Culbin, Moray

[NH 980 615]

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Introduction

Culbin, located on the southern shore of the Moray Firth (see (Figure 10.1) for general location), is a site of exceptional international interest for the scale, complexity and diversity of its coastal geomorphology. The site comprises an emerged sand and gravel strandplain covering over 30 km^2 containing numerous westward-trending spits and ridges, and is backed to landward by a prominent emerged cliff. An extensive and formerly mobile sand-dune system has developed on top of the gravel basement (Mackie, 1897; Steers, 1937; Ovington, 1950; Comber 1993). At one time it was the largest area of open sand dune in Britain, but most of the area was stabilized by conifer afforestation between 1922 and 1963. The active-process environments and landforms of Culbin are no less impressive than their emerged predecessors. A wide intertidal zone extends from Findhorn in the east to Nairn in the west, and displays several well-developed spit and bar features. Overall the Culbin foreland in the east is erosional whereas accretion occurs towards the west at the spit at Buckle Loch. Farther west still, the proximal (eastern) part of The Bar is erosional whereas its distal (western) end is extending (Comber *et al.,* 1994). Landwards of these constructive spit and barrier features, and also within Findhorn Bay, a series of extensive sandflats and sandy saltmarsh has developed in the low-energy, sheltered environment (Comber *et al.,* 1994).

Description

The Culbin coastline extends over *c.* 12 km from the mouth of the River Findhorn in the east to Nairn Links in the west (Figure 11.1). Culbin plays an integral part in understanding the physiographic evolution of the coast of the Moray Firth and should be viewed not in isolation but as part of a similar beach and dune coast that stretches from Spey Bay in the east to Whiteness Head Spit in the west (see site report in Chapter 6). The dominant westerly drift along the southern shore of the Moray Firth (Ramsay and Brampton, 2000c) is integral to the understanding of both contemporary and Holocene landform evolution in this area.

The Holocene gravel ridges that lie beneath the dunes of Culbin Forest provide an exceptional assemblage of emerged features related to higher relative sea levels over the last 6500 years. Radiocarbon dates from peat deposits found on top of the gravels but beneath the dunes show that sea level has fallen in this area during the past 6500 years (Comber, 1993). This isostati-cally driven fall in relative sea level in the Culbin area is reflected everywhere on the coast of the Moray Firth, and followed an earlier period of rapid sea-level rise (Smith, 1997). Given the altitudes and spatial locations of the emerged gravel ridges of Culbin, it is clear that they were emplaced during this phase of falling sea level (Comber, 1993, 1995).

Superimposed on these emerged gravels a major inland dune-system has developed, creating what was formerly the largest area of bare sand in Britain, prior to afforestation. The emerged marine beach deposits, which underlie the entire area of Culbin, are backed by an extensive abandoned cliff whose base lies at *c.* 9 m OD. The cliff can be traced around much of the Moray Firth (Hansom, 1988) and is the counterpart of the cliff at Spey Bay to the east (see GCR site report in Chapter 6). In the Culbin area the 5–7 m-high cliff is cut mainly into Late Devensian glaciogenic and glaciofluvial deposits and forms a divide between older (late Devensian) deposits to landward, and younger (Holocene) deposits to seaward (Firth, 1989).

The most striking landforms preserved within the Culbin dunes are the emerged gravel storm-ridges, found at altitudes of up to 10.9 m OD (Comber, 1993). Owing to the cover of dune sand, the gravel ridges are discontinuously exposed in the field, but can be traced on the ground and in aerial photography in an arcuate form, spanning approximately 5 km of sporadic exposure. These ridges represent abandoned upper beach deposits thrown up under high-energy storm events,

and are composed of gravel dasts 30–50 mm in diameter. A narrow belt of ridges extends westwards across the north-eastern flank of Culbin, before splaying out southwards into a 'fan' at [NH 997 630] (Figure 11.1), location 1). Landwards of this point, the approximately parallel ridges begin to splay out markedly into at least two distinct groups, which extend towards the south-west (Figure 11.1), locations 2 and 3). At the main apex of this 'fan' structure the landward ridges are truncated by the ridges to seaward, indicating erosion of the earlier features (Comber, 1995). Transects levelled across the entire sequence of ridges from the emerged cliff to the present-day beach display declining altitudes to the seaward from a maximum of 10.9 m OD to a minimum of 3.7 m OD. However, between some groups of ridges there is a marked ridge-crest fall of almost 3 m (Figure 11.2).

The Culbin dune system covers an area of approximately 13 km^2 and displays a range of forms unparalleled in any 1JK dune system. The orientation of the axes of most of the dunes is south-west to north-east, with blowthrough patterns preserved on account of their artificial fixing by afforestation. Three main dune types occur at Culbin: parabolic dunes; formerly transgressive dunes; and butte dunes. The parabolic dunes of Maviston, near Loch Loy in the west of the site (Figure 11.2), attain a maximum height of 15 m, with flanks up to 400 m long and a maximum width of *c.* 400 m, making these among the largest of their kind in Europe (Comber *et al.,* 1994). Prior to stabilization by planting, Ogilvie (1923) recorded the maximum height of the active Maviston dunes as 16.5 m, but the crests have since settled. Formation of the dunes progressed as a classic parabolic blowthrough sequence from an initial straight dune crest trending parallel to the coast. Destabilization of the central zone of the crest through the destruction of the vegetated surface produced an area of crestal instability, allowing sand to be blown downwind and allowing the dune crest to migrate and inundate the surfaces behind. Erosion of the lateral slopes of the widening blowthroughs accelerated the process, as did funnelling of the incident wind towards the unstable zone. While the central section of the dune continued to extend downwind, the flanks of the dune remained vegetated and thus stable, creating the distinctive parabolic dune forms found today. The exceptional size of the dunes at Maviston has meant that rates of movement were relatively low, retaining the essential form of the features since at least 1923 until stabilization by forestry (Ogilvie, 1923; Steers, 1937; Edlin, 1976).

Not all of the Culbin dunes display the effects of blowthrough activity, and examples of high dunes, reaching altitudes of up to 30 m, with the smoothed and rounded forms of previously unvegetated transgressive dunes are found, particularly in the west central area of the forest in the vicinity of the underlying gravel 'fan'. A good example of such a dune is Lady Culbin, located at [NJ 013 640] (Figure 11.1). Ovington (1950) noted that the Lady Culbin dune moved at an average rate of 6.5 cm per day over a six-week period. Butte dunes are the eroded remnants of formerly vegetated and stabilized surfaces that have subsequently suffered erosion on all sides to leave a residual flat-topped stump flanked by steep, often unvegetated, slopes of sand. Good examples of butte dunes occur in the north-east of Culbin.

The contemporary coastal geomorphology of Culbin can be considered in terms of five land-form assemblages: the Culbin foreland to the east of Buckle Loch; the Buckle Loch spit; The Bar (locations 6 and 7, (Figure 11.1)), and the extensive intertidal northern sandflats and saltmarshes in the shelter of the spits and barriers (Figure 11.1).

The Culbin foreland extends west from the Findhorn estuary to the Buckle Loch. The foreshore beach is composed mainly of sands, although gravel occurs on the foreshore at the mouth of the Findhorn. Much of this foreland coast is subject to severe erosion, which has resulted in the cutting of the backing sand dunes into prominent bare-sand cliffs up to 8 m high (Figure 11.3). Frontal erosion of these old dunes is recorded to be occurring at rates of up to 1 m a^{-1} (Ritchie *et al.,* 1978; Comber, 1993; Comber *et al.,* 1994). Dune erosion occurs despite the occurrence of relatively wide sandy beaches (up to *c.* 200 m) along the foreland. At the westward extremity of the former Buckle Loch a spectacular recurred spit (the Buckle Loch spit) extends westwards. The spit is presently *c.* 3 km long and up to 130 m wide in its central section, becoming narrower westwards. The spit foreshore is predominantly sandy but the upper foreshore sediment coarsens westwards so that a small gravel ridge has developed on its distal end. The rear of the spit is dominated by several suites of stabilized dune ridges, with actively accreting dunes occurring at both proximal and distal ends of the spit. Erosion of the updrift part of Buckle Loch Spit is resulting in occasional washover of low parts of the frontal dune and gradual infill of the Buckle Loch, which is now infilled.

The Bar at Culbin forms the most distinctive coastal feature on the southern shore of the Moray Firth and is a fine example of a 'flying barrier', with tidal lagoons and saltmarsh behind (Figure 11.4). The feature represents an attached gravel barrier orientated northeast-south-west and extending over a distance of 7.3 km. It is now attached to the

mainland by a low neck of saltmarsh fronted by a gravel beach. At its narrowest the width of the salt-marsh behind the beach is only 250 m, the seaward edge being subject to burial by washover of gravels during storms. Recession of the beach over the saltmarsh has exposed peat on the foreshore. The eastern part of the Bar is mainly sandy, and is adorned with prominent sand dune ridges that sit on top of southward-trending gravel recurves that extend into the intertidal lagoon. The western end comprises the main part of the 'flying barrier' and displays a series of multiple gravel storm ridges backing an active gravel beach (Figure 11.5). Up to 13 major recurving gravel ridges occur landwards of the active ridge and represent recently abandoned shoreline features that have been dated (Figure 11.1), locations 4–7).

An extensive intertidal sandflat with multiple sand-bars occurs seawards of both the Buckie Loch spit and The Bar. These sandflats also extend into the channels and the intertidal zone on the landward side behind the Buckle Loch spit and The Bar, where the shelter afforded has allowed saltmarshes to develop (Figure 11.4) and (Figure 11.5). The marshes commonly have a small undercut edge of *c.* 0.2 m in height (Ritchie *et al.,* 1978); although some edges grade smoothly from sandflat to saltmarsh. The saltmarshes range from low developmental marsh surfaces characterized by intermittent stands of common saltmarsh-grass *Puccinellia* and samphire *Salicornia* (Figure 11.6) to substantial areas of high marsh supporting a full vegetation cover merging landwards to freshwater marsh species. The two largest areas are identified as the marsh surface landward of the central section of The Bar and the area landward of Buckle Loch spit. The marsh landward of The Bar is adorned with numerous saltpans and linear creeks (Figure 11.6). The area of saltmarsh landward of Buckle Loch spit is expanding rapidly as distal extension of the spit continues to provide a lower-energy environment in which prograda-tion can occur. Buckle Loch itself was probably a former saltmarsh, abandoned by westward migration of the active marsh, and subsequently dominated by freshwater species before infilling occurred through washover, sand blow and colonization by trees.

Interpretation

The geomorphology of Culbin was central to Ogilvie's (1923) interpretation of the Holocene development of the Moray Firth. Ogilvie (1923) first described and mapped the emerged gravel features and relict cliff along the southern Moray Firth coast, linking the development of these features to a higher relative sea level and the reworking of vast quantities of glaciofluvial and glacial deposits from the Moray Firth coastal plain and the inner continental shelf as sea level adjusted following deglaciation. Ogilvie's account together with Steer's (1937) work on Culbin emphasized the importance of the westward direction of longshore drift along the southern shore of the Moray Firth to landform development throughout the Holocene Epoch. The excellent groundwork and elegant theories of coastal development provided by these early workers were pursued by Comber (1993, 1995), Hansom and Comber (1994), Comber *et al.* (1994) and Hansom (1999), who provide the most recent interpretation of the evolution of Culbin, and indeed the southern shore of the Moray Firth.

At the peak of the Holocene transgression (*c.* 6500 years BP) the high-stand of relative sea level at *c.* 9 m OD in the Culbin area impinged upon and re-trimmed a pre-existing cliff that probably had been cut initially during the Lateglacial period. During this time of higher relative sea level a marine corridor existed to the east of Culbin, south of the high ground of Burghead-Lossiemouth, which was then an offshore island (Ogilvie, 1923; Comber, 1993). Under conditions of net westerly drift, sediment from the River Spey is thought to have moved freely through this corridor and into a proto-Burghead Bay to be augmented by sediment from the River Findhorn. Combined with the net onshore movement of sediment under a rising sea level, a strongly positive sediment budget was created at the present-day location of Culbin (Hansom, 1999). The shoreline response to such rapid sediment input was to prograde seawards, and progradation at Culbin occurred in a similar fashion to many other gravel-dominated foreshore systems (e.g. Carter *et al.,* 1987) by developing a suite of multiple sub-parallel ridges. Transects across the gravel ridge 'fan' (Figure 11.1) demonstrate the trend in falling sea level that occurred after the peak of the Holocene transgression (Figure 11.2). The highest set of ridges in the 'fan' were deposited at the peak of the transgression, while most of the ridges landwards and eastwards occur at lower altitudes and were deposited as sea level fell and so are younger (Comber, 1993). The falling sea level reduced water depths in the marine corridor to the east of Culbin and it became blocked with westward-drifting sediment from the Spey. At Culbin, the loss of this sediment feed from the east was to dramatically reduce the amount of sediment available for storm ridge sedimentation. The sedimentary record of this decline in sediment supply at Culbin is represented by fewer gravel ridges deposited over time, creating a net steepening of the ridge suite to seaward and the beginning of erosion of the updrift gravels in the eastern part of Culbin itself.

The above interpretation suggests that the locus of gravel accumulation has shifted through time from the east of Culbin to the west, where it is now represented by The Bar. The attached gravel barrier has been migrating alongshore in a westerly direction towards the town of Nairn since least 1685 AD as documented by Ross (1992; (Figure 11.1)). This process of updrift erosion fuelling downdrift accretion has been a feature of the coastal development of the southern Moray Firth throughout the Holocene Epoch (Comber, 1995). (Figure 11.1) shows a hypothesized development sequence, running numerically from 1–7, of Culbin Sands and The Bar proposed by Hansom and Comber (1994), Comber (1995) and Hansom (1999). The reworking of sediment from updrift to fuel downdrift accumulation can be seen to account for the truncated emerged gravel ridge sequences in the 'fan' (Figure 11.1), locations 1, 2 and 3). Radiocarbon dating of peat taken from depressions at the foot of the emerged cliff suggests that abandonment of gravel spit 3 occurred between 4600 and 3300 years BP when the River Findhorn abandoned a westerly course at Cran Loch to breach northwards through the gravel beach close to the present exit of the river (Comber, 1993). The process of spit destruction is suggested to have been repeated several times in the similar, though much younger, features that form The Bar and its predecessors. Hansom (1999) indicates the mode of emplacement of the gravel storm-ridges has remained the same since at least the mid-Holocene and represents a predictable response of sediment recycling within conditions of restricted sediment supply. In conditions of deficit, sediment within specific coastal cells is re-organized by erosion of some parts and re-deposition in others (Carter, 1988). (Figure 11.1) also demonstrates the tendency over time of the Culbin foreshore to rotate clockwise to face north-east in an attempt to align itself normal to incident wave approach, evolving from a drift towards a swash alignment of the coast (Davies, 1980).

The entire length of The Bar at Culbin is subject to reworking as proximal erosion in the east fuels distal accretion in the west (Comber *et al.,* 1994). Where both contemporary and recently abandoned ridges have been truncated in the deeper water of the distal end, wave refraction has carried gravel around the tip (Figure 11.5). This results in recurves forming behind the sequential positions of the former distal ends of The Bar, some of the truncated remnants of which are now found in seemingly anomalous locations (for example (Figure 11.1), locations 4 and 5). Between 1976 and 1989 The Bar continued to extend westwards at a mean rate of 14.6 m a^{-1} (Comber, 1993), demonstrating that the processes that created this section of the Scottish coastline over the Holocene Epoch still operate. Today's Bar is a direct descendant of many previous barriers and spits on this coast.

The Culbin dune system has been described extensively (e.g. Ogilvie, 1923; Steers, 1937; Ovington, 1950; Edlin, 1976). Several well-developed palaeosols are found at various sites throughout Culbin Forest and contain important information concerning the development of the dunes (Comber *et al.,* 1994). The palaeosol profiles are particularly mature, a feature unusual in dune systems of this size given their propensity to become remobilized under combined natural and anthropogenic pressure. The earliest documented reference to the mobile dune belt at Culbin was by Boethius in 1097 AD (in Craig, 1888), who referred to the inundation of parts of Moray by sand thrown up during storms in the North Sea, but several earlier periods are known including a major period of sand dune instability at *c.* 4500 years BP (Hickey, 1991). The most recent period of dune activity at Culbin coincides with the end of the most recent phase of wide-scale dune re-activation. This phase began in the 13th century and ended during the mid-late 17th century with the stormiest period of the 'Little Ice Age' (Hickey, 1991). The maturity of the Culbin palaeosol profiles suggests that some of the dunes remained stable for the early part of this dune mobilization phase (Comber *et al.,* 1994), supporting a full vegetation cover that prevented sand-blow The dunes seem to have become re-activated relatively late in the sequence of dune activity. The documented story of the destruction of the Culbin estate by blown sand reports that the estate was overwhelmed over the course of a single storm in 1694 AD (Steers, 1937). However, it is more likely that the dunes were subject to an extended period of destabilization, with the final inundation occurring during the 1694 event. Destabilization was probably aided by the removal of the closed vegetation cover and, in particular, the removal of marram *Ammophila arenaria* for thatch (Comber *et al.,* 1994). In response to the loss of the important agricultural estate of Culbin, an Act of the Scottish Parliament was passed in 1695 to prevent pulling of 'bent' (marram) from sand dunes (Ross, 1992).

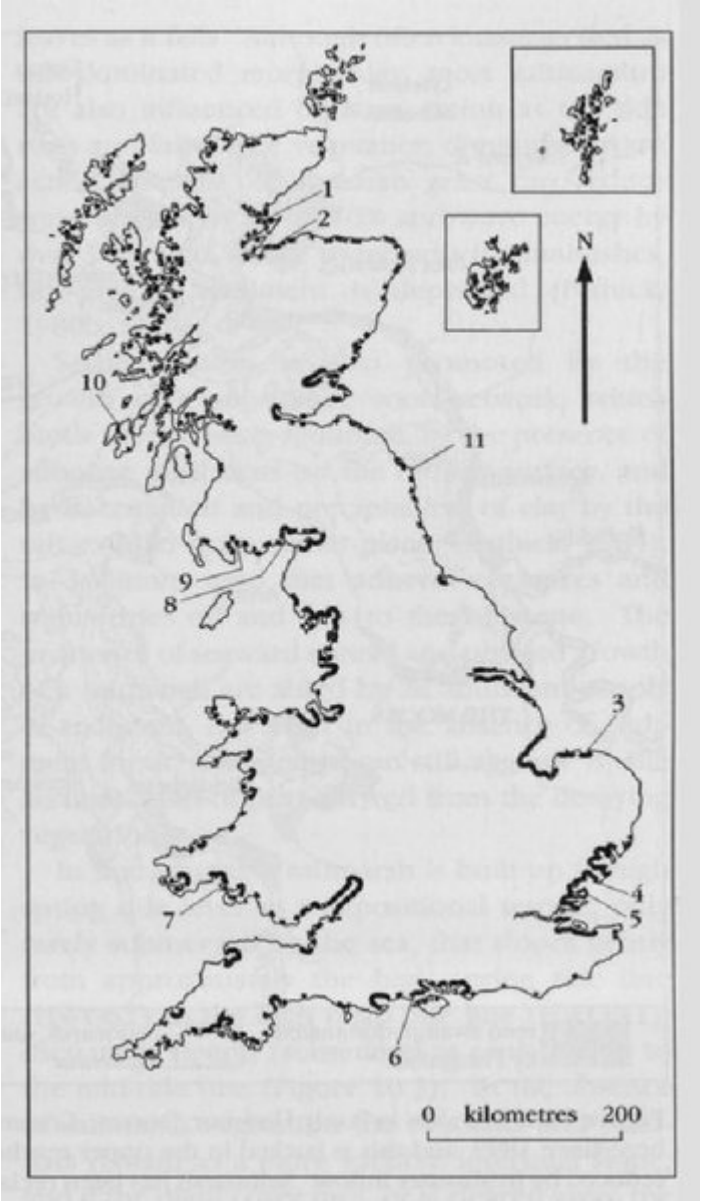
As demonstrated by Comber (1993) the contemporary coastal development of the Culbin foreshore can be directly linked to the Holocene evolution of the entire landform assemblage. The diverse process environment of the Culbin foreshore provides an excellent site for the study of a wide range of coastal processes and land-forms. Erosion of the dunes west of the River Findhorn and on the updrift section of the Buckle Loch spit fuels downdrift accretion of the spit, which has been extending in a westerly direction at a mean rate of 22.3 m a^{-1} over the period 1870–1988 (Comber *et al.,* 1994). As

erosion proceeds at the eastern extremity of the Buckle Loch spit, storm washover and marine incursion into the Buckle Loch occurs. A shallow lake in the late 19th century, the Buckle Loch is now a low, intermittently flooded area of grassland and deciduous trees fronted by a low dune-ridge. It is likely that westerly accretion will progressively seal the upper part of the Buckle Loch spit marsh, creating a new Buckle Loch farther to the west of the original (Comber *et al.,* 1994). By that time the present-day site of the Buckle Loch will have been all but removed, as erosion proceeds at the eastern end. Such change in both the Buckle Loch and The Bar has implications for the extensive saltmarshes that have accreted in the shelter afforded by the two major spits. Migration of the protecting structures and erosion of their updrift ends forces commensurate change in the sheltered environments behind and exposes the backing salt-marsh to erosion. Such activity is presently most severe at the neck, midway along The Bar, where saltmarsh peat is exposed on the intertidal zone as the foreshore transgresses landwards (Figure 11.4).

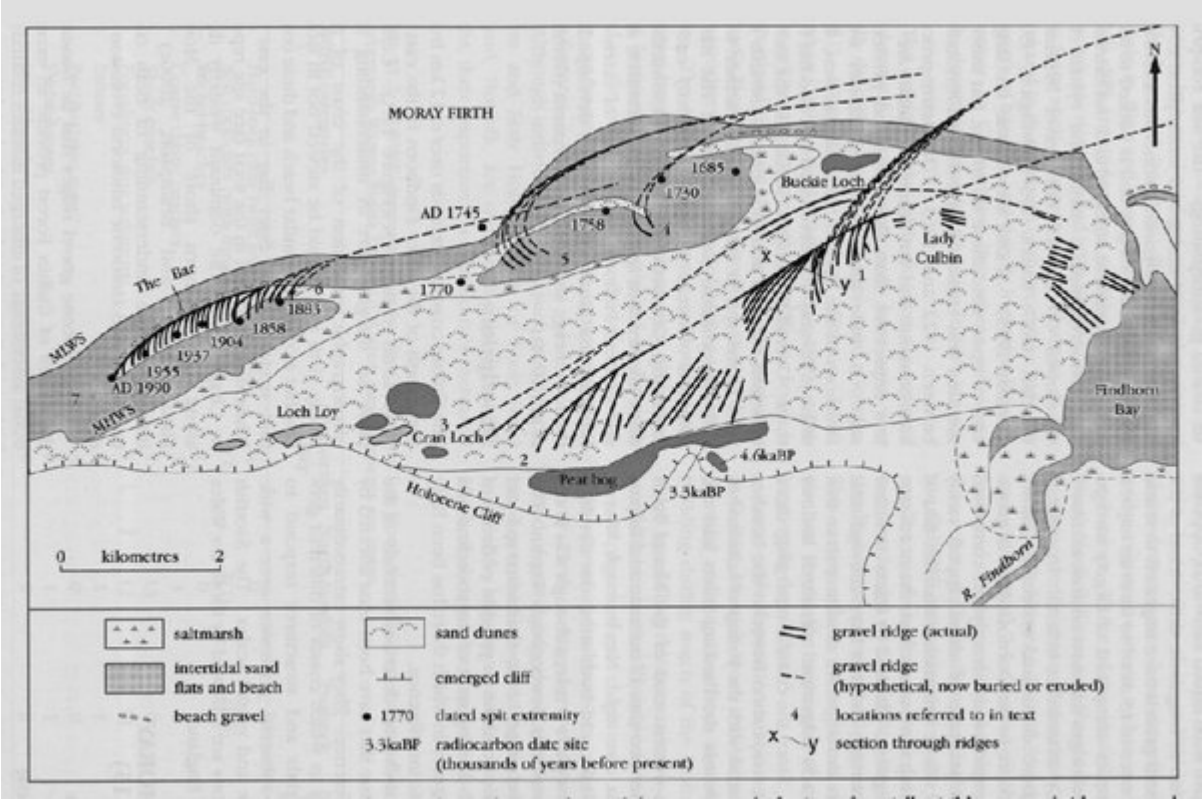
Conclusions

Culbin is an exceptional site for coastal geomorphology. Within Europe, no comparable suite of emerged gravel ridges and spits with capping sand dunes matches the scale, complexity and preservation of the features at Culbin. The gravel ridges record the fall of sea level from its mid-Holocene high at about 6500 years BP to its present-day level. In addition, a reduction in sediment supply forced a switch from widespread gravel accretion to a period of reworking of pre-existing gravel spit structures. Such internal reorganization of sediment has resulted in the sequential development of migrating spits, the most recent of which can be seen in the present-day Bar (Hansom, 1999). Resting on top of the ridges, the Culbin dunes once formed one of the largest areas of blown sand in Britain and although subsequently, and very successfully, stabilized by forestry, they are rated internationally as a geomorphologically important site for sand dune development. Culbin is also a key regional site for the interpretation of the history of Holocene landform evolution in the Moray Firth.

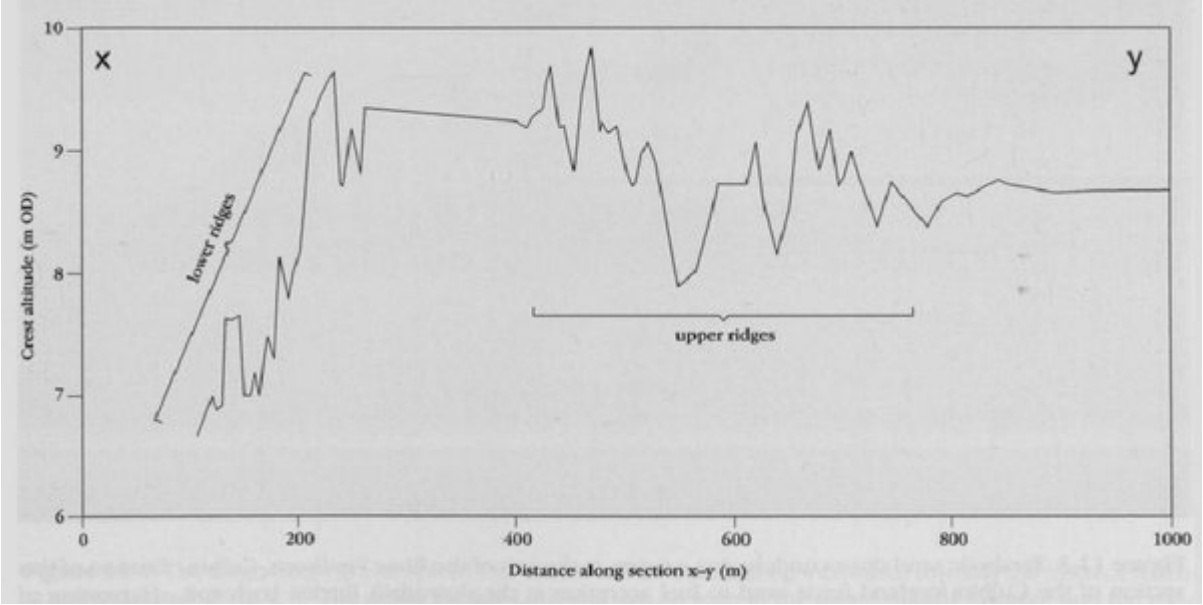
No less impressive are the active process environments of Culbin, with a dynamic migrating sand spit whose extension has led to the infill of a small lake and its imminent erosion. Culbin also has a spectacular example of a 'flying barrier', a spit whose eastern section is a dune-adorned sandy feature and whose western end is a superb rapidly extending gravel spit backed by numerous recurved gravel ridges (Figure 11.5). Both of these features are associated with the development of wide intertidal sandflats on both seaward and landward sides, the latter providing a sheltered environment for the development of saltmarshes. Culbin is a unique mix of spectacular Holocene emerged features together with equally impressive contemporary coastal processes and forms.



(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. Burly 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.)

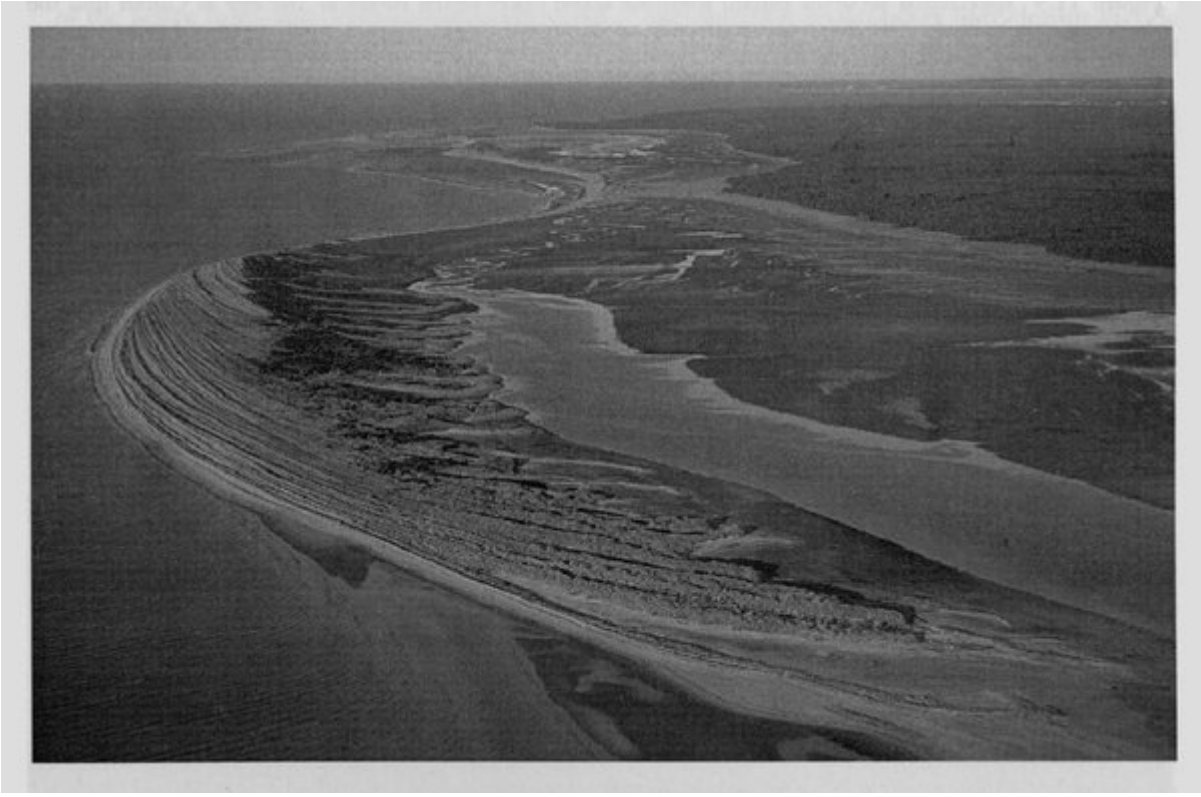


(Figure 11.1) The GCR site of Culbin is a large and complex gravel strandplain composed of suites of partially visible emerged ridges capped by large sand dunes. The pattern of the underlying gravels can be reconstructed into a series of westward-extending gravel spits; the updrift erosion of the earlier spits fed the downdrift extension of the more recent ones that have been dated using historical maps and aerial photographs. Extensive sandflats and saltmarshes have developed in the shelter of the westward-extending spits. See Figure 11.2 for the section X—Y. (After Hansom, 1999.)



(Figure 11.2) The gravel ridges over a 1000 m transect from x–y (see Figure 11.1) show two groups of emerged ridges, the most seaward of which decline rapidly in height towards the north-west. (After Comber, 1995.)

(Figure 11.3) Parabolic sand dunes undergoing erosion at the exit of the River Findhorn, Culbin. Erosion of this section of the Culbin foreland feeds sand to fuel accretion at the downdrift Buckie Loch spit. Harvesting of timber over a 20–30 m-wide dune edge zone is part of a management regime designed to reduce erosion caused by disruption of the dune surface by toppling, and to allow mechanical harvesting to be carried out in safety (Photo: J.D. Hansom.)



(Figure 11.4) The magnificent gravel spit of The Bar at Culbin is extending westwards towards the town of Nairn at approximately 15 m a^{-1}. The sandy Buckle Loch spit can be seen in the upper middle distance and the narrow erosional neck at the eastern end of The Bar. This updrift erosion has truncated earlier ridges and is now encroaching into the area of saltmarsh that has developed behind the bar and may ultimately threaten the larger area of saltmarsh that lies in the right foreground. (Photo: P. and A. Macdonald/SNH.)

(Figure 11.5) Spectacular recurves extend from the active outer beach ridges at The Bar at Culbin into the sheltered area behind. The inner recurved parts of the gravel ridges support small areas of heather, gorse, broom and pine whereas the intertidal flats between the gravel ridges support small areas of saltmarsh (see Figure 11.4). (Photo: P and A. Macdonald/SNH.)

(Figure 11.6) An extensive area of saltpans and linear creeks characterize the area of saltmarsh that has developed at the heads of the two intertidal lagoons that lie either side of the area where The Bar at Culbin is attached to the mainland (see Figure 11.4). (Photo: J.D. Hansom.)