AN ENVIRONMENTAL APPROACH TO THE RESTORATION OF BADLY ERODED SAND DUNES

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ABSTRACT

On a coastline where the natural beach/dune system is essentially stable, the ability of the sand dunes to recover from degradation caused by human activities is seriously impaired, even when conventional remedial techniques are employed. This paper presents a short report on an experimental regrading scheme which has shown that the initial smoothing of the foredune profile by bulldozer is beneficial to ecological recovery. It is felt that this method is the only practical alternative in such areas, and that ecologists, planners and conservationists should not be reluctant to employ engineering techniques if environmental conditions warrant their use.

INTRODUCTION

From experience of dune restabilisation in Northern Ireland, this paper advocates that a more broadly based approach should be made to sand dune restoration problems, particularly at a time when the existing ecological/engineering approach is being critically questioned (Dolan, 1972; Adriani & Terwindt, 1974; Godfrey & Godfrey, 1974) and also becoming more expensive (Bruun, 1972). There is an urgent need to examine and understand whole coastal systems both from physical and biological viewpoints, and subsequently to design restoration and management to fit specific site factors. In particular, effective management can only be based on a sound knowledge of environmental systems *in toto*.

The first part of this paper describes the nature of the erosion problem at Portrush dunes and early unsuccessful attempts at dune restoration. The second part examines the nature of physical processes on the coastline, and the environmental constraints placed on the choice of restoration technique. The third, and final, part compares the relative success of three dune restoration programmes, one of them a

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regrading technique designed to meet the limitations imposed by the physical environment, and two others both in widespread use but involving more conventional methods.

THE PORTRUSH SAND DUNES

Vegetation and recreation pressure

At Portrush, Co. Antrim (lat. 55°12′ N, long. 06°39′ W), a small area (*c.* 160 ha) of sand dunes is intensively used for a variety of active and passive recreational pursuits. Throughout these dunes, dune grassland communities predominate with *Festuca rubra*, degenerate *Ammophila arenaria*, *Rosa pimpinellifolia* and *Pteridium aquilinum*. Both wet and dry slack communities are absent due to the height of the inland dunes (+6·0 m OD, Belfast, at lowest point) and the fact that most low-lying or level ground is occupied by golf course greens or fairways. Calcium carbonate levels in the dune sands are less than 5% and usually absent from the well-leached humic soils. The seaward fringe of the dunes comprises a dune ridge 100 m broad and up to 22 m in height. Here there is considerable diversity of species dominated by *Ammophila*, *Festuca*, *Trifolium repens* and *Lotus corniculatus*, plus many exotic introductions. A successional series of yellow dune habitats characteristic of prograding coastlines is absent and pioneer communities on seaward slopes abut directly onto the closed dune grassland of *Festuca* and *Ammophila* tussocks.

Public access to the dunes is predominantly from the west, adjacent to the town, or via the beach. The presence of the golf course somewhat reduces the area available for informal recreation with the result that the western frontal dunes are under the heaviest pressures (Anderton, 1970). Erosion of these dunes has become a major problem since 1945, damage paralleling the rising demand for leisure activities and continuing expansion of Portrush as a residential resort, particularly through the growth of caravan sites. By 1969, most of the seaward dunes near the town showed signs of severe recreation damage, with the creation of a dense network of bare paths and irregular relief caused by the development of gullies, hummocks and large blow-outs. In places the dune crest had been breached by active gully and blow-out erosion and windblown sand was accumulating inland. In addition to dune erosion, winter storms in 1967 caused marine under-cutting of the seaward faces, accentuating slope angles and initiating avalanches and rotational slumping.

Initial attempts at dune restoration

In 1969 and 1970 some areas of eroded dune were closed to public access and a conventional, but limited, programme of brushwood fencing, thatching and marram planting was carried out. Although these measures appear to have arrested the landward extension of blow-out development (Oldfield *et al.*, 1973), the work was largely unsuccessful in promoting an environmental recovery of the area. The main reasons for this failure were:

(i) Fences built on steep slopes provided only a small horizontal shelter distance, and sand accumulations tended to be highly localised around fences with wind erosion continuing between them. This problem was aggravated by cross-winds parallel to the fences. Therefore the fences simply added to the irregularities of the dune profile and a close network of fences was required to protect bare surfaces from wind deflation. However, where this close-spacing technique was applied, sand accumulations were restricted to fences nearest the sand source, as increased surface roughness of the fenced area reduced the ability of the wind to disperse sand over a wide area. Thus it became apparent that a sand build-up around closely spaced fences would involve a long period of time, which would be unacceptable to both recreation and management demands.

(ii) Where sediment supply was low, particularly near the dune crest, fences were often undermined from the windward side by scouring, eventually resulting in collapse.

(iii) Fences were erected at the rear of the beach with the intention of accumulating foredunes, but these showed no consistent build-up of sand, except for short periods after storm erosion of the beach. Unfortunately many fences were damaged during storm episodes and therefore were unable to accumulate sand efficiently unless repaired quickly.

(iv) Planted marram showed few signs of growth, particularly on steeper slopes (this has been noted before, see Sluiter (1966)), and even where sand accumulated, establishment was inconsistent.

It became apparent that conventional restoration methods were of little value at Portrush, and a full study of beach and dune environments was undertaken in order to identify factors controlling the coastal system. Results of this investigation are summarised below.

THE COASTAL SYSTEM

Coastal changes

Studies by Oldfield *et al.* (1973) and Carter (1975*a, b*) have shown that the coast from Portrush to Magilligan (21 km west)—see Fig. 1—is essentially stable. Minerogenic sediments are almost entirely 'fossil', having been derived from glacial or fluvio-glacial deposits, subsequently sorted and incorporated into the beaches and dunes during Flandrian sea-level changes. No major recent sources or supplies of sediment exist. Coastal changes occur largely as a response to variations in Atlantic swell waves and local weather conditions, but with a relatively low season-to-season magnitude. Over the last 200 years there is some evidence for cyclic coastal changes of between 10 and 40 years duration, probably reflecting secular variations in climate. Since 1966 severe winter storm erosion has occurred regularly, resulting in a periodic retrimming of the seaward dune slopes, but average overall cliff retreat during the last 10 years is less than 1·0 m year^{-1}.

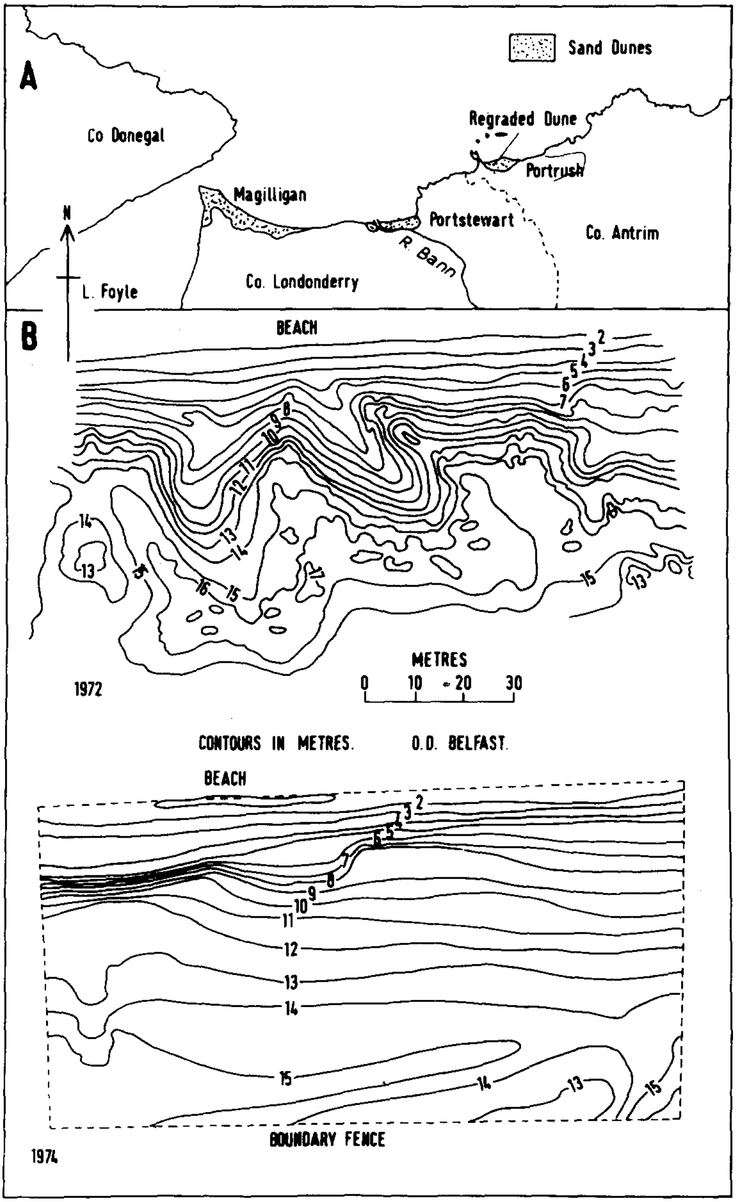

Fig. 1. A. Portrush study area. B. Before (1972) and after (1974) contour maps of the dune regrading site.

Sediment supply to the dunes

Local evidence of stable beaches, general lack of natural foredune development and paucity of artificially induced sand accumulation all suggest that surplus sand, other than that involved in seasonal cycles of sand exchange between offshore, beach and dunes, is not available for new dune building. Weekly monitoring of sand levels at 24 localities along the coast have revealed the existence of three modes of sediment supply all linked to beach processes. These are:

(i) Storm recovery accumulations—marine erosion of the beach and dunes during storms results in a rapid post-storm accumulation of windblown sand back to the level of pre-storm conditions (Fig. 2A).

(ii) Swash bar controlled accumulations—in some areas where wave activity is reduced through shelter the shoreline exhibits a tendency to accrete extensive swash bars during spring and summer, sand blows from these bars to form foredunes (Fig. 2B).

(iii) Variable sand accumulations controlled by wind—when and where neither storm nor bar control is pronounced, backshore sand accumulation tends to be variable, probably reflecting the constant shifting of a small quantity of sand by wind processes (Fig. 2C).

At any point on the coast, processes of sand deposition on the foredunes are controlled by wind speed and direction. Two-thirds of potential sand moving winds are in an off-shore direction and much sand is returned to the beach from the dunes. However, in recent years during increased wind activities the percentage of on-shore sand moving winds has increased by 80% and off-shore winds by 55% (Oldfield *et al.*, 1973).

In 1970, under favourable post-storm conditions of supply and process a maximum sand accumulation rate of 1 $m^3\ m^{-1}\ month^{-1}$ was observed at Portrush (Fig. 3), but at most other times the lack of a regular sand supply has resulted in negligible sediment accretion.

In addition to these major controls, sand supply rate to foredune is also influenced by the textural character of the sediment (Carter, 1976) and possibly by the nature and intensity of recreation pressure (Carter, 1975*b*).

Environmental constraints on the choice of restoration scheme

Against this background of a stable ecological system and a quiescent physical one, it is apparent that intense recreation pressure and its consequences are the major factors promoting degradation and instability, while there is little scope for natural recovery. Also, because of the confined site and high relief any proposed remedial measures would require careful planning if both amenity and protective functions of the dunes were to be preserved.

Elsewhere, restabilisation schemes have been successful where surplus sand allows

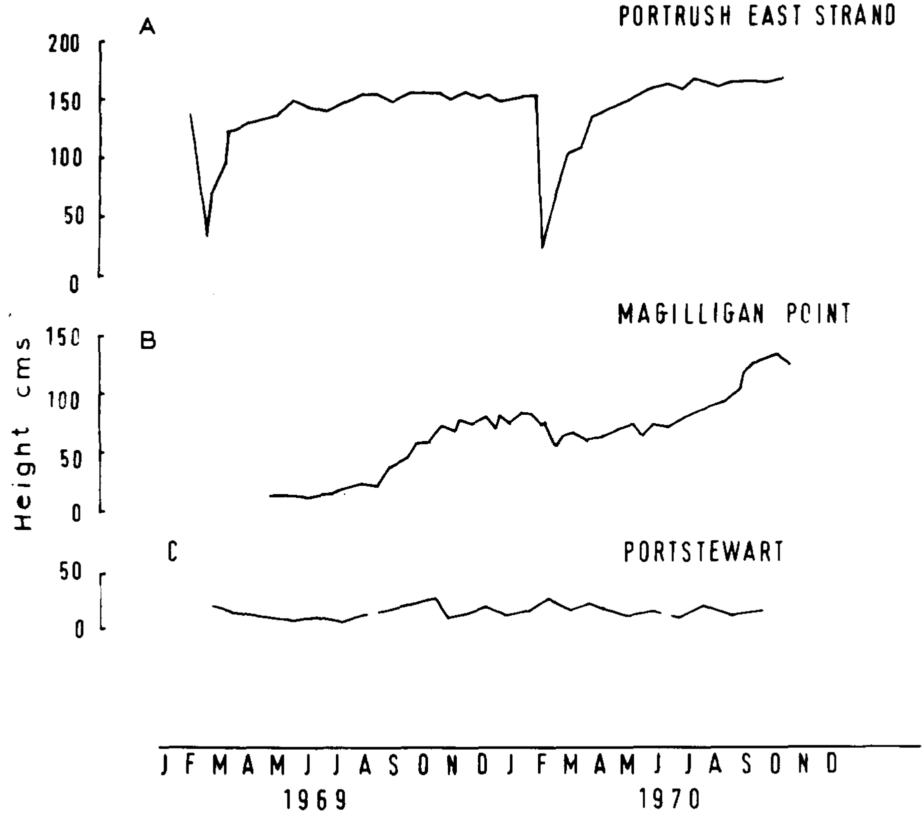

Fig. 2. Three types of sand accumulation: A. Storm (erosion) controlled; B. Swash bar (accretion) controlled; C. Wind controlled. The three graphs show the changes in level of the foredune summits relative to arbitrary datum points.

grasses to establish. Attempts to apply methods developed in such environments have proved unrealistic at Portrush, where sediment supply is low and relief high. Also, where there is no net input of sediment, conservation of sand in the beach/foredune exchange cycle is seen as essential to the continued stability of shoreline processes and hence maintenance of the present position of the duneline. Any scheme which either promotes or condones the finite removal of sand from this system or permanently traps sand on the dunes (thus increasing the relaxation time of the system), as is inherent in the conventional approach, is not appropriate to this environment. Attempts to do this may cause depletion and lowering of the backshore zone and create conditions favourable to shoreline recession. To avoid these problems and, in particular, to allow a potential for natural beach/dune exchange processes to continue, the following technique was adopted, and compared to more conventional methods.

Fig. 3. Foredune growth at Portrush in the summer of 1970, indicative of the maximum possible development under favourable conditions.

DUNE RESTORATION, AT PORTRUSH

In 1973, 10,000 m^2 of badly eroded dune was regraded into an aerodynamically stable form (similar to designs employed in the construction of aircraft hangers—see Chien *et al.*, (1951)) using a bulldozer. Marram was planted at 1 m intervals and covered by a mulch (*c*. 1 kg m^{-2}) of organic compost (Fig. 4). The extreme seaward edge of dune was not planted, allowing a measure of instability at the beach/dune interface, hopefully avoiding the over-strengthening problem experienced on the Outer Banks of North Carolina (Dolan, 1972). At the eastern end of the regraded area an existing dune blow-out was fenced, planted, mulched and thatched; while at the western end a similar area was left untouched. Public access to all three areas was restricted. The progress of each site was monitored at regular intervals.

Since 1973, the regraded dune was proved remarkably stable despite severe storms in both January 1974 and January 1975. In the summer of 1975 the dune surface accreted by 2–3 cm apparently by sand blowing from the eroding dunes to the west. Marram growth has been quite spectacular (Fig. 4); culms 20–30 cm high at planting are now 100–120 cm, and most plants flowered for the first time in 1975. Ground cover has extended from the initial 5–10 % to between 60–90 %. In 1974 and 1975 a

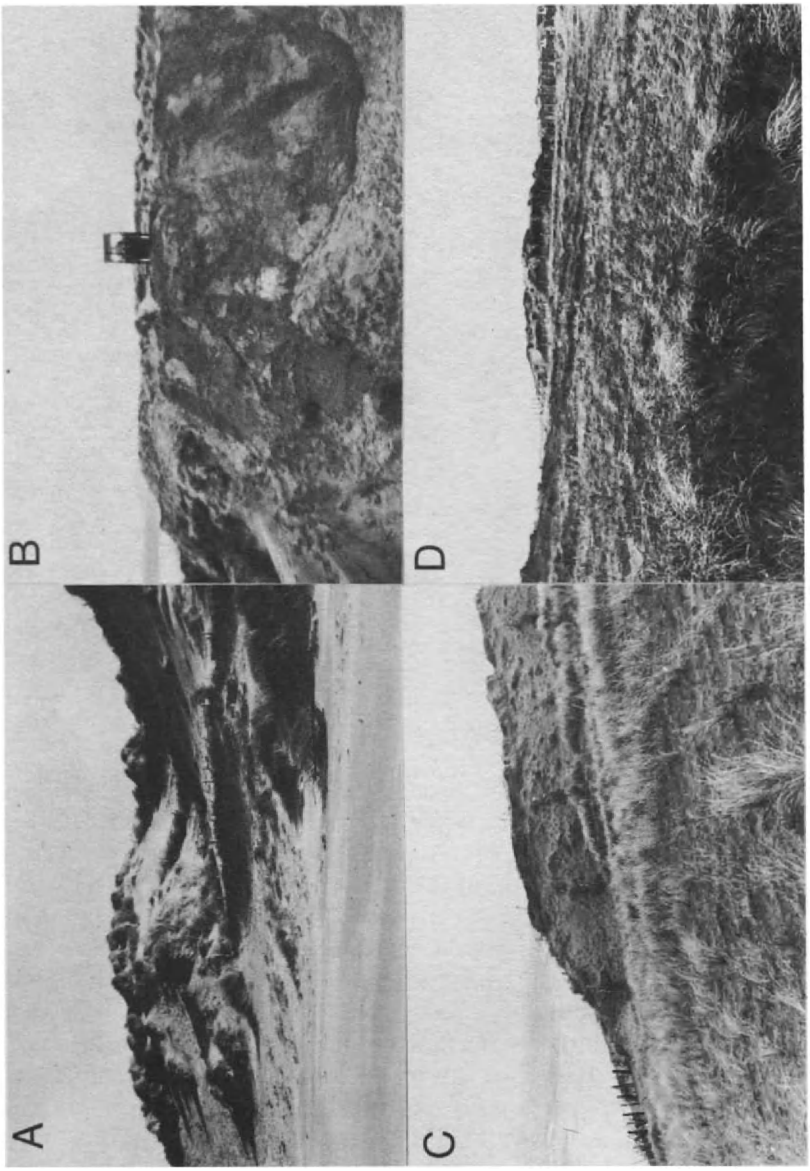

Fig. 4. The dune restoration sites, (A) before, (B and C) during, and (D) after (1976).

TABLE 1
LIST OF SPECIES INVADING REGRADED DUNE AT PORTRUSH

Festuca rubra L.
Agropyron junceiforme (A. & D. Löve) A. & D. Löve
Cirsium arvense (L.)
Tussilago farfara L.
Cerastium holosteoides Fr.
Euphorbia portlandica L.
Senecio jacobaea L.
Lotus corniculatus L.
Vicia angustifolia (L.) Reichard
Plantago lanceolata L.
Bellis perennis L.
Taraxacum officinale agg.
Hieraceum sp.
Leontodon sp.
Rumex sp.

small number of other species, listed in Table 1, appeared on the dune, mostly germinating on remnants of organic compost. By spring 1976 these had noticeably increased to around 10% ground cover, *Festuca* occupying the largest area.

By contrast (Fig. 5) the conventionally treated areas show very little change. There has been a minor build-up of sand against some fences mostly through the redistribution of sand within the blow-out, derived from avalanching on the steeper slopes. The planted marram has not flourished; on those slopes still actively eroding plants are degenerate, dead or missing; while on flatter slopes occasional plants have grown but not flowered. With the exception of odd plants of *Cirsium* and *Taraxacum* no other species have invaded the site.

In the third area erosion has continued as before despite restricting public access. At one point a deep gully has developed and extended into the margin of the regraded area.

One overall problem has been vandalism, particularly to the protective fencing. The seaward fence has been almost completely destroyed, and is now being rebuilt at a slightly higher level which will hopefully deter less athletic vandals. Inland, numerous gaps have been made in the fence either by people attempting a short cut from the caravan site to the beach, or by those seeking further seclusion. Already some paths have been formed across the regraded dune, the marram being highly susceptible to trampling pressures as low as 5/6 'passes' per week (Oldfield *et al.*, 1973). Interestingly, the conventionally treated blow-outs have not been invaded by the public to any noticeable degree, probably because closely spaced fences deter passage and the area has an appearance of being under restoration. In the untreated area, children, in particular, have continued to enter and play on the steep slopes.

There has been no attempt at Portrush to mount the type of public relations exercise which forms a popular accompaniment to many restoration schemes (for example, the methods used at Camber sands described by Pizzey (1975)), largely on account of

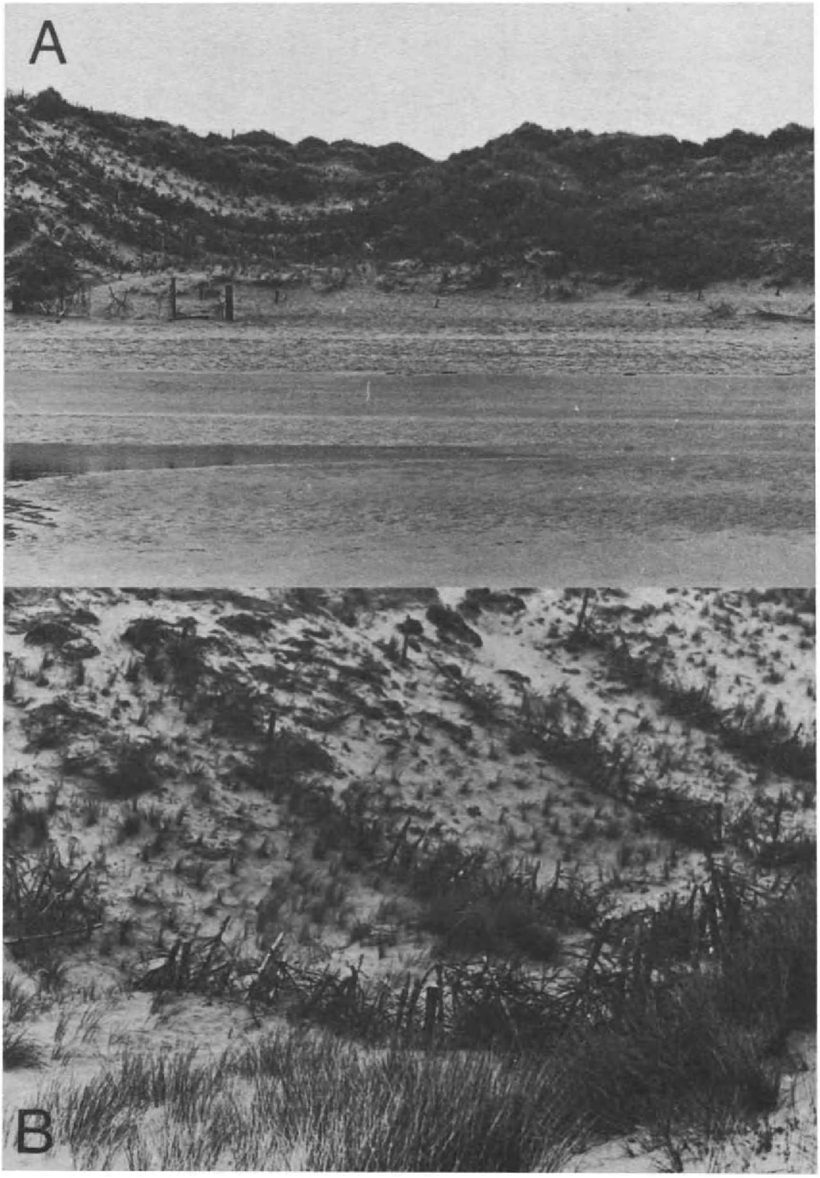

Fig. 5. Conventionally restored blow-out after 3 years. A. Comparison with the regraded dune. B. Close-up view of marram growth.

the previously known high rates of vandalism experienced in the area by both the golf club and the local authority. However, the scheme did receive some local press publicity.

SUMMARY DISCUSSION

The decision to regrade part of the Portrush dunes was not a 'last resort' technique in the face of almost complete physical break-up of the dune system due to intense recreation pressure as at Camber sands (Pizzey, 1975) nor as a response to an unattractive site (Barr & Atkinson, 1970) but was made on the basis that:

(i) conventional techniques were unlikely to be successful within a reasonable time, and
(ii) the beach/dune system was essentially stable with recreation pressure a dominant factor in the pattern of sand erosion. Once this information was available a realistic approach to the problem could be made, at a time when costs were not prohibitive and labour and equipment could still be provided at a local council level.

The three test sites emphasise a number of critical points:

(i) A smooth dune profile is an essential requirement for a stable dune.
(ii) Steep erosion slopes do not stabilise through marram planting alone.
(iii) Initially, at least, marram growth is more vigorous and spatially consistent on stable slopes provided that some additional nutrients are available.
(iv) Conventional restoration techniques are in themselves a deterrent to trespassers, while regraded areas are relatively attractive and therefore require more secure boundary fences.
(v) Great care must be taken to fix the boundaries of a restoration site at a point where (a) public pressure is either negligible or capable of being totally excluded, and (b) adjacent erosion cannot affect the restored site.

We believe that there is a reluctance among dune ecologists and conservationists to advocate the use of engineering methods, until the situation is past any type of reasonable control, at which stage the construction of new dunes becomes a costly and difficult business. An emphasis on biological aspects of conservation in dune areas has led to an attempted fixing of the dune topography in many sites, often ignoring the natural functioning of the physical environment. In particular, the partial mobility of the dune system, essential to continued stability, has often been mistaken for an erosion problem and the ability of the dune system to recover naturally has not been fully understood. This is partly due to lack of knowledge of physical processes which operate in the beach/dune environment and their relationship to biological factors. In one area, however, (Outer Banks, North Carolina) there is recent evidence that the maintenance of the natural ecology of barrier islands is highly dependent upon the unhindered operation of physical processes, including phases of erosion (Godfrey & Godfrey, 1974). Hence an appreciation of the physical environment *specific to each dune area* is essential before recommendations can be made to conserve the environmental system as a stable unit.

What we have attempted at Portrush is in no way innovative in terms of technique, but we feel we have been able to take a realistic decision many years before it might normally have been taken, and in so doing have saved time, effort and money. We do not see the bulldozer as a panacea for all dune erosion problems, and have restricted its use to dunes in the early stages of seral succession and in areas where natural recovery is slow and pressure high. In Britain, there are many dune systems that are geologically, geomorphologically and ecologically similar to Portrush, and it is suggested that the decisions and remedial measures described in this paper would be equally applicable elsewhere.

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REFERENCES

ADRIANI, M. J. & TERWINDT, J. H. J. (1974). Sand stabilisation and dune building. *Rijkswatst. Commun.*, No. 19, 68 pp.

ANDERTON, F. A. (1970). *A questionnaire survey of Portrush and Portstewart Strands.* Northern Ireland Tourist Board Report, 29 pp.

BARR, D. A. & ATKINSON, W. J. (1970). Stabilisation of coastal sands after mining. *J. Soil Conserv. Serv. N.S.W.* **26**, 89–107.

BRUUN, P. (1972). The history and philosophy of coast protection. *Proc. Conf. Coastal Engineering, Vancouver, July* 1972, 13th, 33–74. American Society of Civil Engineers.

CARTER, R. W. G. (1975*a*). Recent changes in the coastal geomorphology of the Magilligan Foreland. *Proc. R. Ir. Acad.*, **75**, (B24), 469–97.

CARTER, R. W. G. (1975*b*). The effect of human activities on the coastlines of Co. Antrim and Co. Londonderry. *Ir. Geogr.*, **8**, 72–85.

CARTER, R. W. G. (1976). Formation, maintenance and geomorphological significance of an aeolian shell pavement. *J. sedim. Petrol.*, **46**, 418–29.

CHIEN, N., FENG, Y., WANG, H. J. & SIAO, T. T. (1951). Wind tunnel studies of pressure distribution on elementary building forms. *Iowa Inst. Hydraulic Res.*, State Univ. Iowa, 32 pp.

DOLAN, R. (1972). Barrier Island dune systems along the Outer Banks of North Carolina: A reappraisal. *Science, N.Y.*, **176**, 286–8.

Godfrey, P. J. & Godfrey, M. M. (1974). An ecological approach to dune management in the National Recreation Areas of the United States East Coast. *Int. J. Biomet.*, **18**, 101–10.

Oldfield, F., Carter, R. W. G., Kitcher, K. J. & Wilcock, F. A. (1973). *Report into investigations of erosion and accretion on the coast lines of Co. Antrim and Co. Londonderry.* N.I. Ministry of Agriculture, 47 pp. (Unpublished).

Pizzey, J. M. (1975). Assessment of dune stabilisation at Camber, Sussex, using air photographs. *Biol. Conserv.*, **7**, 275–88.

Sluiter, G. B. (1966). Restoring a coastal dune. *Victoria Resources*, **8**, 71–2.