Tentsmuir, Fife

[NO 500 275]

J.D. Hanson

Introduction

The extensive lowland surface of Tentsmuir lies between the Tay estuary in the north and the sandstone headlands of St Andrews in the south (see (Figure 7.1) for general location) and is one of the largest areas of blown sand in Scotland (Dargie, 2000). Tentsmuir is a site of long-term accretion with over 3.5 km of shoreline advance in 5000 years (Ferentinos and McManus, 1981). The Tentsmuir GCR site (see (Figure 7.42)), which includes the vast intertidal sand spits, banks and bars of Abertay Sands, forms the point where the coastline turns from the open sea into the Tay estuary and is of outstanding geomorphological interest. The rate and amount of coastal progra-dation at Tentsmuir is unique in Britain (Crawford and Wishart, 1966; Ritchie, 1979b) and has been documented by several workers, notably Grove (1950), Deshmukh (1974), Wal (1992) and 'Whittington (1996). The area is known to have been accreting in a north-eastward direction since 1812 at an average rate of 4.8 m (McManus and Wal, 1996). Long-term net accretion at Tentsmuir is the result of the integrated impacts of several natural processes acting in concert, both wind and wave activity resulting in the accumulation of sediment at the Point (McManus and Wal, 1996). Close relationships between the geomorphological and ecological evolution of Tentsmuir (Crawford and Wishart, 1966; Garcia-Novo, 1976) enhance the scientific interest of this highly dynamic and outstanding site.

Description

The Tentsmuir Point GCR site forms a relatively small proportion of the 3300 ha of sand dune in the greater Tcntsmuir area (Dargie, 2000) (Figure 7.48). Low, emerged beach sands and silts form the substrate materials for much of the Tentsmuir links and dune system, however the boundaries between the emerged ('raised') beach sand and blown sand are imprecise (Ritchie, 1979b). Most of the Tentsmuir area was stabilized by afforestation in the 1920s and as a result much of the morphological detail has been obscured. Nevertheless, there is evidence that beneath the forest cover there are sets of sand ridges running parallel to the coast (Ritchie, 1979b), and to the south and west, intervening lochs that have since been drained (Hutcheson, 1914). Structurally, Tentsmuir is composed mainly of two sequences of dune ridges arranged approximately parallel to the nearby coast with intervening slacks. In the north, bordering the Tay estuary, they trend east-west and along the open east-facing coast of St Andrews Bay they trend north-south. At Tentsmuir Point the often rather poorly developed 2–4 m-high dunes are weakly aligned north-west-south-east (McManus and Wal, 1996).

The morphology of Tentsmuir Point is intimately linked to the intertidal sand spits, banks and bars of Abertay Sands that stretch eastwards for 6–7 km beyond the Point (Figure 7.48). Abertay Sands are more than 1 km in width and incorporate a substantial island area at the southern entrance. These sand formations are highly dynamic and respond to the complex interplay of the three main variables, estuarine discharge, tidal streams and wave climate (Ritchie, 1979b). The complex development of the Abertay sand spits and bars, including an analysis of the main ebb and flood channels, is investigated in detail by Green (1973).

Tentsmuir Point provides a complex topography where it is possible to identify fragments of earlier phases of development, including former coastlines that evolved as a result of processes that are essentially similar to those operating today. The low-gradient sand beach at Tentsmuir Point reaches widths of up to 400 m and the lower foreshore typically shows ridge and runnel structures trending north-south (McManus and Wal, 1996). Tentsmuir Point is largely composed of medium-grained sands (D_{50} = 0.28 mm) that are highly susceptible to wind action. Sediment transport by wind is very important in the upper foreshore and backshore zones where the development of dune systems has led to an increase of vegetated land surfaces elevated above high spring tide levels. Active 2–4 m-high dune accumulations in the lee of the beach are found extensively at Tentsmuir Point. These low, hummocky marram *Ammophila*-clad dunes grade landwards into a *c.* 50 m-wide zone of low dunes where four separate ridges can be identified (Ritchie, 1979b). To landward, there is a distinctive flat dune-slack zone at *c.* 1–2 m OD that is of considerable ecological interest. Landwards of the dune slack there is a line of broader mature dune ridges that correspond approximately to the 1941 line of concrete antitank blocks (Ritchie, 1979b). The mature dune systems are heath-covered whereas the younger forms have characteristic *Ammophila*-dominated vegetation. The average surface elevation of the dunes and slacks at Tentsmuir Point is around 3–4 m OD (Ritchie, 1979b).

The south part of Tentsmuir Point (i.e. the east-facing coastline) is affected by the rhythmic changes of erosional coastal sections alternating with progradational sections, which is typical of the coast southwards as far as the Eden estuary (Ritchie, 1979b). Coastal erosion has been documented along different stretches of the Tentsmuir coast since 1964, notably north of the Eden estuary, but also at the southern end of the GCR site (McManus and Wal, 1996). The 3–4 m-high sand cliff cut in the coast-parallel dune ridges just north of the entry of the Powie Burn suggests this section of the coast was undergoing a period of recession in the 1970s (Ritchie, 1979b). The north coast of Tentsmuir is subject to substantial changes in response to the pattern of ebb discharge and flood tide channel migration associated with the dynamics of the south side of the Tay estuary (Figure 7.49).

The Tentsmuir area is a site of long-term net coastal accretion with over 3.5 km of shoreline advance in 5000 years (Ferentinos and McManus, 1981). Based on analysis of historical and recent data sources Tentsmuir Point is known to have been accreting in a north-eastward direction since 1812 (Grove, 1950; Deshmukh, 1974; Wal, 1992; Wal and McManus, 1993). The rates and form of coastal prograda-tion at Tentsmuir have been reconstructed in (Figure 7.50)). In the earliest documented growth phase, 1854–1912, the high-water mark advanced north-eastwards by about 40 m on average, although in the south the shoreline receded. The next documentary evidence of the shoreline position is in 1941, the year when the line of anti-tank traps and the low ridge (the Defence Dune), which lies 80–160 m seawards of the traps, were constructed at or above the high-water mark. Aerial photographs show a *c.* 500 m-wide flat beach surface seawards of the dunes in 1948. By 1962 hummocky aeolian sand accumulations supporting pioneer vegetation were present along the backshore, separated by narrow channels occasionally occupied during high tide. This dune growth had extended 40 m seawards of the Defence Dune. By 1972, the isolated hummocks had largely amalgamated so that a continuous vegetated area had been created extending a further 25–30 m seawards. Again a series of sand mounds supporting pioneer plants were present on the backshore. By 1978 the dune margin had advanced a further 60 m seawards as the mounds became incorporated within the vegetated dune area. New actively accreting mounds lay to the seaward. To the east a 400 m-long dune-covered spit extended northwards from Tentsmuir Point, providing shelter from waves. By 1985 the spit had broadened from 25 m to 80 m and the northern extremity had separated to create a recurved 'islet' over 300 m long. By 1990 the southern part of the spit had linked with the accreting sand mounds and the northern 'islet' had extended in all directions, although a narrow tidal channel remained between it and the vegetated land area.

Overall, in the 178 years between 1812 and 1990 the vegetated land area at Tentsmuir Point advanced 870 m in a north-eastward direction perpendicular to the coastline (McManus and Wal, 1996), and eroded about the same distance inland in the south. The average long-term (178-year) accretion rate is 4.8 m a^{-1}, although by plotting forward growth against time McManus and Wal (1996) show that accretion rates have increased greatly through time. The very high rates of accretion have been achieved by the retention of sand upon an already high beach surface. The vegetation has responded to rapid coastal accretion at Tentsmuir, with an outward movement of vegetation zones over time (Crawford and Wishart, 1966; Ritchie, 1979b). The pattern of floristic development is matched closely to the distribution of slacks in relation to coastal accretion (Crawford and Wishart, 1966).

Interpretation

Tentsmuir is one of the most rapidly accreting parts of the British coastline (Crawford and Wishart, 1966). Continuing coastal progradation is relatively rare in Britain and most dune systems are currently undergoing a period of retreat. Thus, the natural dynamism of the north-eastwards accretion observed at Tentsmuir Point has attracted considerable scientific interest and research. Grove (1950) first mapped the coastal progradation at Tentsmuir and suggested three main possible sand sources: sediment entering the coastal system from the Rivers Tay and Eden; offshore sediments; or sediment derived from coastal erosion. Later research established the detail of coastal changes between 1854 and 1990 (Figure 7.50) and the recent evolution of Tentsmuir Point is now relatively well documented (Deshmukh, 1974; Wal, 1992; McManus and Wal, 1996) and is summarized above. More recently research has focused on the processes and mechanisms fuelling the observed coastal accretion at Tentsmuir (e.g. Ferentinos and McManus, 1981; Sarrikostis and McManus, 1987; Wal, 1992; Wal and McManus, 1993; McManus and Wal, 1996).

The vast Tentsmuir dune and links system is the result of massive Holocene progradation, comparable to the formation of the Morrich More and Culbin systems (Ritchie, 1979b). Ferentinos and McManus (1981) note that the Tentsmuir shoreline has advanced over 3.5 km in the last *c.* 5000 years. The exact mechanism of coastal progradation is unknown, but Ritchie (1979b) envisages three possibilities. Firstly, as the sea level fell from a Holocene high of *c.* 10–15 m OD, successive beach zones built seawards and continue to do so. Secondly, the falling sea level left a wide beach zone upon which dune systems developed, or thirdly, some form of spit–bar complex curved southwards from the Tay enclosing a broad lagoonal area that was subsequently infdled from the east by blown sand. A detailed stratigraphical and geomorphological investigation is required to elucidate the Holocene evolution of the Tentsmuir system.

Recent process studies at Tentsmuir may provide a key to understanding the past. Tide, wave and wind activity are the major constructive processes contributing to the current growth of Tentsmuir (McManus and Wal, 1996). The floor of St Andrews Bay, an area within which sediments have been deposited during Late-glacial and subsequent times (Browne and Jarvis, 1983), may provide the immediate source of sediment for the Tentsmuir area (McManus and Wal, 1996). Sediments are also swept northwards onto Tentsmuir by a gyre in the flood tide (see (Figure 7.47)), whereas ebb tides may sweep sediments south, across Abertay Sands (Ferentinos and McManus, 1981). Based on wave refraction analysis, Sarrikostis and McManus (1987) demonstrated that wave fronts approaching the Fife coast from most directions become deformed in such a way that they sweep towards the Tentsmuir area. Consequently, as the result of sediment movement by waves approaching the shore at an angle, Tentsmuir Point experiences accretion due to the transport of bed material not only shorewards from the bed of the embayment but also northwards along the shore (Sarrikostis and McManus, 1987). Longshore drift also transports sediment from the eroding sections of the south Tentsmuir coast northwards to the Point. Based on a comparison of aerial photographs and maps, McManus and Wal (1996) estimated that the volume of sediment eroded from the dune margins along the Tentsmuir coast between 1978 and 1990 was 46 x 10^4 m^3. The volume of sediment that had accumulated at Tentsmuir Point over the same period was estimated to be 33 x 103 m^3. Thus the coastal erosion on the Tentsmuir beaches to the south could have readily supplied the material accreted at the Point. Long-term natural progression of sediment northwards along the beach face to Tentsmuir Point has led to the creation of a wide beach-surface that has extended north-eastwards and is protected behind the offshore Abertay Sands (McManus and Wal, 1996).

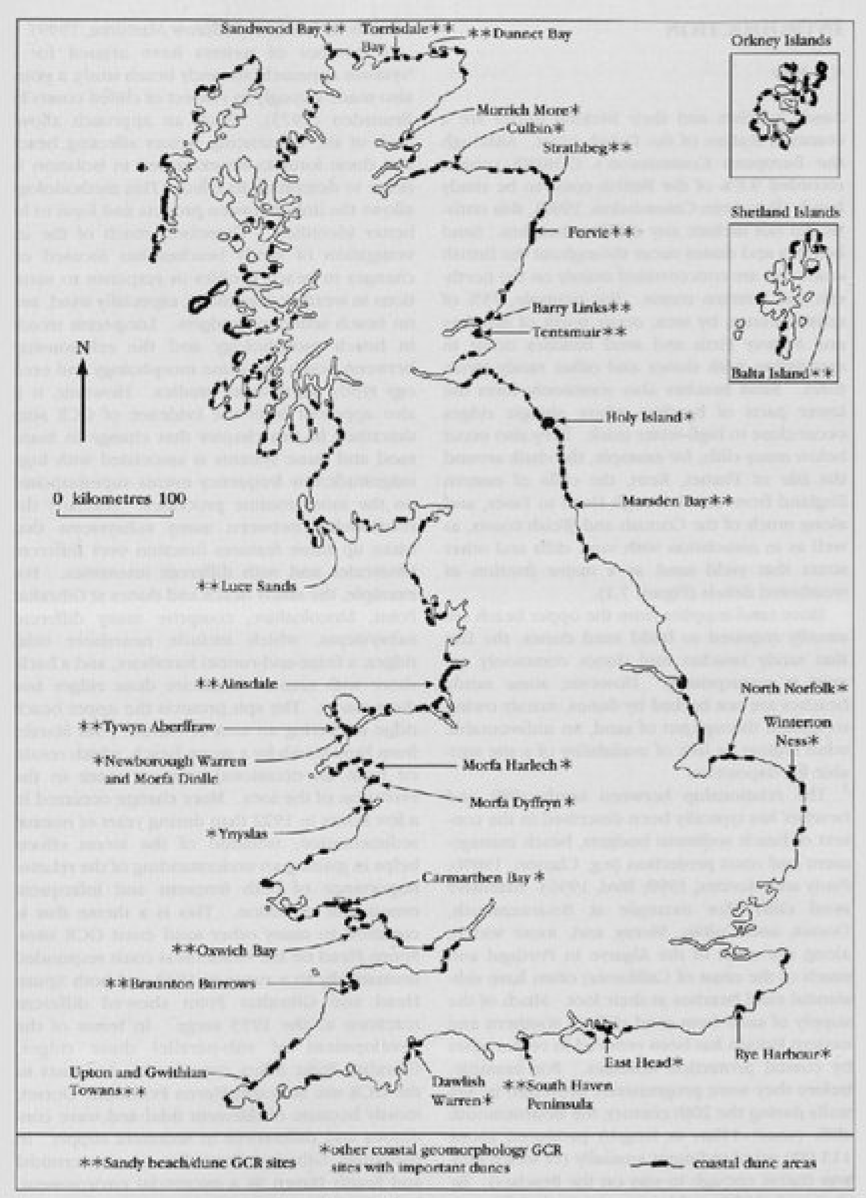
Wind activity is also a major constructive process contributing to coastal accretion at Tentsmuir (Wal and McManus, 1993; McManus and Wal, 1996). By 1990, over 300 m of the 500 m-wide beach surface noted in 1948 was covered with low vegetated dunes. The present area of accretion is now well above the level of spring high-water mark, indicating that the sediment covering the beach surface has been transported to the site by wind action (McManus and Wal, 1996). A detailed study of the wind regime at Tentsmuir identified high-energy seasonal 'unimodaf (offshore or onshore) and 'bimodal' (both offshore and onshore) wind regime patterns (Wal and McManus, 1993). In addition, there can also be a 'unimodaf longshore wind and a 'bimodal' one that possesses a longshore component. Each of the major wind directions initiate sand transport at certain velocities and form a distinctive group of landforms. The commonest offshore winter winds may carry sand from the dunes to create wind-shadow foredunes at the back of the upper beach. Offshore winds also carry sand onto the lower beach and into nearshore tidal waters where wave and tidal activity recycles it to the beach. Therefore, the principal geomorphological impact of offshore winds is the production of shadow foredunes (McManus and Wal, 1996). Onshore winds, common in spring and autumn, transport sand up the beach face, enhancing foredune growth and carrying sand landwards into the dune systems. Longshore winds from the south can transport large volumes along the coast towards Tentsmuir Point (McManus and Wal, 1996). For example, strong winds in November 1968 carried continuous sheets of sand northwards along the Tentsmuir coast for at least three hours forming a swarm of barchan dunes up to 1 m high on the beach at the Point. It is calculated that as a result of this storm, more than 40 000 tonnes of sand were transported to Tentsmuir Point (McManus and Wal, 1996) although much of the sediment was swept north into the channel of the Tay estuary, perhaps to be recycled into the system at a later date.

The close relationship between the geomorphological and ecological evolution of Tentsmuir Point has also attracted considerable research (e.g. Crawford and Wishart, 1966; Desmukh, 1974; Garcia-Novo, 1976; Whittington, 1996). From the wide intertidal beach to the margins of the forest (which is encroaching naturally onto the older dunes) there are excellent examples of the interaction of vegetation and landform, with particular emphasis on accretionary forms and processes. Vegetation zones have encroached seawards gradually stabilizing the accreting coastline. For further details of the biological interests and the complex vegetation successions at Tentsmuir Point see Crawford and Wishart (1966), Steers (1973) or Garcia-Novo (1976).

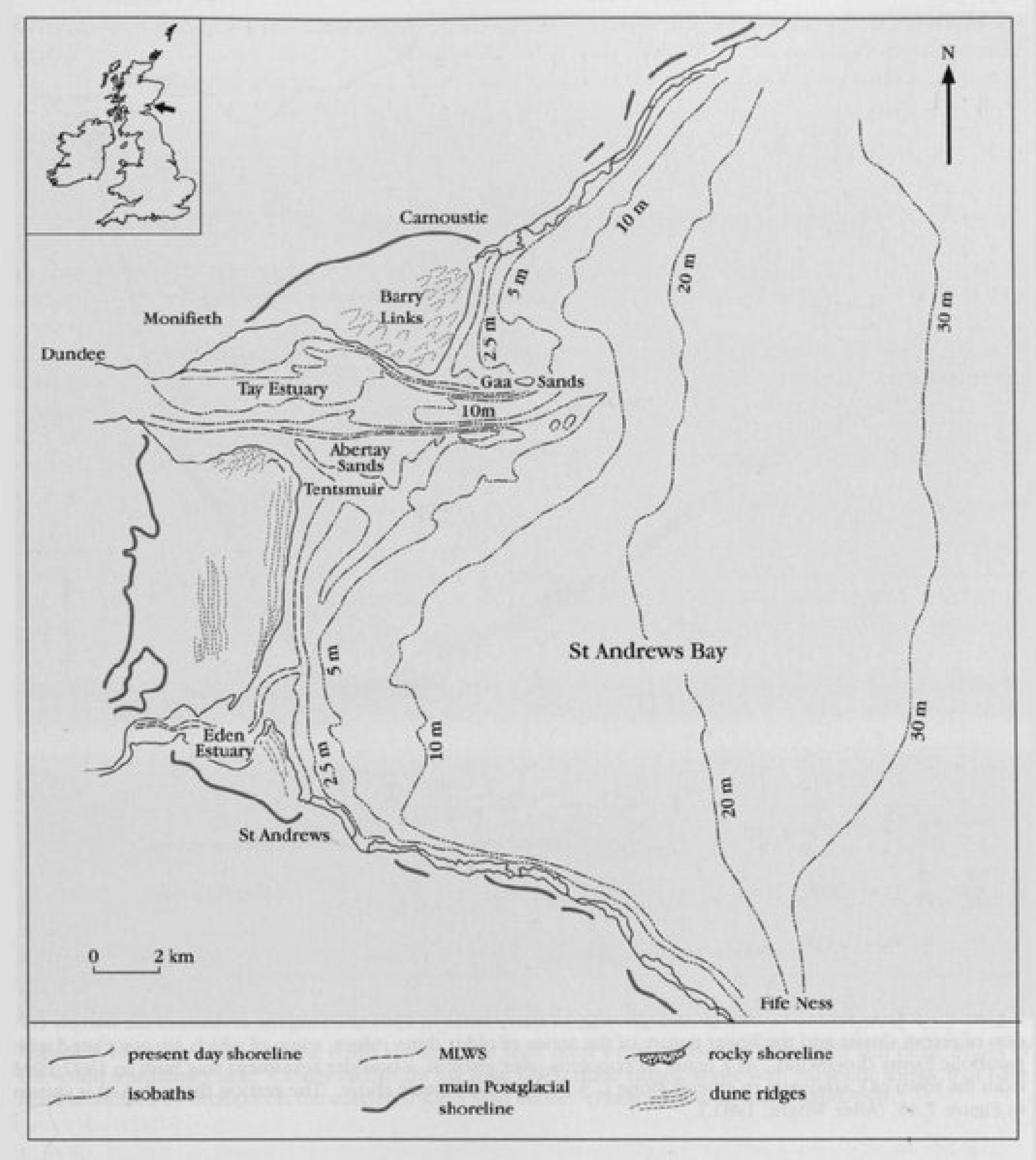
Conclusions

Tentsmuir Point, Fife, marks the southern limit of the Tay estuary and is one of the most rapidly accreting parts of the British coastline. In contrast to the majority of dune systems in Britain, which are generally undergoing retreat, Tentsmuir Point is actively accreting. Since 1812 Tentsmuir Point has advanced 870 m in a northeasterly direction at an average rate of 4.8 m per year in part, fuelled by erosion of South Tentsmuir. The very high rates of accretion have been achieved by the retention of sand upon an already high beach surface. Net accretion at Tentsmuir Point is the outcome of the integrated impacts of several natural processes acting in concert. Wave activity in St Andrews Bay results in the transport of sediment to the head of the embayment and northerly longshore drift along the Tentsmuir coast encourages progression of sediment along the beach face towards Tentsmuir Point. Wind action acts simultaneously, resulting in the accumulation of low dune forms on top of a wide beach surface. Onshore, offshore and longshore winds are all important in dune formation at Tentsmuir. The outwards movement of dune vegetation zones is related to long-term coastal accretion at Tentsmuir, and this dose association between the geomorphological and ecological evolution enhances the scientific interest.

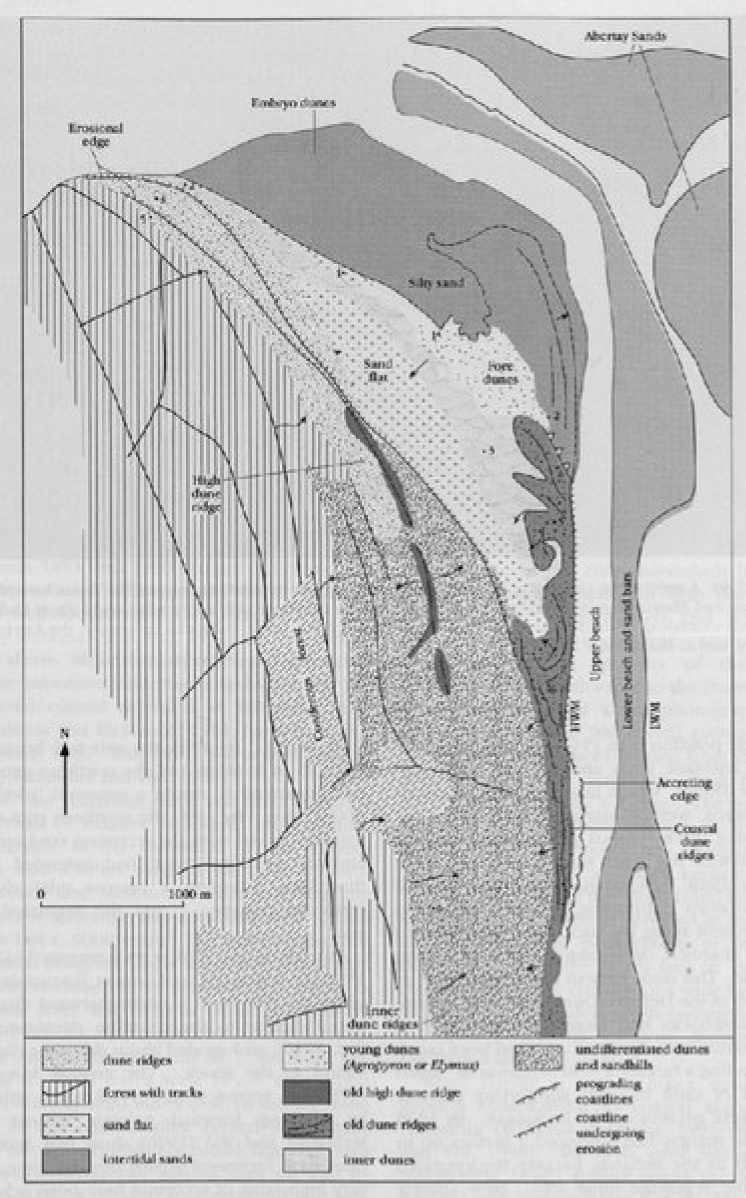
The site is also important as a National Nature Reserve and is part of a Special Area of Conservation.



(Figure 7.1) Great Britain sandy beaches and coastal dunes, also indicating the location of GCR machair–dune sites (see chapter 9) and other coastal geomorphology GCR sites that contain dunes in the assemblage.

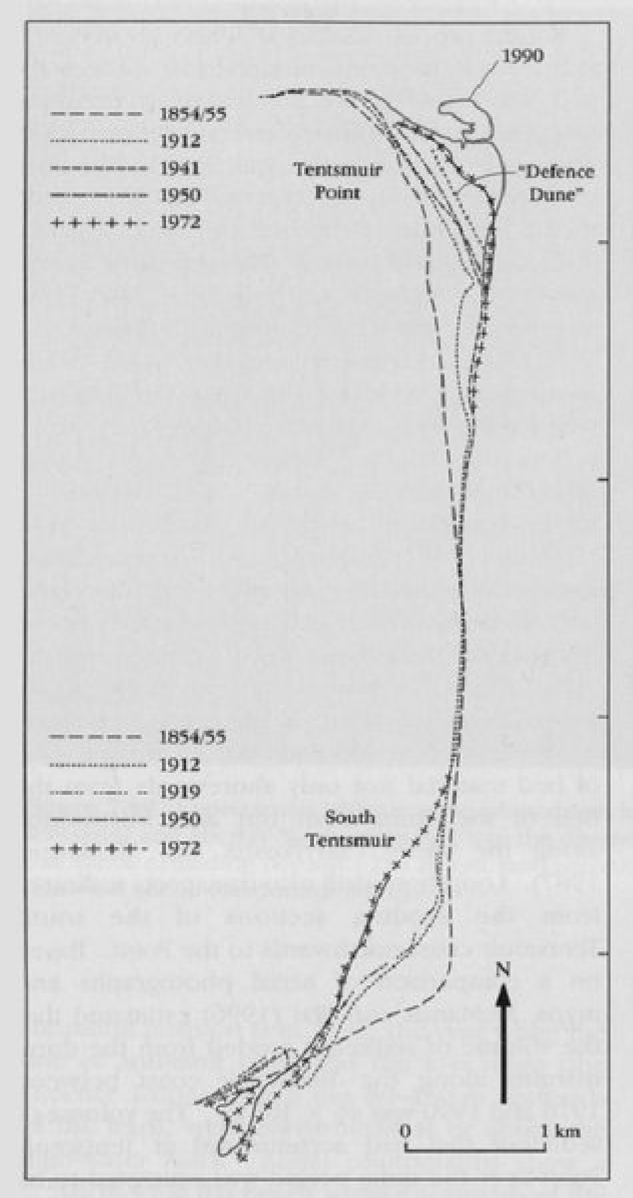


(Figure 7.42) Location of Tentsmuir and Barry Links in St Andrews Bay. Tentsmuir and Barry Links have built out eastward of the main Postglacial (Holocene) shoreline at the mouth of the Tay estuary. Extensive intertidal and subtidal sand banks have also accreted at Abertay and Gaa Sands in the zone where river discharge interacts with open coast tides and waves. (After Ferentinos and McManus, 1981.)

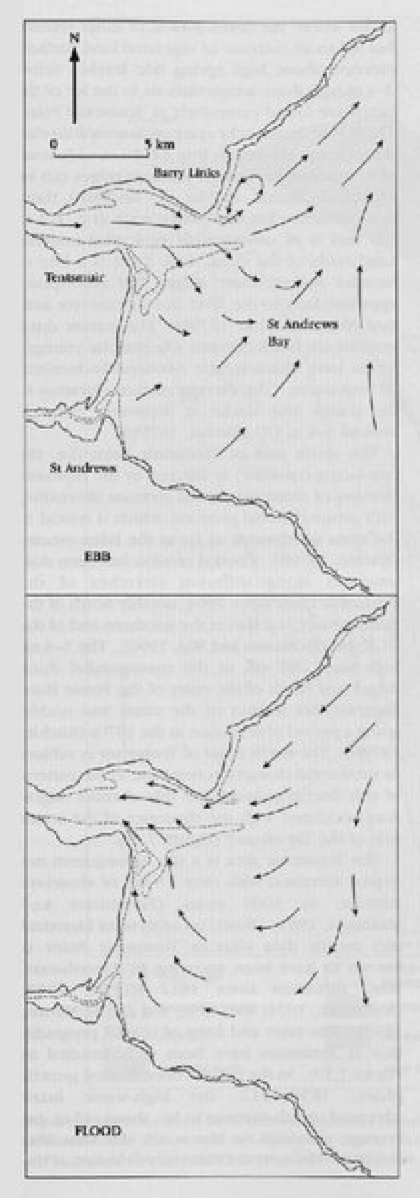


(Figure 7.48) The coastal landforms of Tentsmuir showing the extensive areas of sandflat, foredunes and intertidal sandbanks that extend out to Abertay Sands. Erosional edges are found in the south of Tentsmuir and along parts of the Tay estuary coast. (Based on Ritchie, 1979b, and McManus and Wal, 1996.)

(Figure 7.49) A spectacular oblique aerial photograph looking east towards the exit of the Tay at low tide with Tentsmuir and Abertay Sands extending into the distance on the south side and on the north Barry Links with Gaa Sands extending beyond. The recent sand accretions of Tentsmuir Point can be seen in the foreground. (Photo: P and A. Macdonald/ SNH.)



(Figure 7.50) Long-term changes in the position of south and north Tentsmuir showing a general trend of erosion in the south and accretion in the north. (Compiled from McManus and Wal, 1996.)



(Figure 7.47) Mid-flood and mid-ebb tidal stream patterns in St Andrew's Bay based on a combination of direct measurement and hydraulic modelling. The open coast at Tentsmuir is affected by northward movement on the flood and south-eastward movement on the ebb, whereas the open coast at Barry Links is affected by southward movement on both the flood and the ebb. (After Ferentinos and McManus, 1981.)