent aerial photographs, the 1973 aerial photographs were in black and white and a different approach had to be taken when interpreting these. For the 1973 photographs the only distinctions that could be made were between vegetation cover, rock, sand and blown sand covering vegetation so only these habitat groups were recorded. In order to compare these to the other maps created, the habitats maps for 2000, 2005 and 2007 were subsequently grouped into the same categories as for 1973 (Table 3).

Tracks were added once the digital habitat maps were completed with the track maps for 2005 and 2007 being based on aerial photographs and field work data, while the

Table 2 Ranking system for tracks surveyed at Aillebrack, Truska/Doonloughan and Mannin at Slyne Head, Ireland

Level	Track	Damage
0	No tracks	No damage
1	Emerging tracks, old disused tracks	Track clearly visible but still covered by vegetation
2	Used tracks	Vegetation cover eroded, but sand not or only slightly eroded
3	Frequently used tracks	No vegetation cover, sand cover eroded or severely eroded

Table 3 Summary of habitat information used for the habitat maps for Aillebrack, Truska/Doonloughan and Mannin at Slyne Head, Ireland

Year	1973	2000	2005	2007
Aerial photograph	black & white	colour	colour (2004)	colour (2006)
Field work	no	no	yes	yes
Habitat map	1. sand/rock/vegetation	1. sand/rock/vegetation	1. sand/rock/vegetation	1. sand/rock/vegetation
		2. all habitats	2. all habitats	2. all habitats

track maps for 2000 and 1973 were based on aerial photographs alone. The tracks could be recognised in both the 2000 and 1973 photographs but without field comparisons the level of accuracy when mapping these is lower than that of the 2005 and 2007 maps. However, based on comparisons with the maps from 2005 and 2007 and on the good quality of the aerial photographs used, it can be assumed that the earlier track maps display a high level of exactness. The same ranking system was used throughout the study, with the caveat that the earlier maps were based on aerial photographs alone while those for 2005 and 2007 were ground truthed.

Questionnaires

Questionnaires were used to gain an overview of recreational activities carried out in the coastal conservation area. This information was gathered to serve as indicator in relation to recreational activity. To ensure that the survey questionnaire was designed appropriately, a pilot study was conducted at a nearby site, Gurteen Bay/Dogs Bay, Co. Galway, which is similar in habitat composition and recreational activity to the sample sites. The questionnaire was designed with a mixture of different types of questions including both open and closed questions.

Closed questions were used where the possible answers were restricted to few options, although in some cases the option 'other' was provided in case not all possible responses had been considered in the questionnaire design. Open questions were used to encourage respondents to phrase their opinions on matters such as their reasons for choosing that particular site or proposing changes to site access. Both types of questions were designed to be easy to understand and phrased in such a way as to not lead respondents towards a particular answer.

Overall the questionnaires were used to sample a cross section of the visitors who came to the sample sites. A total of 60 people answered the questionnaires in August 2005, 20 visitors at each site. This was deemed adequate as the questionnaire results were merely meant to serve as indicators of recreational activity in addition to observed behaviour and habitat data accumulated. All respondents were chosen at random from the recreationists present at the sample site on the days of the survey. Of those who were approached, all responded and there were no non-responses.

Results & discussion

Habitat maps

Table 4 shows the results obtained from the habitat maps, displaying the percentage area of vegetation, rock and sand for all sites as well as the percentage area for the different habitats present for 2000, 2005 and 2007.

Table 4 includes all the habitats found at Aillebrack, Mannin and Truska/Doonloughan from 1973 to 2007. The list includes the individual categories as well as mosaics or combinations (such as fixed dune and exposed siliceous rock mosaic or machair/fixed dune) where the separation of the individual habitats was not possible. Most of the habitats occur in all three sites but some were particular to one or two sites.

It is clear from Table 4 that the data for the percentage cover of vegetation, rock and sand remains broadly similar for the period from 2000 to 2007, while the percentage cover for 1973 is lower for all three sites. This is due to major changes in sand and vegetation cover over time. Many of the sand areas that were visible on the 1973 aerial photograph were covered by vegetation in 2000.These were most likely areas of blown sand and marram dunes which in the intervening period of 27 years have become stabilised and colonised by dune vegetation. This is especially apparent at Truska/Doonloughan where the percentage cover of vegetation changed from 44.5% in 1973 to 81.3% in 2000, where areas of blown sand have become machair grasslands and moving dunes have become stabilised. This is a process common in dune systems which are highly dynamic by nature and was most likely accelerated by the build up of sand on the dune ridge itself, causing the height of the ridge to increase and thereby provide more shelter for the area behind.

As for the percentage cover of the different habitat types listed, the most prominent differences are between 2000 and 2005. Similar to the differences in vegetation and sand cover between 1973 and 2000, these changes in the areas covered by different habitats are probably due to dune

Table 4 Percentage area for all habitat groups (sand/rock/vegetation) and habitats (1973–2007) present at all three study sites, Aillebrack, Truska/Doonloughan and Mannin, based on the habitat maps created from aerial photographs and field work (2005 & 2007). Figures are rounded to one decimal place. (Does not include percentage cover of flowerbeds and borders which were also present at Truska/Doonloughan and Aillebrack, but excluded in the habitat cover as they were outside the cSAC border)

	Aillebrack				Truska/Doonloughan				Mannin			
Habitat	1973	2000	2005	2007	1973	2000	2005	2007	1973	2000	2005	2007
Vegetation	61.5	69.3	66.0	68.1	44.5	81.3	80.8	81.4	41.2	60.0	59.5	60.7
1. Drainage ditches		0.2	0.2	0.5		–	–	–		0.3	0.3	0.3
2. Dry calcareous grassland		5.0	5.2	5.2		0.5	1.0	0.9		0.7	1.2	1.4
3. Dry calc. grass/Exposed rock		0.5	0.5	0.3		–	–	–		–	–	–
4. Dry siliceous heath		–	–	–		0.1	0.1	0.1		0.1	0.1	0.4
5. Dry siliceous heath/Exposed rock		–	–	–		–	–	–		1.1	1.2	1.4
6. Dune slacks		0.3	0.5	0.8		2.3	0.7	0.5		–	–	–
7. Fixed dune		15.7	17.0	14.7		6.9	12.4	12.8		4.0	7.9	11.0
8. Fixed dune/Exposed rock		4.0	3.00	4.7		5.4	6.2	6.2		5.5	5.9	4.2
9. Fixed dune/Machair		8.8	13.3	11.2		17.4	12.5	12.6		25.1	19.4	20.1
10. Fixed dune/Marram dune		1.0	–	–		1.3	2.2	–		0.3	0.1	–
11. Fixed dune/Wet grassland		–	–	–		0.9	3.4	1.9		–	–	–
13. Machair		31.1	25.6	29.7		26.0	24.9	26.9		16.5	19.4	19.3
17. Machair/Exposed rock		0.1	–	0.2		–	0.1	–		–	–	–
15. Marram dune		2.1	0.4	0.5		11.1	7.4	7.7		2.8	2.1	1.0
16. Rich fen & Flush		–	–	–		7.6	7.6	8.2		0.1	–	–
17. Scrub		0.02	0.02	0.02		–	–	–		–	–	–
18. Wet grassland		–	–	–		2.0	2.4	3.6		2.3	1.9	1.6
Rock	17.6	18.2	21.3	21.2	10.2	6.4	6.3	6.5	14.5	13.5	13.6	13.1
1. Exposed rocky shore		18.2	20.9	21.0		6.0	6.1	6.1		11.3	11.6	12.0
2. Exposed siliceous rock		–	0.4	0.2		0.1	–	0.1		2.2	2.0	1.1
3. Shingle & Gravel bank		–	–	–		0.2	0.2	0.3		–	–	–
Sand	20.9	12.5	12.7	10.7	45.4	12.3	12.9	12.1	44.4	27.6	26.9	26.6
1. Blowout		0.5	1.4	0.9		3.8	4.1	3.3		3.7	1.4	0.8
2. Sand shores		12.0	11.3	9.8		8.5	8.8	8.8		24.0	25.5	25.8

stabilisation which tends to alter dune systems over time, considering that they are changeable and dynamic in nature. However, it is also possible that the changes in habitat cover are due to the different habitat mapping techniques used. As the habitat maps for 2000 are based on aerial photographs alone there is a possibility that they are less accurate then the maps for 2005 and 2007 which were created from field work and aerial photographs. However it is unlikely that the changes, which are large, would be due to this fact alone.

Damage

While many studies have been carried out on the impacts such as loss of vegetation cover and changes in botanical composition caused by trampling and vehicle use on habitats (Westhoff 1967; Liddle 1975; Liddle and Greig-Smith 1975a, b; Hylgaard and Liddle 1981; Luckenbach and Bury 1983; Andersen 1995; Cole 1995a, b), this study focused on the distribution of the tracks created by recreationists driving to coastal conservation sites as well as the overall damage caused by vehicles driving on coastal habitats.

Site damage and track creation

The damage caused by cars driving onto the study sites was assessed by recording the different types of tracks (Table 2) present at the sites. This was then compared to the activities recreationists were recorded and observed to be carrying out at the sites.

The habitat maps created for each site were used to assess the track damage to the different habitats over time (Table 5). The damage to the Aillebrack and Truska/Doonloughan sites shows an overall increase from 1973 to 2007. For 1973, it is only possible to give overall site

Table 5 Damage to the habitats at Aillebrack, Truska/Doonloughan and Mannin from 1973 to 2007. Damage is recorded as damage to the overall site, followed by all the different vegetation types

	Aillebrack				Truska/Doonloughan				Mannin			
	1973	2000	2005	2007	1973	2000	2005	2007	1973	2000	2005	2007
% of overall site damaged:	0.65	2.87	3.52	3.82	0.67	2.40	3.05	3.34	1.26	2.64	2.16	2.19
% of each dune habitat damaged:												
Dune Slacks		–	–	–		3.63	–	0.43		–	–	–
Fixed Dune		8.05	9.00	9.72		3.63	5.82	6.45		0.82	2.6	2.11
Fixed Dune/Exposed Rock		6.38	6.87	9.21		0.16	–	0.18		0.66	1.01	0.17
Fixed Dune/Machair		7.08	7.83	7.66		6.27	5.94	5.66		6.54	4.85	4.48
Fixed Dune/Marram Dune		16.79	–	–		7.63	5.86	–		–	–	–
Machair		1.77	2.36	3.63		2.89	5.24	5.66		7.19	4.21	4.80
Machair/Exposed Rock		–	–	1.66		–	–	–		–	–	–
Marram Dune		–	0.26	1.74		1.01	1.11	3.03		0.70	–	–

damage as different dune habitats cannot be differentiated from the black and white aerial photographs. At these two sites, the habitats most damaged by tracks for 2000 to 2007 are fixed dune and machair, either as a habitat on their own or in a mosaic with each other, marram dunes, or exposed siliceous rock. At Mannin, the percentage of damaged area to the overall area increased initially from 1973 to 2000 and then decreased after 2000, presumably after 2001 when the boulder barricade was erected, decreasing vehicular access. The habitat most damaged over the years in this case was machair, either on its own or in a mosaic with other habitats. For all three sites, the habitats most damaged constitute the level and firm parts of the sites and are mostly found near the shore. This indicates that the flat parts of the site are most attractive for vehicle traffic due to their stability and the easy manner with which vehicles can move over them.

Having established the overall damage and damage to dune habitats for each site, the next step was a detailed evaluation of the created track maps to investigate the changes in tracks over time for each of the three sites (Fig. 3).

The track maps show the track patterns created at each of the sites as well as the changes in track categories. In relation to track pattern, it is obvious that at each site the tracks fan out from a number of access points off the roads leading to or through the sites. In the case of Aillebrack, there are six access points in 1973, eleven in 2000, 15 in 2005 and 18 in 2007, a pattern that can also be observed at Truska/Doonloughan, where access points increase from four in 1973 to 10 in 2007. At both sites the original access points remain in use, some move slightly to either side of the original access point while new access points are created along the access roads over the years. Mannin differs from this pattern as there are only two public access points into the site, which remain constant over the years. From these points the tracks lead further into the site, fanning out and creating a network of tracks. This distribution pattern is commonly observed in off-road driving as is the creation of new access points (Priskin 2003). What is interesting is the comparison to Mannin, which is fenced with only two access points. This seems to suggest that a simple measure as restricted access can reduce the number of access points created and potentially reduce the number of tracks on a site.

The assessment of the tracks created at the three sites showed the change over time in the amount of area (in km^2) the tracks took up (Fig. 4).

Figure 4 shows that for all three sites there was an increase in track area from 1973 to 2000. For both Aillebrack and Truska/Doonloughan the rise continued steadily until 2007. At Mannin however, after an initial increase the path area decreased and remained the same until 2007. The overall results indicate that there was a steady increase in track creation across Aillebrack and Truska/Doonloughan, which is most likely due to increased vehicular traffic at these sites. At Mannin the decrease in track area in 2005 and 2007 was probably because vehicle access to the site became restricted when boulders were placed close the most easterly entry point into the site in 2001.

Figure 5a and b show that at Aillebrack and Truska/Doonloughan the area of all tracks rose steadily from 1973 to 2005, indicating a steady flow of traffic across both sites. After that there is a decease in category 2 tracks at both those sites. In both cases some of the category 2 tacks developed into category 3 tracks while some reverted back to category 1 tracks, with vegetation having recolonised the bare ground of the tracks. This is particularly evident at Aillebrack (Fig. 3a). However, some of the category 2 tracks also disappeared entirely, something which is particularly evident

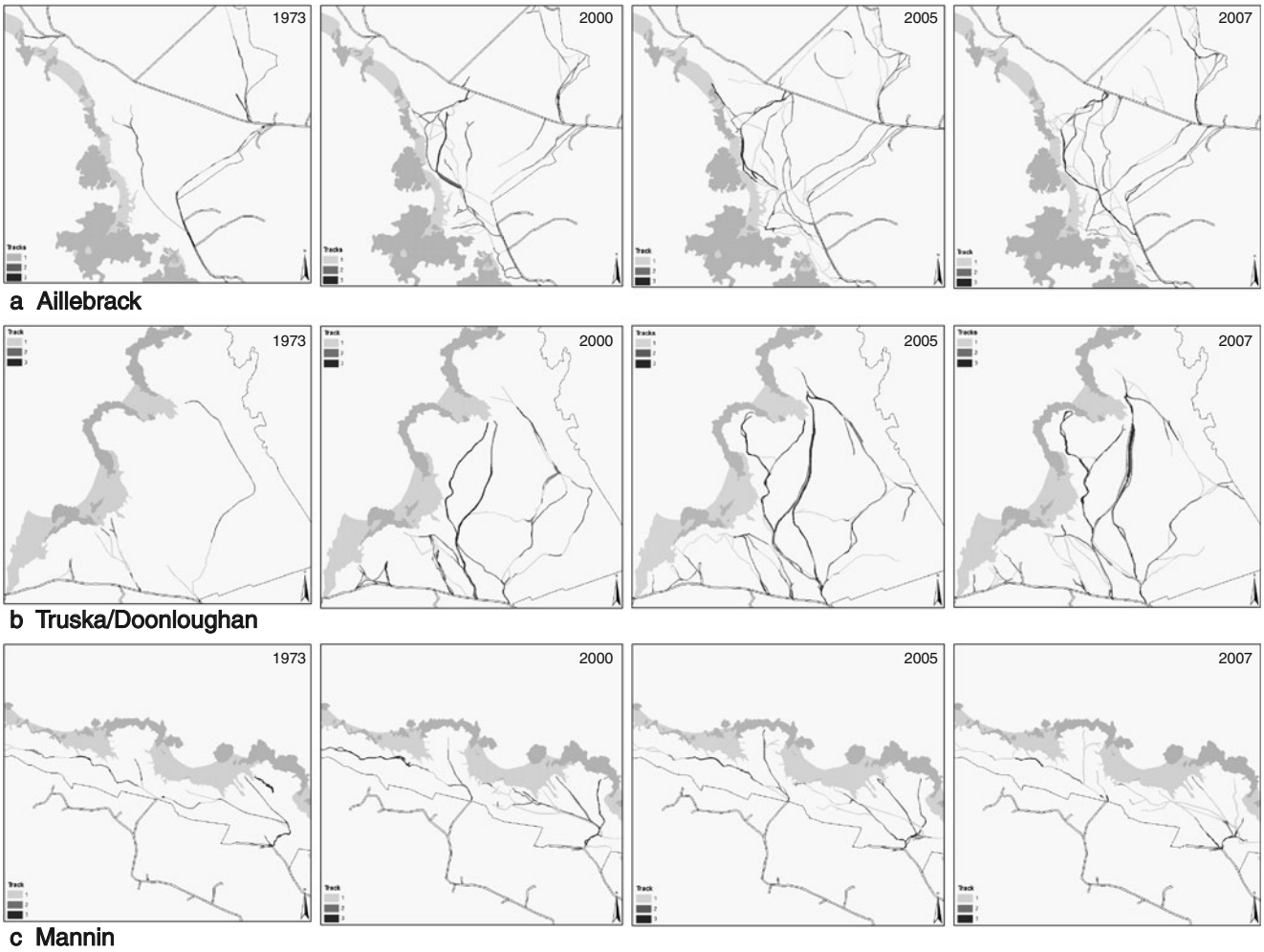

Fig. 3 **a**, **b**, & **c** Maps displaying the change in track area for all track categories (*1* = Track clearly visible but still covered by vegetation, *2* = Vegetation cover eroded, but sand not or only slightly eroded & *3* = No vegetation cover, sand cover eroded or severely eroded) over time (1973–2007) at Aillebrack

at the eastern side of Truska/Doonloughan (Fig. 3b). This can be attributed to a change in use of the tracks. Some of the formerly well used tracks have become less used, while others have become more intensively used and even new ones were created that were so intensively used over the 2 year period between being surveyed, that they went from not being present to category 3, as is the case at the case at the north-western part of Truska/Doonloughan (Fig. 3b). What is also very obvious from the track maps is that at Truska/Doonloughan the more intensively used tracks were towards the coast, while the change to lesser used tracks and the tracks which disappeared were at the landward side of the site. At Aillebrack this pattern was less obvious, with the circular track from the pony racing contributing to the changes in tracks also.

Mannin, however, presents a different picture. Here there was an increase in all track categories till 2000, after which there were marked changes in track categories. These changes can be attributed to the restricted access to the site from 2001. What is especially striking is the change in category 1 tracks. These drop from 2000 to 2005 by 24.9%, before increasing to 124.2% of the 2000 figures in 2007. Here the initial decrease can be attributed to an initial loss in category 1 tracks due to decreased traffic across the site, before the numbers increase again due to category 2 tracks decreasing in severity to category 1 levels (Fig. 3c). The changes from category 3 to 2 is less pronounced, due to the fact that most of the category 3 tracks are at the entrance to the site, before the boulder barricade, hence these have a higher intensity of use. Overall it can be said that the track changes at all three sites indicate that the intensity of use plays a major part in the creation of tracks and in the amount of erosion that takes place on the tracks. This corresponds to the findings by Weaver and Dale (1978)

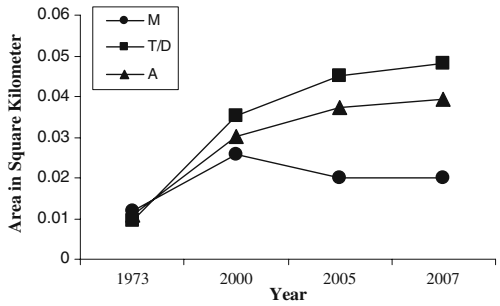

Fig. 4 Changes in area cover (km^2) the tracks took up at all three study sites, Aillebrack (*A*), Truska/Doonloughan (*T/D*) and Mannin (*M*)

who concluded that trail depth increased with use up to 1,000 passes and with Schofield (1967) who reported that on grey dunes exposure of sand and soil occurred after 4,000 passages. Also, frequency of use also plays an important role. The more frequently a tracks is used, the faster it wears down and the intervals between use are also of importance, as repeated use over a short period of time can be more damaging than the same amount of repetitions taking place over a longer period of time (Hylgaard and Liddle 1981). This may very well be the case for these sites, as they are more frequently used in dry, warm weather, and in the case of Truska/Doonloughan at times when the surf is particularly good.

Track distribution

Having investigated the track damage to the site and changes in damage over time, the track maps were further used to assess the distribution of the tracks created and if this was indicative of the recreational activities carried out on the sites. In order to investigate this, track distribution within 100 m strips was examined, starting at the high water mark (HWM), working back to the landward end of the site.

Figure 6 shows that at Aillebrack (Fig. 6a) and Mannin (Fig. 6c) the majority of tracks were located within 200 m of the HWM, mostly within a distance of 100 to 200 m for all 4 years of the study. This indicates that access to the shore is the main reason for vehicle traffic across the site. From the road the sites are entered via access points by the road, from which the tracks fan out, with the highest number of tracks being close to the shore. This is a fan-like pattern already mentioned above (Fig. 3). At Aillebrack (Fig. 6a) the increased track creation at 500 to 750 m from the HWM is due to the road which bisects the site at a distance of 500 to 600 m from the HWM, leading to increased traffic around the area. From the road cars are accessing both sides of the site and the landward side of the site shows an increased number of tracks where it borders a lough (lake). The pattern at Mannin (Fig. 6c) is more limited as the site is only 300 to 400 m wide.

At Truska/Doonloughan (Fig. 6b) the graph shows tracks to be present at all distances from the shore. This site has one main beach, False Bay, which is located 1 km from the road. Although most of the tracks lead to this beach none follow a straight line but they meander, branch and rejoin throughout the site (Fig. 3b). These tracks cover the whole extent of the site, showing the same fan pattern from the access points as in evident at the other two sites. However the distribution of tracks within distance zones from the shore displayed in Fig. 6 differs from the other two sites. This is due to the fact that the site is triangular is shape, with the distance between the road and the shoreline ranging from 0 m to 1.5 km at Truska/Doonloughan. Therefore, the measurement of track density according to distance from the HWM, results in similar numbers of tracks measured at all distances. At Truska/Doonloughan and Mannin very few tracks are present within 100 m of the HWM. This can be attributed to the fact that there are mostly rocky and sandy shores within this area which are not accessible for vehicles, although the few areas that are accessible show increases in tracks in 2005 and 2007.

Overall the distribution of tracks shows that there are a higher number of tracks at the shore, which seems to be the

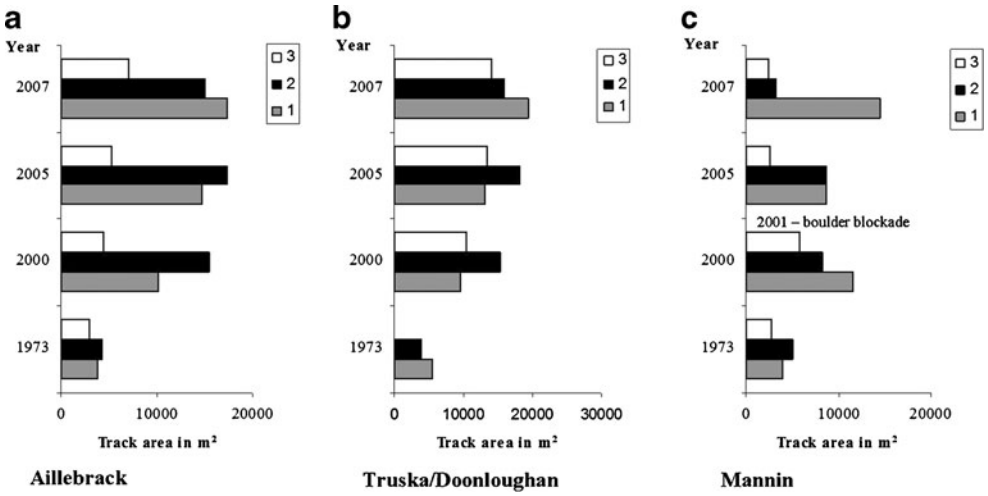

Fig. 5 a, **b** & **c** Changes in track cover for all three track categories (1, 2 & 3) over time for all three study sites, Aillebrack (**a**), Truska/Doonloughan (**b**) and Mannin (**c**), in m^2

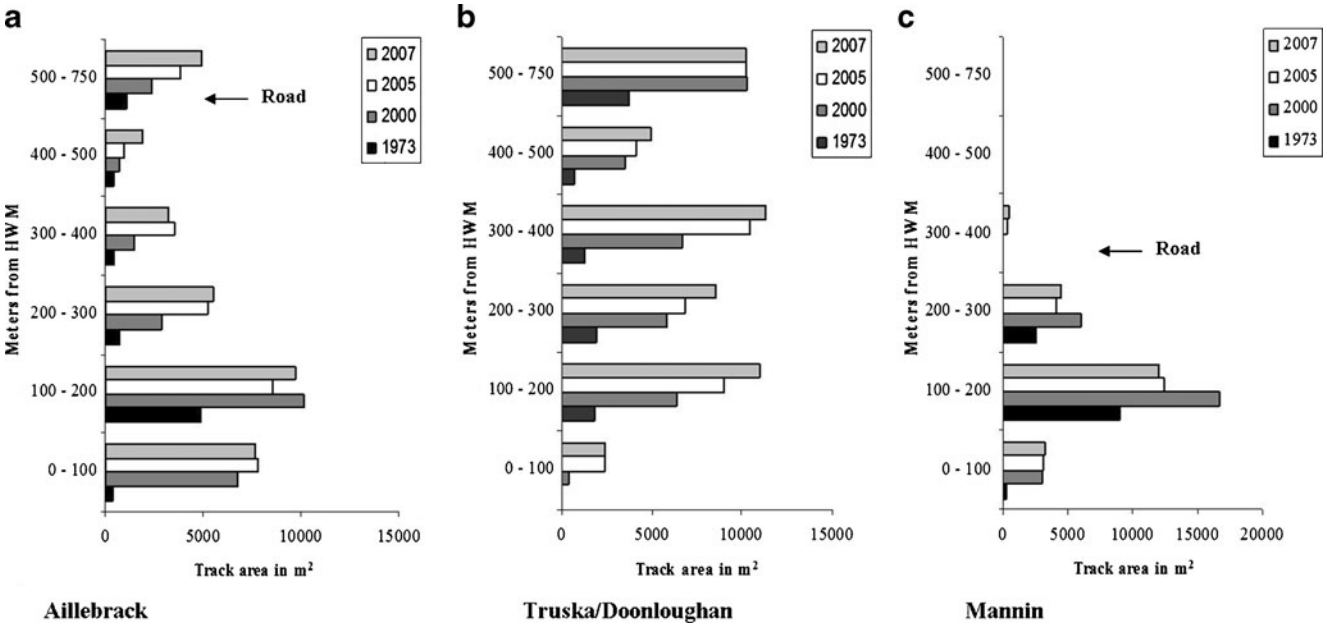

Fig. 6 **a**, **b** & **c** Distribution of track area at all three study sites, Aillebrack (**a**), Truska/Doonloughan (**b**) and Mannin (**c**), in m^2 in relation to the shoreline, indicated by the High Water Mark (*HWM*)

main target of vehicles crossing the sites. Most of the tracks also terminate at the shore (Fig. 3), which indicates that most people who travel to the site and travel across it wish to access the beaches for recreational activities. This is further confirmed by observation and results form the indicator questionnaire. Observations made at site visits showed that recreationists visited the sites to go swimming, walking or surfing. This was confirmed by the questionnaire results, which showed that when questioned on the primary activity recreationists came to carry out those three activities scored highest (29% swimming, 21% surfing, 16% walking). Where the answer 'walking' was given, the addition 'by the sea' was made by 90% of respondents. These results indicate that recreationists came to the site to carry out these water-based activities, making it evident that the majority of recreationists coming to the sites do so with the specific aim of spending their visit on the beach or in the water. This corresponds to the track creation patterns in that most tracks created were within close proximity of the HWM and hence the shore. Access to the shore is the main objective of the majority of visitors to all three study sites. Further evidence of this was found when observing the parking patterns recreationists exhibited at the sites. Most recreationists drove to the sites (85% according to questionnaire results), with the remainder having walked or cycled (2% of interviewees). The closest form of public transport, the bus stop in Ballyconneely, is over 2 km away, therefore the easiest form of access for those who travelled from further away was the car. Hence the parking of vehicles was of interest, especially since only one of the sites (Aillebrack) had a car park near by. Most recreationists were observed parking near the beaches of the sites, on the machair and fixed dune habitats closest to the sandy shores. Again the questionnaires gave further proof of this behaviour, with 54% of people stating that they had parked on the dune grasslands, while 17% stated they had parked on the actual beaches. At the site where access was limited, people had also parked at the road verge (57% of interviewees at Mannin) while at Aillebrack, where a car park and caravan park were available, recreationists had also used these facilities for parking (4% of the total number at each facility). Since the main road runs through the site and is only about 500 m away form the shore, the distance to get to the shore is not too great at this site, which also seems to encourage people to park at the road side (21% of interviewees at Aillebrack). Aillebrack also had a higher percentage of people (15% of those asked), who came to carry out activities such as golf which would promote parking away from the shore as the sea was non-essential to the carrying out of those activities. This suggests that where access is restricted, fewer recreationists will park on the dune grasslands, while where facilities are provided, these will be used. At Truska/Doonloughan, which has open access from the road and where there are no parking facilities provided, all respondents had either parked on the beach or the dune habitats behind this. At this site the link between activities and parking is particularly obvious since most people come to surf. This is only possible at one of a number of beaches at the site (False Bay) which is about 1 km from the road into the site. To get

to the site people drive across the site and park their car either on the grassland by the beach or even on the surfing beach itself to avoid having to carry their equipment long distances.

Overall, considering all three sites, the fact that visitors parked on the grassland, which includes the priority habitat machair, corresponds to the vehicular traffic across the site and the activities people stated to be carrying out at the sites. However, what is evident is that even simple measures, such as limited access or even the provision of parking facilities, has some impact on the behaviour of recreationists on site. A further indication of this is the response interviewees gave in relation to their knowledge of the conservation status of the sites visited. Of those asked, the majority (62%) were not aware that they were visiting a site of conservation status and 77% felt that the information available on the conservation site was inadequate. While the number of interviewees was limited, it still gave an indication that if information were available it might influence the behaviour of those visiting the sites for recreation purposes.

Management options

Considering the conservation status of the studied sites and the impacts of vehicle traffic across the dune systems by recreationists, the need for management of these and other coastal dune systems becomes apparent. In order to prevent damage to conservation sites while still allowing for recreational activities to take place, management in required. Orams (1995) suggests four visitor management strategies for the management of wildlife tourism which can be applied to any natural area under recreational pressure (I-Ling 2002). These are: a) physical management; b) regulatory management; c) economic management; and d) educational management. These should all be considered as possible options in relation to the management of coastal areas used for recreational activities.

a) Physical management strategies: relate to physical structures which may be put in place to manage visitors to sensitive areas (McArthur and Hall 1993; Curthoys 1998). In relation to recreationists using vehicles in conservation areas, this would include access routes, for example paved or gravelled paths, but also fences to stop visitors from entering sensitive areas. The positive effect of this can be seen in this study at the Mannin site, where track creation was reduced due to limited access. Car parks, which in some cases are limited in size to keep visitor numbers down, could also be used. The results at Aillebrack suggest that the presence of car parks may also reduce the number of vehicles driving and parking on a conservation site. In dune systems it is important to consider the dynamic nature of these habitats and to avoid disturbing the dynamics of these systems when constructing any facilities (Van der Meulen and Salman 1996).
b) Regulatory management strategies refer to establishing and imposing rules and regulations for sites to ensure visitors to a site behave appropriately during their visit (Orams 1995). This would include restricted access at certain time periods, the prohibition of certain behaviour such as speed and noise limits or prohibition to have camp fires.
c) Economic management strategies use pricing to influence visitor behaviour. By charging for access to a certain resource or charging for parking, some visitors will be disinclined to visit the site and this will reduce visitor numbers (I-Ling 2002). Another way to apply this strategy is by imposing fines for undesirable behaviour, for example fining people for camping outside of designated areas or for driving outside of designated routes.
d) Educational management refers to the provision of information and interpretation material relating to a resource which is being used by tourists and recreationists (Cooper et al. 1998). Inappropriate behaviour is often the result of the fact that visitors are unaware of the sensitivity of an area, and the provision of information may influence visitor behaviour.

When considering these management strategies it is important to realise that not all will be suitable for a certain site and not all strategies will always be required at the same site or at the same time. However, it is also important to realise that different strategies may need to be employed in combination with each other to be successful. For example educational strategies tend to be required for physical and regulatory management to be successful as people are more likely to use facilities and comply with regulations if they are aware of the reasons for their application.

The question is which management strategies should be employed to successfully manage coastal SACs containing sand dune systems to ensure their conservation while also allowing recreational activities to take place. When considering which management option is most suited to the situation at a site, all factors investigated were taken into account. This includes the current state of the site in relation to damage and visitor activity at each site.

There is often a lack of knowledge in relation to damaging activities and in relation to the status of an area. In this case there is a need for information, which can only be provided by introducing educational measures. These include educational signs or panels at each of the sites, firstly to label the site as a conservation site, but also to

provide information on the different habitats and features present at the sites. For coastal conservation sites the signs should include information on the dune habitats present at the sites, in particular machair or other priority habitats, while also providing information on special animal and plant species present at the sites. Attention should be paid to special features present at the sites, as for example at Truska/Doonloughan and Mannin which contain archaeological sites which should also be included in the information panels. The aim is for the signs or panels to inform visitors, encourage desirable behaviour on the sites and also to ensure visitors are safe.

In order to further encourage visitors to behave in a manner that ensures enjoyment of the site on their part but also prevents damage to the sites, the educational signs could also include regulatory measures in the form of behaviour rules. The introduction of rules improves the effectiveness of the above measures as clearly stated rules will encourage positive behaviour such as the use of physical facilities and discourage inappropriate behaviour of which visitors were previously unaware. These rules in combination with the site information will provide visitors with insight as to why these rules are necessary and how desired behaviour can protect the sites and their features. At sites where vehicle damage is a problem the regulatory rules should restrict vehicle use to prevent further damage to the dune habitats present. In relation to regulations this includes the signposting of existing car parks or other facilities that may be available.

At sites suffering from vehicle related damage, where track creation shows direct links to the recreational activities carried out at the sites, there is a need to control vehicle access. This can be done by limiting access points to the site, for example by fencing the site and providing gates allowing only pedestrians onto the site. If fencing is undesirable, which can be the case if sites are used for additional purposes such as animal grazing, then other methods of vehicle restriction should be considered. This could for example be facilitated by a series of pollards, preventing cars from entering but allowing free passage to livestock or by using low beams or railway sleepers which are low enough to be stepped over by livestock. Further options to be considered here are the provision of car parking facilities and the provision of roads or set tracks into the sites. In relation to this it is important to consider current parking patterns of visitors and the uses of the site to optimise the effectiveness of these facilities. However, it is also important to include the views of visitors in this who had reservations about the creation of those kinds of facilities. At Aillebrack, the site where car parking is provided close by, this essentially means the prevention of vehicles driving into the site and possibly providing additional car parking.

Economic management options are generally employed to reduce or control the visitor number to an area. These should only be considered where excessive numbers of recreationists frequent a site. If it is simply recreationists' behaviour that is causing the problem, then economic measures would be unnecessary. The above mentioned management measures should be sufficient to ensure conservation of the sites by providing information, regulation and facilities to prevent further major damage to the sites.

For all these measures to be successful it is important to ensure landowner involvement, first and foremost for their permission to implement the measures but also for their support as case studies suggest that the involvement of locals in the management processes is most effective when it is co-operative, collaborative, representative of the local community, informed and committed to the common agenda (McLeod et al. 2001).

Conclusions

The scenic landscapes of Ireland are one of the country's most valuable resources. A survey by Fáilte Ireland (the Irish tourist board) revealed that, in 2005, 82% of tourists who came to Ireland rated scenery as a main reason for visiting the country, while 77% said the natural unspoilt environment was a big attraction for them (Matthews 2006). If the tourism industry wants to ensure further growth of the industry, it is essential that the natural habitats of Ireland are maintained. This requires management. At the same time it is essential that Ireland complies with its European obligations to protect its valuable habitats in accordance with the Habitats Directive (92/43/EEC). This also requires management. As both tourism and conservation rely on the maintenance and possibly improvement of natural areas and since the two impact on each other, it seems obvious that the management strategies of nature conservation areas should include recreation management. This study aimed to assess the impacts of recreation, which is a vital part of the tourism sector, on coastal conservation areas containing sand dune systems and interpret the needs of both conservation and recreation to sustainably manage the sites.

To date, uncontrolled access has caused environmental degradation to the Slyne Head cSAC dune systems. Vehicle movements by visitors have damaged the dune habitats, have created tracks throughout the sites which have worsened with increased vehicular traffic on the sites. As the main point of focus for the activities at the sites is the sea, most traffic movement is directed towards the shore and within the first few hundred meters of the HWM is where most tracks are found. This is most likely the case in any coastal dune system which is accessible to vehicles and

where recreationists use cars to get to their destination. In order to control these impacts on the coastal dune systems, management is required.

The examples given in this study suggest that even the provision of simple measures may be sufficient to reduce track creation and erosion due to vehicle traffic over dune grasslands. Orams (1995) suggests four different strategies for the management of visitors to wildlife areas. These should all be considered when trying to find management solutions for coastal dune areas under recreational pressure. However, it is essential to assess damage caused by recreationists at each site, and consider the usefulness of each of the management options accordingly.

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References

Andersen UV (1995) Resistance of Danish coastal vegetation types to human trampling. Biol Conserv 71:223–230

Andrés-Abellán M et al (2005) Impacts of visitors on soil and vegetation of the recreational area 'Nacimiento del Río Mundo' (Castella-la Mancha, Spain). Environ Monit Assess 101:55–67

Angus S, Elliott MM (1992) Erosion in Scottish machair with particular reference to the Outer Hebrides. In: Carter RWG, Curtis TG, Sheehy-Skeffington MJ (eds), Coastal dunes: geomorphology, ecology and management for conservation. Rotterdam, Balkema, pp. 93–112

Burden RF, Randerson PF (1972) Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. J Appl Ecol 9:439–457

Cabot D (ed) (1977) An overview of the Irish situation. An Foras Forbatha

Catto N (2002) Anthropogenic pressures on coastal dunes, southwestern Newfoundland. Can Geogr 46:17–32

Cole DN (1995a) Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. J App Ecol 32:203–214

Cole DN (1995b) Experimental trampling of vegetation. II. Predictors of resistance and resilience. J Appl Ecol 32:215–224

Coombes EG, Jones AP (2010) Assessing the impacts of climate change on visitor behaviour and habitat use at the coast: a UK case study. Glob Environ Change (in press, corrected proof available online 18 January 2010)

Cooper C, Fletcher J, Gilbert D, Wanhill S (1998) Tourism Demand. In: Sheperd R (ed) Tourism: Principles and practices 2nd ed. Addison Wesley Longman, Essex

Crawford I, Bleasdae A, Conaghan J (1996) Quadrat Data from the Western Coastal Survey, 1996: Dublin, National Parks and Wildlife Service

Curr RHF, Koh A, Edwards E, Williams AT, Davies P (2000) Assessing anthropogenic impact on Mediterranean sand dunes from aerial digital photography. J Coast Conserv 6:15–22

Curthoys LP (1998) Ramsay Canyon Preserve, Arizona: a case study in successful small protected area management. Nat Areas J 18:28–37

Dúchas—The Heritage Service, The Department of Agriculture FaRD (2001) Manual for the production of grazing impact assessments in coastal habitats. Dúchas—The Heritage Service, Department of Agriculture, Food and Rural Development, Dublin

Fossitt J (2000) A guide to habitats in Ireland. The Heritage Council, Dublin

Gibbons EK, Kelly EP (2003) A viking age farmstead in Connemara. Archaeol Irel 17:28–32

Gilbertson D et al. (1995) The Machair vegetation of South Uist and Barra in the Outer Hebrides of Scotland: its interacting ecological, geomorphic and historical dimensions. Institute of British Geographers 32:17–44

Gosling P (1993) Archaeological inventory of county Galway (West Galway). Stationary Office, Dublin

Gremmen NJM, Smith VR, van Tongeren OFR (2003) Impact of trampling on the vegetation of Subantarctic Marion Island. Arct Antarct Alp Res 35:442–446

Heritage Council (2002) Habitat survey guidelines: a standard methodology for habitat survey and mapping in Ireland—draft. Heritage Council, Dublin

Hylgaard T, Liddle MJ (1981) The effect of human trampling on a sand dune ecosystem dominated by Empetrum nigrum. J Appl Ecol 18:559–569

I-Ling K (2002) The effectiveness of environmental interpretation at resource-sensitive tourism destinations. Int J Tour Res 4:87–101

Joint Nature Conservation Committee (2000) Maritime communities and vegetation of open habitats, vol. 5. Cambridge University Press, Cambridge

Joint Nature Conservation Committee (2003) Handbook for Phase 1 habitat survey—a technique for environmental audit, vol 1. JNCC, Peterborough

Liddle MJ (1975) A selective review of the ecological effects of human trampling on natural ecosystems. Biol Conserv 7:17–36

Liddle MJ, Greig-Smith P (1975a) A survey of tracks and paths in a sand dune ecosystem I. Soils. J App Ecol 12:893–908

Liddle MJ, Greig-Smith P (1975b) A survey of tracks and paths in a sand dune ecosystem. II. Vegetation. J App Ecol 12:909–930

Love J (2003) Machair. Scottish Natural Heritage, Perth

Luckenbach RA, Bury RB (1983) Effects of off-road vehicles on the biota of the Algodones Dunes, Imperial County, California. J Appl Ecol 20:265–286

Marine Institute (1999) Ireland's marine and coastal areas and adjacent seas. Marine Institute, Galway

Matthews P (2006) Tourism in Ireland—The environment challenges: heritage outlook—the magazine of the Heritage Council, 22–24

McArthur S, Hall CM (1993) Visitor management and interpretation at heritage sites. In: Hall CM, McArthur S (eds) Heritage management in New Zealand and Australia: visitor management, interpretation and marketing. Oxford University Press, Auckland, pp 18–39

McCormick F, Gibbons M, McCormac FG, Moore J, Weir D, Alison S (1996) Bronze age to Medieval coastal shell Middens near Ballyconneely, Co. Galway: J Ir Archaeol 7:77–84

McLeod M, McKenna J, Cooper A, Power J (2001) Community group involvement in rural beach and dune management. Tearmann 1:101–113

Met Éireann (2008) Climate of Ireland. http://www.meteireann.ie/climate/rainfall.asp. Last cited 26 Jan 2009

Nairn R (2005) Ireland's coast. The Collins, Dublin

National Parks and Wildlife Service (1998) Conservation plan for NATURA 2000 Sites—Slyne Head Peninsula SAC (candidate Special Area of Conservation), Co. Galway. National Parks and Wildlife Service, Dublin

National Parks and Wildlife Service (2003) Slyne Head Peninsula SAC Site Synopsis http://www.npws.ie/en/media/Media,4147,en.pdf. Last cited 26 Jan 2009

Neto F (2003) A new approach to sustainable tourism development: moving beyond environmental protection. Nat Resour Forum 27:212–222

O'Donnell G (2005) personal communication, National Parks and Wildlife Service

O'Flaherty C (2006) personal communication, Farmer & Local Resident

O'Hagan AM, Cooper A (2002) Spatial variability in approaches to coastal protection in Ireland. J Coast Res, SI 36, 544–551

Orams MB (1995) Using interpretation to manage nature-based tourism. J Sustain Tour 4:81–94

OSi (1973) Aerial photographs no. IGN L_0155

OSi (2000) [digital raster map] West County Galway. Ordnance Survey Ireland

OSi (2000) Aerial photographs nos. 02929A, 02929B, 02929C, 02929D, 02930A, 02999A, 02999B, 02999C, 02999D and 02861C

OSi (2003) Six inch map No. GY 063. OSi, Galway

OSi (2004) Aerial photographs nos. 04929A, 04929B, 04929C, 04929D, 04930A, 04999A, 04999B, 04999C, 04999D and 04861CC

OSi (2006) Aerial photographs no. FMK_06_8069

Pinho L (2007) The role of maritime public domain in the Portuguese coastal management. J Coast Conserv 11:3–12

Priskin J (2003) Physical impacts of four-wheel drive related tourism and recreation in a semi-arid, natural coastal environment. Ocean Coast Manag 46:127–155

Provoost S, Ampe C, Bonte D, Cosyns E, Hoffmann M (2004) Ecology, management and monitoring of grey dunes in flanders. J Coast Conserv 10:33–42

Quigley MB (1991) A guide to sand dunes in Ireland. European Union for Dune Conservation and Coastal Management, Dubin

Schofield JM (1967) Human impact on the flora, fauna and natural features of Gibraltar Point. The Conservancy, Monks Wood Symposium, No. 3. Cited in: Burden RF, Randerson PF (1972) Quantitative studies of the effects of human trampling on vegetation as an aid to the management of semi-natural areas. J Appl Ecol 9:439–457

Tourism Policy Review Group (2003) New horizons for Irish tourism—an agenda for action. Ministry for Arts, Sport and Tourism, Dublin

van der Meulen F, Salman AHPM (1996) Management of Mediterranean coastal dunes. Ocean Coast Manag 30:177–195

Weaver T, Dale D (1978) Trampling effects of hikers, motorcycles and horses in meadows and forests. J Appl Ecol 15:451–457

Westhoff V (1967) The ecological impact of pedestrian, equestrian and vehicuar traffic on vegetation. IUCN Publ New Ser 7:218–223

Wilcock F (1977) The formation and erosion of sand dunes. In: Young R (ed) Planning for the use of Irish sand dune systems. Conference Proceedings, An Faras Forbatha, Wexford