MORRICH MORE

J.D. Hansom

OS Grid Reference: NH803835–NH892830

Introduction

Morrich More is a large coastal strandplain on the southern shore of the Dornoch Firth (see Figure 10.1 for general location) between Tain and Inver. Its development is related to a shallow offshore zone and the presence of abundant sandy material, which has been brought onshore and deposited in a series of sequential beach ridges under conditions of a falling relative sea level. The stratigraphical and morphological record contained within Morrich More is central to the understanding and reconstruction of the Holocene coastal development of the Dornoch Firth and wider Moray Firth (Hansom and Leafe, 1990; Hansom, 1991, 1999, 2001; Smith *et al*., 1992; Firth *et al*., 1995). Access to Morrich More is restricted on account of its use as a Royal Air Force weapons range.

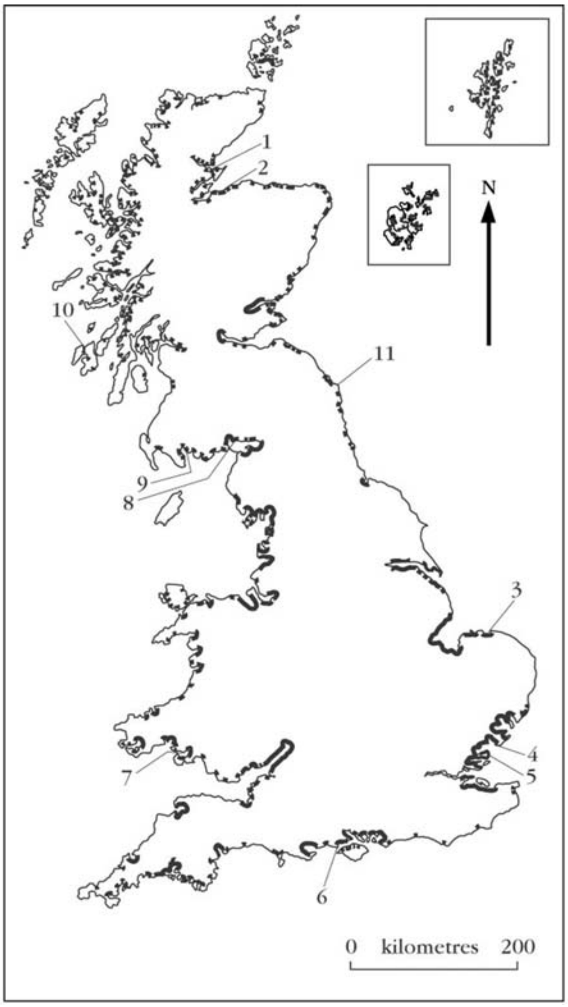

Figure 10.1: The generalized distribution of active saltmarshes in Great Britain. Key to GCR sites described in the present chapter or Chapter 11 (coastal assemblage GCR sites): 1. Morrich More; 2. Culbin; 3. North Norfolk Coast; 4. St Osyth Marsh; 5. Dengie Marsh; 6. Keyhaven Marsh, Hurst Castle; 7. Burry Inlet, Carmarthen Bay; 8. Solway Firth, North and South shores; 9. Solway Firth, Cree Estuary; 10. Loch Gruinart, Islay, 11. Holy Island. (After Pye and French, 1993.)

Morrich More contains a diverse variety of constructional coastal landforms including an emerged strandplain, attached sandy barriers and spits, stabilized dunes including parabolic dunes, embryo and foredune succession, saltmarshes and sandflats. The importance of Morrich

More, both within the British Isles and internationally, lies in the extent, scale and diversity of its geomorphology together with the fact that the transitional zones between accretionary landforms are well developed and preserved. In view of the quantities of sediment involved, it is likely that the mid-Late Holocene seaward growth of Morrich More was the most rapid of any coastal feature in Great Britain.

The continuity between the Holocene and contemporary landforms of Morrich More make it an invaluable site for the reconstruction of past process environments as well as for study of the interaction of modern process-form relationships.

Description

The Morrich More strandplain consists of an alternating sequence of low dune-capped sand ridges separated by lower and wetter areas and saltmarsh. The entire landform covers an area of *c*. 34 km^2, of which *c*. 29 km^2 lies within the GCR site. The southern limit of the low-lying area of emerged sands is the *c*. 8–10 m OD base of a prominent slope that marks the line of an emerged cliff. Seawards of the cliff, a strandplain with 50 or so emerged sandy ridges extend *c*. 8 km to the north-east into the Dornoch Firth. The main ridges are marked on Figure 11.7. The majority of these features are aligned north-west–south-east and decline in altitude from 8.6 m OD close to the base of the cliff to 1.4 m OD at the present-day coastline. The emerged marine ridges of Morrich More are composed entirely of medium- to fine-grained sand, capped with dune sand and can be split into four distinct altitudinal groupings (Hansom, 1991). In the south of the site, the highest group of ridges are typically 1–1.5 m high, occur at 6.0 to 8.6 m OD and are spaced about 100 m apart. At 6.4 m OD beneath one of these higher ridges, a layer of woody peat yielded a radiocarbon age of 6445 years BP (Hansom and Leafe, 1990). A second set of ridges at heights of between 4.4 and 5.5 m OD occur to the seawards of the higher ridges and occupy the central section of Morrich More. Farther north and seawards, the lowest sets of sand ridges occur at altitudes of 2.5 to 4.0 m OD and 1.4 to 2.4 m OD. The latter group occur at the same altitude as the modern beach ridge. These lower ridges are more widely spaced than those to landward (Figure 11.8) and are adorned with windblown sand, taking their height to 4–5 m OD. As a result, the most recently deposited ridges on the outer coast, those of Patterson Island and Innis Mhór, are the largest and most prominent of any of the Morrich ridges.

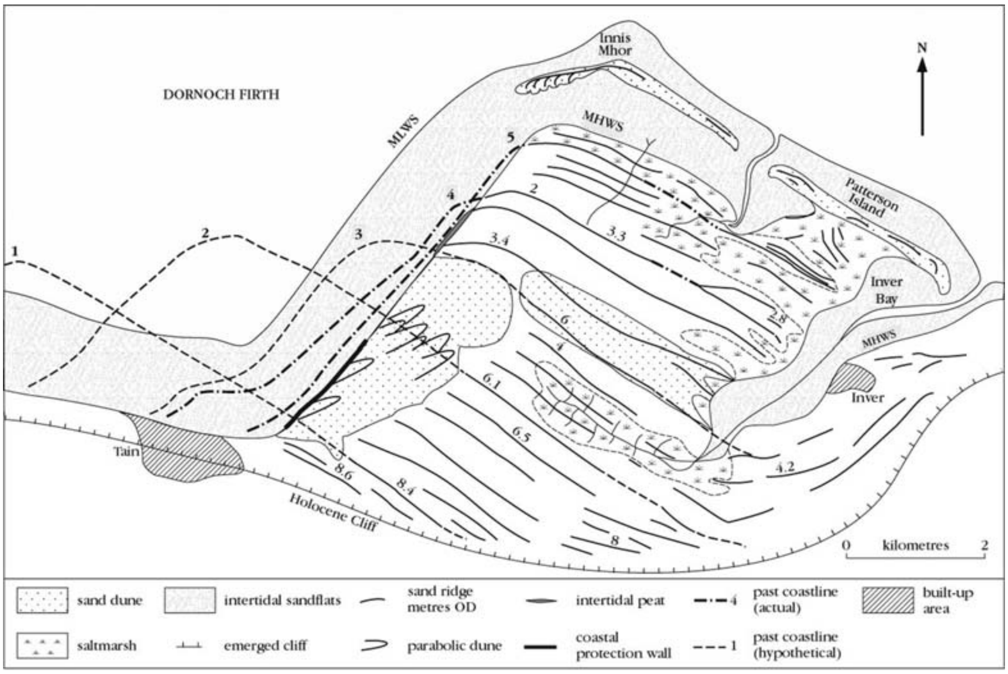

Figure 11.7: Morrich More is a series of emerged sand beach ridges adorned with sand dunes, which together form a progradational strandplain jutting out into the Dornoch Firth. Saltmarsh interdigitates between the sand ridges in the north and east of the structure. The numbered coastlines correspond to the approximate locations of reconstructed and actual coastal positions. Heights of the sand ridges are given in metres above OD. (After Hansom, 1999.)

Figure 11.8: Aerial view of Morrich More from the north-west. The islands of Patterson and Innis Mhór (the eastern end of which is seen to the right) are separated by a tidal channel, which connects with a large area of sand accretion in the shelter provided by Innis Mhór. The inlet of Inver Bay in the centre middle distance supports large areas of saltmarsh, which interdigitates between sand-beach ridges capped with blown sand. (Photo: P. and A. Macdonald/SNH.)

In summary, as the emerged strandplain falls in altitude from over 8 m OD at the base of the cliff to 1.4 m OD at its seaward margin, there is a corresponding fall in the number of beach ridges, an increase in their spacing and a general increase in their prominence towards the open coast (Figure 11.7). Although many of the emerged ridges are covered in a thin veneer of blown sand, their form is obscured in three areas by extensive dune development, in the west, in the east and on the outer coast at Patterson Island and Innis Mhór. A feature of many of the emerged sand ridges is that they display truncated westward trending recurves at their northern ends, comparable to the modern features of the contemporary coast.

In the nearshore and intertidal zone, active sand-bars move onshore to produce a prominent sandy barrier (Hansom and Leafe, 1990). This barrier comprises two dune-capped high-tide ‘islands' of Innis Mhór in the west and Patterson Island in the east, punctuated by a tidal channel in the middle (Figure 11.8). The fronting beach is shallow and sandy and is mainly backed by accreting sand dunes. Both extremities of the barrier islands are characterized by recurving sand spits. At the entrance to Inver Bay in the east, a simple low sand spit is deflected southwards into the bay. At the entrance to the Dornoch Firth in the west, a section of Innis Mhór characterized by erosion is connected to a *c*. 2 km-long westerly trending sandy spit that extends into the Firth. This spit is weakly recurved and is composed of several ridges that are now capped with dunes. The two dune-clad islands of Innis Mhór and Patterson Island are now connected to the main body of the strandplain by sandflat and saltmarsh, which is inundated to a depth of 1 m at high spring tides.

In contrast to the accretion and new dune development displayed on the north coast of Morrich More, the side that faces west to the Dornoch Firth is backed by an eroding dune edge whose base lies at MHWS and is fronted by a steep and narrow sandy beach (Figure 11.9). The height of the cliff undergoing erosion varies depending on the height of the sand dune behind, being usually about 2 m but reaching 14 m in the afforested dunes in the south-west, where mature trees topple onto the foreshore. In places along this shore, outcrops of peat are exposed on the intertidal beach. Extending from the foot of the beach, a prominent low-gradient, intertidal sandflat reaches 1 km in width before the low-tide channel of the Dornoch Firth is reached to the north-west. Low sand-bars exist on the sandflat surface (Figure 11.9). In response to erosion of the western flank of Morrich More, a series of low boulder revetments have been constructed over a 2 km stretch north-east from Tain. These have been effective in reducing erosion locally, but have contributed to accelerated erosion of the dune coast down-drift (Figure 11.7).

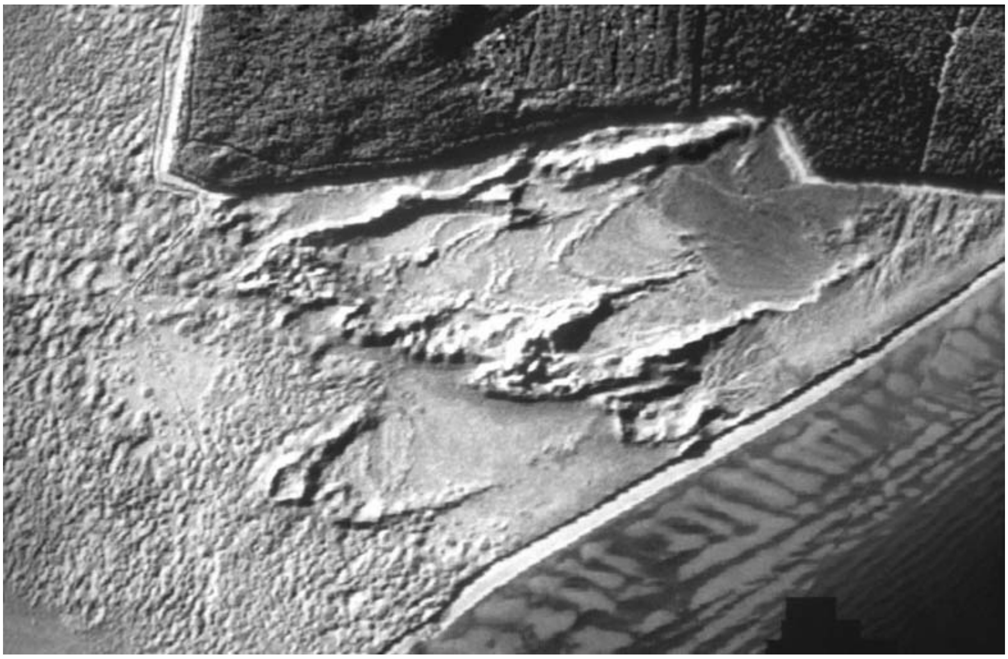

Figure 11.9: A remotely sensed image of the narrow upper beach and eroding edge on the western flank of Morrich More showing the large fixed parabolic dunes and the area of low dunes downwind. Intertidal bars are well-developed on the 1 km-wide intertidal flats on the Dornoch Firth side of Morrich More, and may indicate the direction of sediment movement under the flood tide (onshore) and ebb tide (alongshore to the north-east). North is at the top of the image. The arrow indicates direction of migration of the parabolic dunes. (After Hansom and Leafe, 1990.)

In addition to the extensive areas of intertidal sandflat on the western flank of Morrich More, similar areas also exist in the shelter provided by the barriers of Innis Mhór and Patterson Island and within Inver Bay. On the more-elevated sections of sandflat, tidal inundation is of lower frequency and duration, thus allowing saltmarsh vegetation to colonize. The 260 ha of saltmarsh on Morrich More represents 5% of the remaining natural saltmarsh in Scotland and it is a distinctive system in its own right on account of its relationship with the beach ridges (Hansom and Leafe, 1990). The saltmarshes are drained by linear creek systems, which extend into Morrich More along the axes of the inter-ridge swales or hollows (Figure11.7). Thus, saltmarsh and emerged beach ridges interdigitate, and the extremities of the beach ridges become progressively buried. The complex vegetation pattern of Morrich More is dominated by this pattern of interdigititated ridges and slacks (Smith and Mather, 1973) and the strandplain carries a rich flora of over 200 flowering species, ranging from intertidal sandflat species to Juniper–*Calluna* heath on the oldest landward ridges (Stapleton and Pethick, 1996). The vegetation succession of Morrich More is discussed in further detail in Smith and Mather (1973) and Dargie (2000).

The most striking feature of the western sand dune margin of Morrich More are the exceptionally high parabolic dunes, which extend for up to 1 km inland and have a relief amplitude in excess of 14 m (Figure 11.9). The dunes are fixed by vegetation, mainly marram *Ammophila arenaria* and heather *Calluna vulgaris*, although the southern part is now artificially stabilized by afforestation. The highest dunes occur at the northern tip of the forested area and reach 20 m OD in a series of large parabolic dunes. These dunes exhibit exceptionally steep and often knife-edged slopes in excess of 30°. The alignment of the ridges and deflation hollows (250°) indicates a north-eastwards migration, sub-parallel to the western edge of Morrich More (Figure 11.10). Within the deflation hollows the water table is visible, and the sides reveal buried palaeosols. Only a small part of the most easterly of these dunes remain mobile with sand faces spilling forward, and the majority of the system has been stabilized by vegetation. The dunes of the outer coast islands of Innis Mhór and Patterson Island reach 7 m OD and are dominated by a mixture of marram and lyme-grass *Leymus arenarius*, both of which grow vigorously in the active aeolian depositional conditions on the outer coast.

Figure 11.10: The large parabolic dunes on the western flank of Morrich More have migrated north-east (towards the camera) but have since stabilized, mainly by marram colonization. The low hummocky dunes in the foreground have been influenced in the past by sand blown from the parabolic dune field but are now also stable and covered mainly with marram and smaller areas of heather. (Photo: J.D. Hansom.)

Grass-covered low dune surfaces are confined to the western shore and its landward environments. A low undulating dune plain is truncated along the western edge by backshore erosion producing a scarp of about 1 m high and enabling the limited beach sand available to be blown up onto the dune surface behind. The dune surface carries browntop bent–sheep's fescue (*Agrostis tenuis–Festuca ovina)* and white clover *Trifolium repens* and locally is being stripped by wind-scour. A number of erosional scarps dissect the surface, taking the form of small linear cuts orientated east and north-east. The sand scarps often have small areas of sand accumulation at their downwind ends, which are progressively being colonized by marram.

Interpretation

Morrich More forms part of a network of sites used to infer the complex interaction between sea level, sediment supply and coastal evolution of the Dornoch Firth over the Holocene Epoch (Hansom, 1991, 2001; Firth *et al.*, 1995). The scientific importance of the immense Morrich More coastal strandplain has been recognized for many years. For example, Ogilvie (1923) described Morrich More as 'a wave-built sandy strandplain ... built out gradually throughout the uprising of the coast'. Further work (e.g. Smith and Mather, 1973; Smith, 1983) described Morrich More as an emerged strandplain built up during a succession of changing land–sea relationships during the Holocene Epoch. Smith (1986) goes further, suggesting that the entire Morrich More system is genetically a coastal strandplain created by *c.* 6500 years of shoreline accretion in the form of swash-bars thrown up by wave activity. However, perhaps as a result of the size and complexity of Morrich More, there was a lack of any detailed geomorphological studies until the work of Hansom and Leafe (1990). This work led to the reconstruction of the Holocene evolution of the Dornoch Firth (Hansom, 1991; Firth *et al.*, 1995) and emphasized the role that contemporary processes play in the continued development of Morrich More (Stapleton and Pethick, 1996; Hansom, 1999, 2001). The interpretation below is drawn mainly from this more recent research.

Hansom and Leafe (1990) suggest that at the peak of the Holocene transgression, in a situation of plentiful sediment supply, large amounts of sand were transported onshore and beach ridges began to develop rapidly close to the Holocene cliff. A radiocarbon date of 6450 years BP from peat found in a section at 6.4 m OD beneath one of these ridges (Hansom and

Leafe, 1990) indicates that the ridge formed soon after this date. The age and altitude of the suite of sand ridges, at altitudes of 6.0 to 8.6 m OD, suggests development at the culmination of the Main Postglacial Transgression (Firth *et al*., 1995). The progressive eastward progradation of the Morrich More shoreline was probably produced by onshore movement and vertical accretion of nearshore bars fed from offshore sediments, the narrow spacing and number of the landward-most ridges indicating that sediment supply was relatively abundant and that accretion was rapid at this time (Hansom and Leafe, 1990). Subsequently, as the rate of eustatic sea-level rise fell below the rate of isostatic uplift of the land, relative sea level fell and a second suite of ridges were formed between 4.4 and 5.5 m OD (Hansom, 1991; Firth *et al*., 1995). Between 6400 years BP and *c*. 5000 years BP, the limited sea-level fall seems to have been conducive for large amounts of sands to move onshore to produce rapid shoreline regression and the addition of beach ridges. Although undated (except by regional sea-level curves) Hansom and Leafe (1990) suggest that the bulk of the Morrich More sands higher than 4 m OD, may have been in place by *c*. 5000 years BP. Seawards of the beach ridges at about 4 m OD, the true ridge altitude drops (although covered by sand dunes) and the spacing between beach ridges increases. It is hypothesized that the wider spacing between the most seaward, and thus most-recently deposited, ridges, indicates that rates of accretion and sediment supply have progressively reduced since 6500 years BP and certainly since deposition of the second group of higher ridges (Hansom and Leafe, 1990; Hansom, 1991; Firth *et al*., 1995). The postulated reduction in offshore sediment supply is supported in part by the morphology of the current beach ridge of Innis Mhór and Patterson Island, which, in relative terms, is the highest of the Morrich More ridges. It supports the assertion of Davies (1980) that during conditions of reduced sediment supply, beach ridges simply build higher, rather than constructing additional, ridges on the seaward beach face.

The general trend of north-eastward accretion of Morrich More over the Holocene Epoch is mirrored by the more recent changes that are known to have occurred since the first accurate map of the area was produced by Sangster in 1730 (Hansom and Leafe, 1990; Stapleton and Pethick, 1996). In 1730, MHWS of the outer coastline lay north-west of Inver and lay along the line of a prominent emerged ridge (Figure 11.11). Since then, Ordnance Survey maps and aerial photography of numerous dates have recorded the north-eastward migration of MHWS and MLWS as accretion has progressed on this shore. Such a migration has resulted in progressive narrowing of the entrance to Inver Bay and the shallowing of the bay itself. As the outer beaches moved north-eastward, the low-lying swales behind were flooded by tidal waters, promoting the development of sandflat and saltmarsh. The development of saltmarsh seems to be a rapid process, since the 1887 Ordnance Survey does not show Patterson Island at all and displays Innis Mhór as a small unvegetated sandbank. Patterson Island had emerged above MHWS by 1946 and although aerial photography shows a small dune area present, the intertidal area behind remained entirely intertidal sandflat until the late 1960s. Infilling is ongoing and comparisons between the 1981 map and 1987 aerial photography shows saltmarsh edge migration of 100 m over the six-year period as a result of accretion and colonization by saltmarsh plants (Hansom and Leafe, 1990).

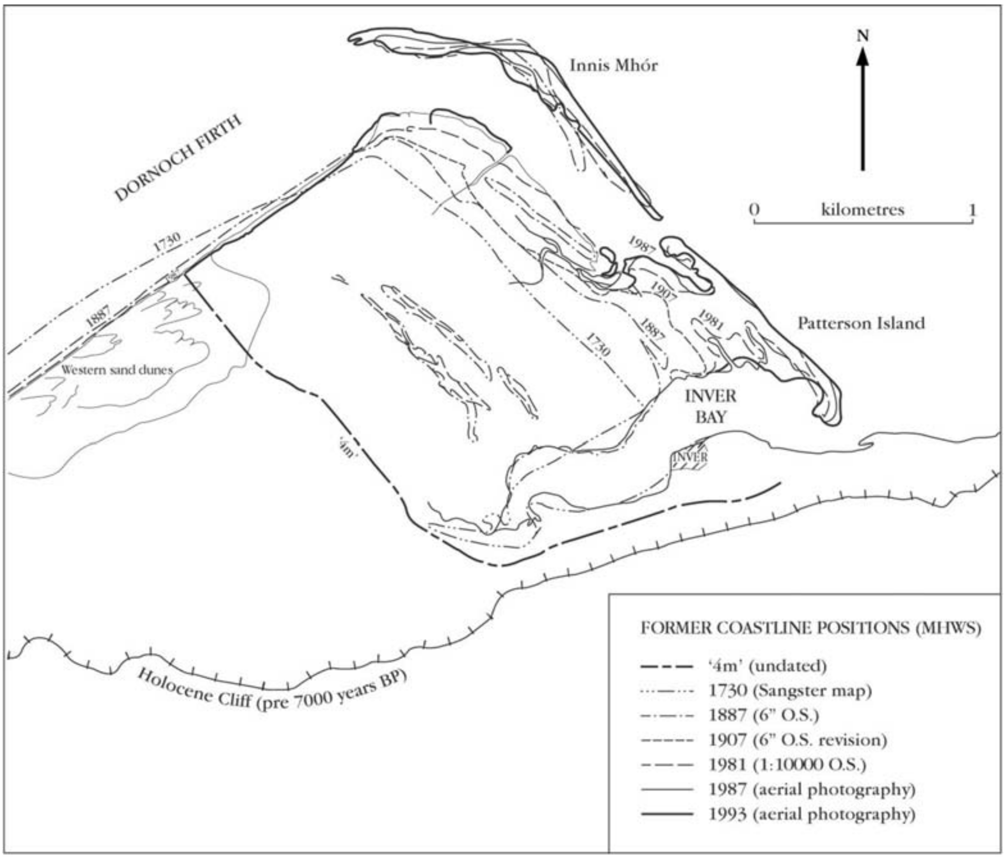

Figure 11.11: Former coastal positions of Morrich More, based mainly on historical sources and Ordnance Survey maps and aerial photography. The north-east coast has extended by about 1 km since 1730, but the western flank has eroded by varying amounts over the same period. Sediment eroded from the west is moved north-east by tidal streams and waves at high tide to be deposited in the area behind Innis Mhór and Patterson Island. (After Hansom and Leafe, 1990.)

Accretion on the outer north-eastern coast is matched by erosion on the inner Dornoch Firth coast of Morrich More (Figure 11.11). Erosion along the western flank of Morrich More has occurred at a mean rate of 0.47 m a^{-1}, with some 117 m lost between 1730 and 1990 (Hansom and Leafe, 1990). This has resulted in peat (radiocarbon-dated at 325 years BP), which probably developed in dune-slacks, being buried by dune migration eastwards and now being exposed on the foreshore by erosion. The narrow fringing beach of this north-western flank is now clearly erosional and is backed by a vertical erosional scarp that truncates the orientation of both dune ridges and emerged beach ridges. Although there is a lack of evidence concerning the length of time that erosion has predominated on the western shore of Morrich More, it is highly likely to have been ongoing for as long as deposition has built ridges on the north-eastern flank (Hansom and Leafe, 1990). Sand transport occurs northwards along the upper beach and so erosional activity on the north-western flank contributes directly to infill of the sandflat areas behind Innis Mhór and Patterson Island and indirectly contributes to deposition on the outer beach. Based on this evidence, Hansom and Leafe (1990) suggested that Morrich More has been migrating from west to east for some 7000 years and Hansom (1999) presents a five-stage schematic reconstruction of this migration based on breaks in the size and spacing of the emerged ridges (stages 1–5 on Figure 11.7).

The size and relatively undisturbed history of almost 7000 years of continuous sedimentation on Morrich More has led to the development of a range of successional stages of dune development from embryo dune on the outer shore, through foredune and mature dune forms, parabolic dune forms and low undulating dune plain, some of these in association with interfingered saltmarsh that grades into freshwater marsh and dune slacks. Ratcliffe (1977) describes sand dune vegetation of Morrich More as 'one of the most important and distinctive dune systems in Europe', and Doody (1986) echoes this by regarding it as one of the finest sequences of natural vegetation in Great Britain. Dargie (1989) demonstrates the importance of the vegetational transitions at Morrich More, with those between the saltmarsh and dune systems being of particular complexity and therefore of high conservation value in view of a clear relationship with geomorphological conditions. Vegetational transitions from saltmarsh to sand dune are extremely rare in Britain and the transition on Morrich More from saltmarsh to calcareous dune, wet acid dune or dry dune grassland makes the upper saltmarsh vegetation, and its interaction with geomorphology, uniquely important.

The relationship between the mainly stabilized parabolic dunes in the west and the low undulating dune plain downwind to the north-east is unusual, since neither has an obvious upwind nourishment zone of foredune and young dunes (Figure11.9). The orientation of the axes of both the parabolic dunes (250°) and the low dunes behind indicate dune forms produced by sand movement driven by south-westerly winds. Although some active sand movement still occurs over the crest of the northernmost of the parabolic dunes, and there remains active deposition from the beach to the south-west, the volumes are insufficient to sustain large-scale changes to dune forms. If the backshore erosion experienced by this side of Morrich More is a long-lived phenomenon, then it seems reasonable to assume that erosion has removed the feeder dune cordon that once fed the downwind dunes. Support for this assumption comes from the 1730 Sangster map that shows a coastal position*c.* 350 m to the west of its current location. The intertidal peat exposed on the beach and beneath the dunes also indicates erosion since its deposition, probably within a damp dune-slack some 325 years BP. It may also be likely that coastal recession itself contributed to dune instability and further movement of the parabolic dunes. Ogilvie (1923) noted that parabolic dunes on the western flank were then mobile and appeared to have moved some 183 m between 1873 and 1913. It seems probable that the earliest parabolic dunes of western Morrich More were fed from a beach and dune system in the west beyond Tain that now no longer exists.

Conclusions

The scientific interest of Morrich More is outstanding both in terms of the variety and scale of its coastal landforms, many of which have well-developed transitional zones between accretionary landforms, and because of a well-preserved morphological and stratigraphical record that records shoreline change and coastal development over the last 7000 years. The development of this large coastal strandplain is related to a shallow offshore zone and abundant sandy material, resulting in a series of sequential beach ridges deposited under conditions of a falling relative sea level. From a stratigraphical and morphological perspective, the extensive emerged strandplain of Morrich More is central to an understanding of the Holocene coastal development of both the Dornoch Firth and the wider Moray Firth. From a contemporary process and form viewpoint, there exists a diverse variety of forms including attached sandy barriers and spits, stabilized dunes including parabolic dunes, embryo and foredune succession, saltmarshes (some of which are interdigitated between beach and dune ridges) and sandflats. The importance of Morrich More, both within Great Britain and internationally, lies in the extent, scale and diversity of its Holocene and contemporary geomorphology and in the continuity that exists between them.

Reference list

Dargie, T.C.D. (1989) Morrich More S.S.S.I., Ross and Cromarty. Vegetation Survey 1988. Nature Conservancy Council CSD Report, No. **915**, 126 pp + maps.
Dargie, T.C.D. (2000) Sand Dune Vegetation Survey of Scotland, Scottish Natural Heritage Commissioned Report No. F97AA401, SNH, Edinburgh, 193pp.
Davies, J.L. (1980) Geographical Variation in Coastal Development, 2nd edn, Geomorphology Texts, No. **4**, Longman, London, 212 pp.
Doody, P. (1986) Proof of Evidence. Tain Public Inquiry, Land and Marine Engineering Ltd Development Proposal.
Firth, C.R., Smith, D.E., Hansom, J.D. and Pearson, S.G. (1995) Holocene spit development on a regressive shoreline, Dornoch Firth, Scotland. In Coastal Evolution in the Quaternary: IGCP Project 274 (eds O. van de Plassche, M.J. Chrzastowski, J.D. Orford, A.C. Hinton and A.J. Long), Marine Geology Special Volume, **124**, Elsevier, Amsterdam and London, pp. 203–14.
Hansom, J.D. (1991) Holocene coastal development in the Dornoch Firth. In Late Quaternary Coastal Evolution in the Inner Moray Firth: Field Guide (eds C.R. Firth and B.A. Haggart), West London Press, City of London Polytechnic, London, pp. 45–55.

Hansom, J.D. (1999) The coastal geomorphology of Scotland: understanding sediment budgets for effective coastal management. In Scotland's Living Coastline (eds J. Baxter, K. Duncan, S. Atkins and G. Lees), Natural Heritage of Scotland Series, No. **7**, The Stationery Office, London, pp. 34–44.

Hansom, J.D. (2001) Coastal sensitivity to environmental change: a view from the beach. Catena, **42**, 291–305.

Hansom, J.D. and Leafe, R.N. (1990) The geomorphology of Morrich More: development of a scientific database and management prescription. Nature Conservancy Council CSD Report, No. **1161**, 174 pp + maps.

Ogilvie, A.G. (1923) The physiography of the Moray Firth coast. Transactions of the Royal Society of Edinburgh, **53**, 377–404.

Ratcliffe, D.A. (ed.) (1977) A Nature Conservation Review. The Selection of Biological Sites of National Importance to Nature Conservation in Britain. Volume 1, Cambridge University Press, Cambridge, for the Natural Environment Research Council and the Nature Conservancy Council, 401 pp.

Smith, J.S. (1983) The Morrich More. In North-East Scotland Coastal Field Guide and Geographical Essays (ed. W. Ritchie), International Geographical Union Coastal Commission, Department of Geography, University of Aberdeen, pp. 43–5.

Smith, J.S. (1986) The coastal topography of the Moray Firth. In The Marine Environment of the Moray Firth (ed. R. Ralph), Proceedings of the Royal Society of Edinburgh, **91B**, pp. 1–12.

Smith, J.S. and Mather, A.S. (1973) The Beaches of East Sutherland and Easter Ross, Department of Geography, University of Aberdeen, Aberdeen, 97 pp.

Smith, D.E., Firth, C.R., Turbayne, S.C. and Broooks, C.L. (1992) Holocene relative sea-level changes and shoreline displacement in the Dornoch Firth area, Scotland. Proceedings of the Geological Association, **103**, 237–57.

Stapleton, C. and Pethick, J. (1996) Coastal Processes and Management of Scottish estuaries I: The Dornoch, Cromarty and Beauly/Inverness Firths, Scottish Natural Heritage Review, No. **50**, Scottish Natural Heritage, Edinburgh, 99 pp + maps.