MORPHOLOGICAL CHANGES AT BRAUNTON BURROWS, NORTH-WEST DEVON

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A selective re-survey within the Braunton Burrows dune system reveals the location and degree of change in this highly dynamic environment. Areas of sediment gain, loss, and stability are compared with ground survey data from 1955-58 and from a photogrammetric survey in 1983. This latest work, therefore, establishes an observational time series (25 year and 12.5 year intervals) from which a clearer picture of progressive/regressive trends, both physically-based and man- induced, in the development of the system can be postulated.

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INTRODUCTION

Sand dunes cover much of the British coastline and many studies have described them from the point of view of contemporary physiography (Mather and Ritchie, 1977; Ritchie, 1979; Rose, 1980; Wright, 1981; Ritchie and Mather, 1984). However, comparatively little quantitative work has been carried out in terms of detailed scientific appraisal of their development over different time scales. The complex nature of the topography and the often rapidly changing morphology appear to have precluded serious attempts to establish base lines to monitor their expansion, contraction or movement on anything other than a very local scale. There have only been two detailed surveys of major dune areas carried out previously by photogrammetric means, that by Wright and Ritchie (1975) of the Sands of Forvie in north-east Scotland and by Glasgow University (1983) of Newborough Warren in Anglesey, North Wales.

Long-standing interest in physical geography research on Braunton Burrows by the University of Wales, Aberystwyth was initiated by the comprehensive large-scale ground survey carried out in the period 1955-58. Follow-up work involved a complete photogrammetric re-survey of the dune system beginning in 1983 and detailed topographic mapping was carried out for the complete Burrows area at a scale of 1:2,500 with a 2 m contour interval and vegetation overlay. Whilst the 25 year interval between the first two surveys allowed important questions to be answered on the degree and location of change, the extent to which these quantified changes could be extrapolated over time is limited. A series of repeat surveys, of which this present study is the first, of selected areas are required to establish a time series of observations from which a clearer picture of trends in the development of the system might be established.

THE AREA

Braunton Burrows is an area of sand dunes, measuring approximately 6 km north to south and over 2 km east to west, extending northwards from the estuary of the rivers Taw and Torridge in north-west Devon (Figure 1). It is a National Nature Reserve and, with international recognition by UNESCO, an International Biosphere Reserve. The complete dune system of just under 1000 ha is owned by the Christie Estate Trustees, but a southern portion of 603 ha is leased to the Ministry of Defence who have used it for military training since the last war. In fact, American troops used it in field training for the Normandy Landings. These activities caused a great deal of damage to the dunes and led to severe erosion problems. From 1964, the Nature Conservancy sub-leased these 603 ha from the MOD and manages the area for conservation of the dune system and the wildlife which it supports. Although not part of the "Burrows" proper, the inter- tidal area is the responsibility of the North Devon District Council.

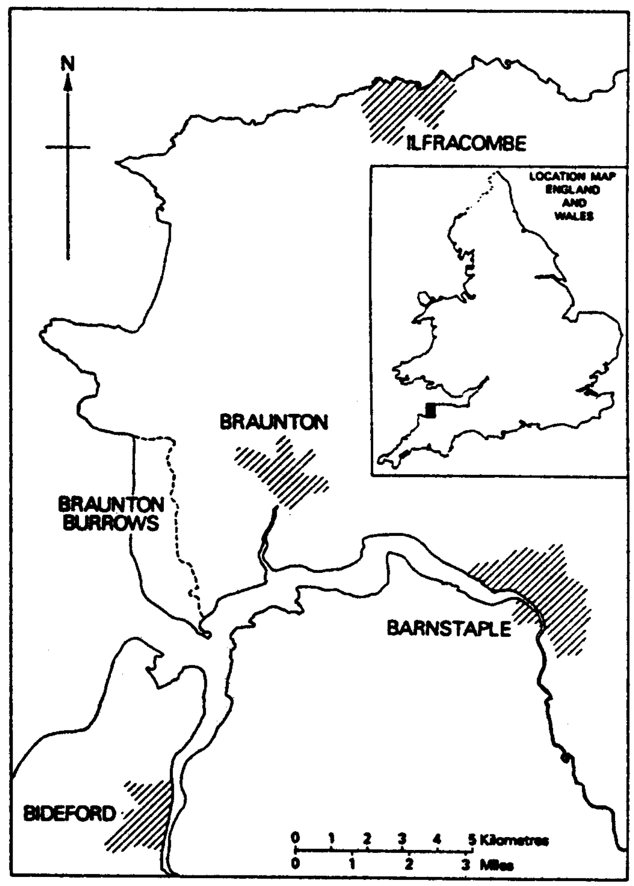

Figure 1. Location of Braunton Burrows.

The dunes are formed almost entirely of windblown sand of marine origin lying on a bedrock of cemented sandstone, marine clay and shingle. These shingle beds can be seen in some of the low-lying slacks. Much of the sand consists of crushed marine shells, identifiable fragments of which can be identified in the coarser sand. The overall form of the area is a series of high ridges of sand, oriented parallel to the coast and separated by the low-lying slacks across which stretch some cross-ridges and dune blow-outs. Marram has been the main sediment trap for the sand borne by the prevailing on-shore winds and dunes in excess of 40 m in some places have been formed.

SURVEY HISTORY

A ground survey was undertaken by the Nature Conservancy between 1955 to 1958 from 85 permanent ground markers (concrete posts) established throughout the dunes. These survey points were co-ordinated on the National Grid and formed the basis of a plane table survey at a scale of 1:2500 of the entire dune system. In the central section of the dune system - the part most seriously affected by wartime military usage - a comparison on a limited scale was attempted between this survey data and the admittedly limited information shown on the Ordnance Suvey map of 1885. This comparison showed that the landward two of the three dune ridges had migrated landward by up to 125 m, whilst the seaward edge of the vegetated area had maintained itself and even pushed seaward in places (Kidson and Can, 1960). It was also clear that the ridges had become much higher and the area of land above the 100-ft contour had increased some 35-fold between these two dates.

A complete photogrammetric re-survey of the area was carried in 1983 from 1:5000 scale infrared false colour photography flown by Fairey Surveys Ltd at 12.57 hrs on March 29th at low tide. (Figure 2). To facilitate the linking of this new mapping with the 1958 survey, 27 undisturbed posts acting as permanent markers for the main survey stations of the earlier mapping were pre-marked prior to the overflight. Photogrammetric mapping at 1:2500 scale was completed using a Kern PG2-L plotter. The scale of photography allowed accurate plotting of all planimetric detail, including the paths used by people to gain access to the beach and throughout the area generally. The greatest concentration of these was in the western dune ridge immediately flanking the beach, where the sand was less consolidated and less bound by marram and where, obviously, there was most recreational activity. Mapping of the paths, which were evidenced in the dune areas by bare sand, was a vital component in assessing the effect of their creation and accentuation on erosion development and the importance of paths in sand dune areas has also been reported by Boorman and Fuller (1977). Mapping of the broad vegetation classes was greatly enhanced by the false colour photography.

The 1:5000 air photo scale would also have allowed contours with a vertical interval of 0.5 m to be plotted (Chisholm, 1989). Whilst necessary in detailed examination of the inter-tidal areas, such relief depiction is excessive in areas of highly complex topography and widespread minor relief variations. The best compromise between accuracy of relief portrayal and clarity was achieved by plotting 2 m contours and spot heights recorded to the nearest 0.1 m. The complete survey was subsequently generalised to 1:5000 scale and produced as a coloured map by the Nature Conservancy Council (Chisholm and Collin, 1990).

Whilst the line mapping represents a highly detailed record of the Burrows, comparison with the 1958 survey is difficult by purely visual assessment. To provide the means whereby changes in the dunes could be quantified, a photogrammetric digital elevation model (DEM) was also observed thoughout the area at a 25 m grid interval oriented to the National Grid. Elevations at the corresponding 25000 grid nodes were interpolated from the large number of randomly distributed spot elevations of the 1958 survey. Volumetric calculations based on these two digital data sets allowed identification of the areas of net loss and gain over the 25 year period (Kidson *et a1*., 1989). A rather crude generalisation of the results of this quantification of

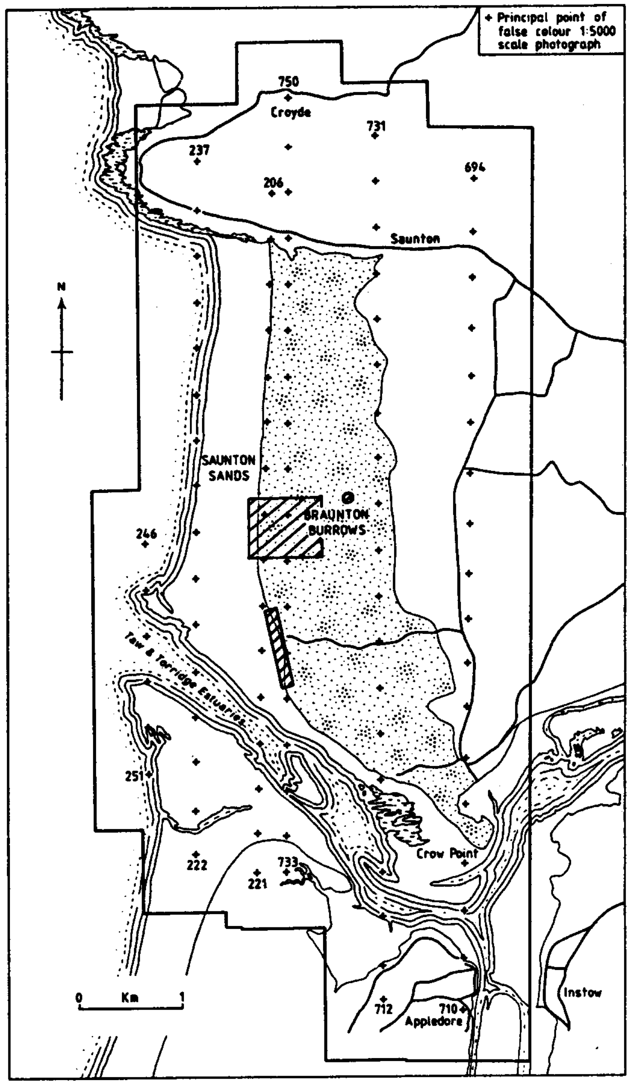

Figure 2. Sortie diagram of 1983 false colour photography. Shaded areas indicate the locations of the 1995 ground survey operations.

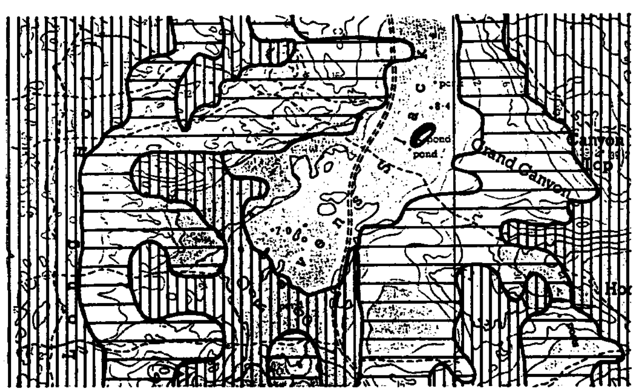

Figure 3. Quantification of net sand movement between 1958 and 1983. Vertical shading = net gain; horizontal shading = net loss; no shading = no change.

change is given for a sample area of the dunes (Figure 3). The areas shown contain the merged 25 m x 25 m "tiles", upon which the volumetric calculations were based and the original net loss/gain values ranged in value from ± 200 m^3 to > ± 2000 m^3 of sand movement.

CURRENT WORK

For reasons of cost it was not possible to re- survey the whole area completely by photogrammetric methods, although this would have been the ideal solution and allowed direct comparisons with the 1983 work. The alternative solution was to undertake ground survey missions in selected areas of the dunes and the first of these was carried out in 1995. To this end, an area measuring approximately 650 m east- west x 575 m north-south was surveyed as a series of regular cross-sections, using a Sokkisha SDM-3E electro-optical tacheometer - an integrated theodolite and infrared distance measurement instrument. 8 lines were observed at an average spacing of around 80 m and the southern 5 lines encompassed the same area as that of the DEM comparison described above (Figure 4). Lines 1- 4 and Line 8 had the original concrete posts from the 1958 survey as their eastern end points. Height control was established by conventional spirit-levelling using a Zeiss automatic level from Ordnance Survey Bench Marks located beyond the eastern extent of the Burrows. The heights of the concrete posts and the temporary bench marks (TBMs) forming the end points of the cross-sections were thus tied to OD and allowed direct comparison with the earlier surveys.

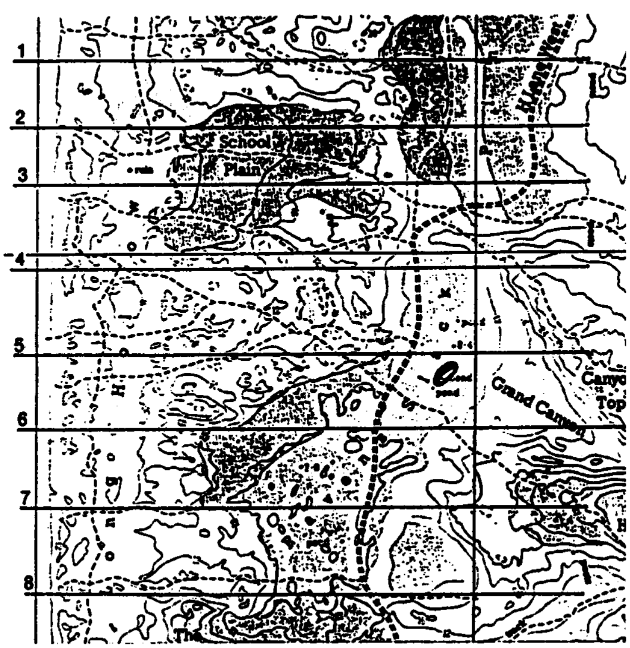

Figure 4. Location of ground surveyed cross-sections.

Dune cross-sections

With the exception of Line 1 (at the northern end of the area) there is a consistency of landform development shown by these transects (Figure 5). In general terms they show a significant increase in the height of the foredunes and occasionally minor increases in the secondary dune ridges. For the most part, there has been little change in between-dune hollows and slacks where the programme of encouraging vegetation development has succeeded in stabilising these areas. Where erosion has occurred in such hollows, as can be seen in the area of Long Hollow in Line 6, this is usually accompanied by deposition on the landward (and leeward) side of the adjacent ridge. More detailed examination and plotting of the differences between the foredune sections of these profiles of 1983 and 1995 shows clearly that not only has there been an average increase in overall height of around 2 m but that there has also been an extension of the dune ridge inland by around 25 m in many cases.

An important outcome of this survey was confirmation of the severe erosion which has been taking place in the area known as Grand Canyon, where wind scouring of the bare sand has caused a reduction in the base level of the blow-out from around 18 m down to 11.5 m (Figure 6). Active steps are currently being taken to introduce marram grass to, and to encourage the colonisation of, the seaward apron of this blow-out in an attempt to arrest this erosional cycle. Although not covered by the present survey observations, it is likely that an increase in the landward extent of the ridge known as Canyon Top will have been the product of this blow-out expansion.

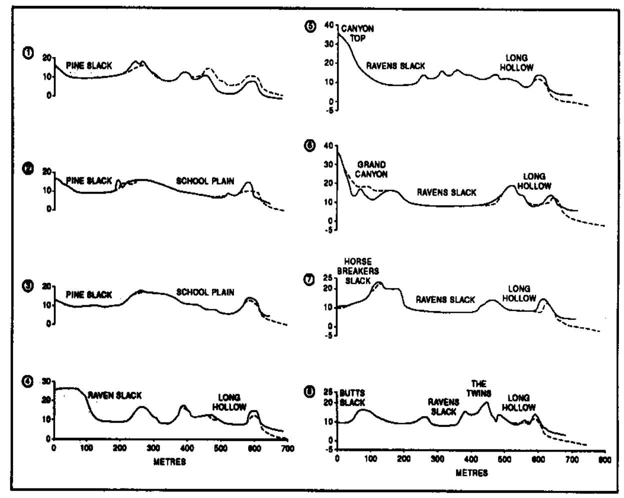

Figure 5. Cross-section lines plotted in an east-west direction to end point on foreshore. Solid line = ground survey; pecked line = profile derived from 1983 photogrammetric mapping.

Rationalisation of the anomalous results from the northernmost cross-section (Line 1) is more difficult. Whilst the increase in height and landward migration of the tertiary ridge on the seaward edge of Pine Slack follows the pattern of morphological changes to be found elsewhere in the survey area, the overall reduction in height of the foredunes, the adjacent hollows and the secondary dune ridge along this line is not repeated anywhere else. The line does follow a route which lies along a cross-ridge which connects the foredunes, a minor secondary ridge and the more developed tertiary ridge and the vegetation cover in this area is lighter than elsewhere. This comparative lack of stabilising marram grass is probably contributing to its overall reduction. Also, it is interesting to note that this line is at the northernmost edge of the area extending to the south where the primary ridge - the foredunes - becomes more pronounced. Conversely, the elevation and cohesion of these primary dunes, northwards from Line 1, reduce in height and ridge-like form and will be a target area for future surveys. It is suspected that there may be an overall reduction in the primary dune system to the north.

Embryo dune development

Further survey work was undertaken immediately to the south of the cross-section study area. Here the emphasis was on measuring changes which had occurred in the extent and form of the primary dune ridge only. It had been noted that this area was actively prograding, with the development of embryo dunes in front of the older more established primary dune ridge (Figure 7). An 800 m section divided at 70 -75 m intervals produced 12 profiles each comprising 4 observation points (Figure 8). These were adjudged, by eye, to be at the top and bottom of the "old" dune ridge and the top and bottom of the new embryo dune ridge. The seaward extent (the bottom) of the embryo dunes was difficult to establish because of their merger in a gentle gradient with the inter-tidal sand.

The 1995 survey profile of this western edge of the Burrows was plotted against the data derived from the previous photogrammetric survey (Figure 9). Profiles 3 - 10, inclusively, show the differences in dune form between the two dates, although the same caveat applies to

Figure 6. Grand Canyon looking west from from Canyon Top.

Figure 7. Embryo dunes viewed from end of "J" Lane looking north.

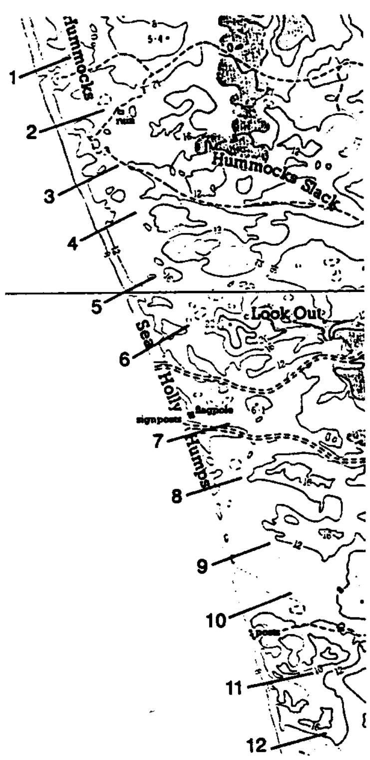

Figure 8. Location of embryo dune profile lines.

the accuracy with which it is possible to derive heights from the 1983 contours. Not only do the results show the increase in height of the old coastal ridge at these locations, but they also show the seaward extension of the system by the development of embryo dunes. These typically extend from around 7 m AOD to 11 m and are marked by colonising patches of marram grass. Future work will test the theory that these will grow progressively higher while migrating inland to become established and prominent foredunes. Whilst purely physical processes are probably causing these developments, it is interesting to note that this section of the coastline is one of the most popular beach sites in the southern Burrows for holidaymakers. It straddles the exit of "J" Lane, one of the main paths running from the so-called American Road marking the eastern boundary of the Burrows, on to the beach sand. It is possible that refuse left by holiday-makers, who tend to settle at the top of the beach at the base of the coastal dunes, has provided minor obstacles to the wind-blown sand and created the necessary conditions for plant colonisation and the establishment of these embryo dunes.

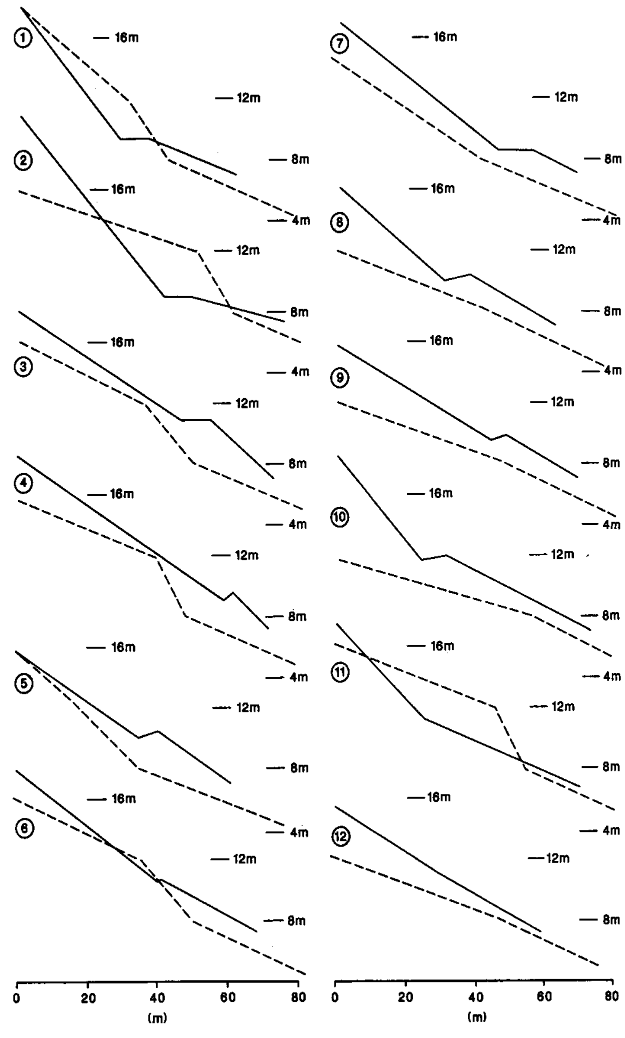

Figure 9. Comparison between 1995 (solid line) and 1983 (pecked line) profiles of foredune area experiencing embryo dune development.

From Profile 7 to Profile 12, but excluding Profile 11, it can be seen that the old dune system has a rather more shapeless morphology and that on this stretch of coast there is no prominence to the primary dune ridge. Nevertheless, the 1995 results show that, for Profiles 7 to 10, these areas have developed more recognisable primary ridges with abutting embryo dunes. Profiles 1, 2 and 11, however, show that, in these particular locations, erosion is attacking the old dune system but that this too is encouraging inland migration as well as promoting an increase in height of the old dunes.

Flagpole Dune

Perhaps the most prominent feature of Braunton Burrows over many years has been the large, almost isolated "outcrop" of the large sand dune feature known as Flagpole Dune. It is also the most landward of the dune complexes, being located some 2 km east of the High Water Mark, and is, therefore, an extremely old feature of the Burrows. The dune was subjected to measurement in 1995 because of the obvious changes which had taken place since the 1983 survey. At that time, Flagpole Dune was, to the casual observer, a seemingly conical mountain of bare sand and its shape then can be gauged from the contours plotted photogrammetrically (Figure 10). Present-day viewing of the same feature presented an entirely different picture in that there was no longer an obvious highest point but now seemed to present a broad, extended, level- topped wall of sand. This was particularly true when viewed from the east (Figure 11) but closer inspection from the western side revealed that this solidity was an illusion and that active erosion was eating back into the centre of the dune (Figure 12). The old concrete flagpole base now lies exposed and abandoned in a position many metres lower and to the west of the present highest point and it is reported that the flagpole has had to be re-positioned several times over the past

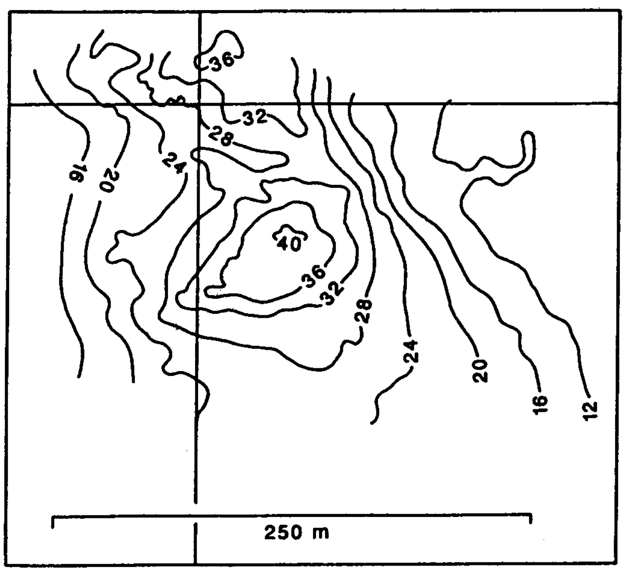

Figure 10. Flagpole Dune as defined by 1983 contours.

Figure 11. Flagpole Dune viewed from the east.

Figure 12. Flagpole Dune viewed from the west.

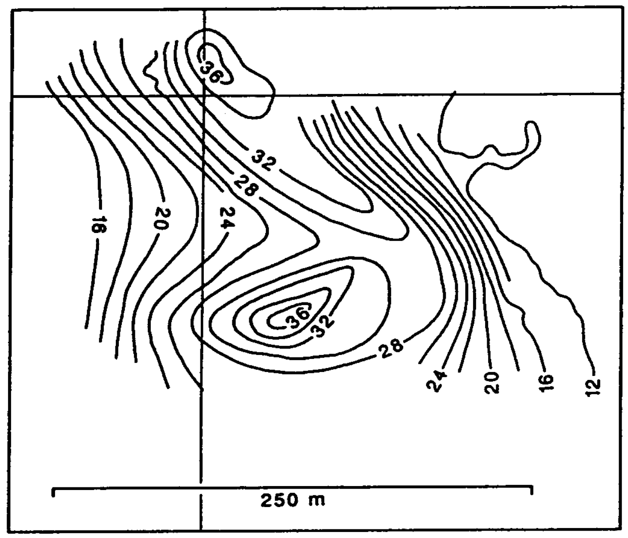

Figure 13. Flagpole Dune as defined by contours derived from 1995 ground survey observations.

few years, The present form can be seen from the contours derived from ground survey observations carried out in August 1995 (Figure 13).

Comparison of the two contours plots shows the extent to which the shape and the position of this feature have altered. What is represented is not so much a net gain or loss in the volume of sand (approximately 350000 m3) but more a change in shape. The clearest evidence for this is the development of a large eroded central area on the western flank, which destroyed the original peak and caused a bulging wall of sand to the east of what has now virtually become a central ridge. This also caused an overall lowering of the maximum elevation to 36 m which is now to be found some 50 m south of the former highest point and the dune is showing signs of developing into a classic crescent-shape.

The developments here, therefore, also represent a continuation of the migration eastwards of the dune complex largely in the face of the prevailing winds which are the main shaping force. However, the Burrows are aptly named and one cannot discount the effect by the rabbit population of creating weaknesses in the root systems of the vegetation cover binding the loosely consolidated and potentially extremely mobile material. Human influences too have played their part in mobilising this previously relatively stable feature and military exercises with frequent establishment of temporary field camps have contributed to occasional interruptions to the consolidation of the vegetation cover. Perhaps the greatest influence in accelerating this dramatic geomorphological change, however, has been the use of Flagpole Dune for recreation. Large expanses of bare sand are a magnet to those using the Burrows for pleasure. On other parts of the dune system four-wheel drive vehicles and scrambling bikes may pose a bigger threat to conservation but on Flagpole Dune the main threat is simply from the continual use of the bare slopes for "sand-sledging" by children and adults alike. These activities destroy thin vegetation cover and move substantial quantities of sand downslope.

CONCLUSIONS

Whilst there are hopes that this important area will be subjected to a complete and comprehensive re-survey by photogrammetric mapping methods in the future, this present work represents the first of a series of ground-based operations aimed at providing data on aspects of the developing morphology of the Burrows. By so doing it builds on and increases the value of the earlier surveys and allows an observational time-series to be established. Without continued monitoring, the earlier work, particularly the 1983 survey, would be in danger of being devalued by its relegation to the status of being "one-off".

In this initial follow-up work, three sample locations within the dune complex have been studied and useful data acquired. The cross-sectional measurements quantified the degree of change, and lack of, in a central area of the dunes and can be used as evidence by those with direct responsibility for the dunes for justification of their current management practices. Future extensions to the other parts of the dune system will highlight those areas which may require attention. Recording and measurement of the development of embryonic dunes along one section of the coastline has been an important feature of the current work and will allow close monitoring of their future development, as well as raising questions of why this development should have taken place at these precise locations. Careful measurements in other sections at the land-sea interface are necessary. The measured changes at Flagpole Dune may be more site-specific but are no less important and should be incorporated into, and be instrumental in the development of, modelling of dune development.

ACKNOWLEDGEMENTS

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