Journal of Coastal Conservation 6: 207-218, 2000

The sands of Forvie (Scotland) : A case study in geomorphology and conservational management

Ritchie, William

Office of Vice-Chancellor, Lancaster University, LA1 4YW, United Kingdom;
Fax +44152436841; E-mail w.ritchie@lancaster.ac.uk

Abstract. The Sands of Forvie, National Nature Reserve, Scotland is a complex coastal sand dune system which is associated with the dynamic estuary of the River Ythan. The dune system has developed over more than 5000 years. The south part is a peninsula of dunes, sand hills, sand arcs, erosion and deflation surfaces. The north part is superimposed on a rock plateau with a cliff coastline. This plateau is covered in glacial deposits and is essentially an upland heath landscape. Some of the best examples of large active parabolic dunes in Britain are found in North Forvie. The sequence of geomorphic development is described. As a nature reserve with a rich ecology it has been managed for conservational purposes since 1960s. As such it is an excellent case study of how conservational management has changed to become more flexible and more aware of the importance of dynamic processes.

Keywords: Coastal sand dune; Dune heath; Nature reserve; Parabolic dune.

Location

The coastal dunes of Forvie (Fig. 1a, b) are the northernmost element in the extensive bay which is defined by the headland of Girdleness at Aberdeen in the south and the till-covered cliffs at Rockend in the north. Within this 24 km long, east-facing bay three large rivers divide the continuous beach and dune systems into unequal segments. Forvie lies to the north of the smallest river, the Ythan, and this complex area of wind-blown sand, which is one of the largest dune areas in Scotland, owes much of its origin and development to the position and morphodynamic changes of the estuary (Fig. 2, below) – especially during the main formative period when the Ythan was the prime source of sand for beach nourishment and dune development. As a National Nature Reserve there are three closely-linked physical and ecological components; the estuary, the sand dune peninsula (South Forvie) and the high plateau with its dispersed groups of dunes and intervening areas of heath (North Forvie).

As a large, complex dune system, the development of the Sands of Forvie has been controlled by climate, sediment sources, underlying surface geology, sea level changes, land drainage, ecology and history of land use. Although sand movements are not presently on a large-scale, the age of the system is likely to be more than 5000 yr.

Changes in sea level

Research in the lower Ythan Valley has demonstrated that around 6000 yr ago sea level was 4 to 4.5 m higher and estuarine terraces and raised beaches were superimposed or cut into the much older glacial and fluvio-glacial features which lie on the margins and beneath the Sands of Forvie (Smith et al. 1982). With a falling sea level, these surfaces were abandoned, typically as gravel and shingle spreads which may be exposed from time to time by shifting sands, and notable examples are found in low areas between the dunes in the South Forvie peninsula. At the time of higher sea levels, the Ythan estuary would be enlarged and the hydraulic efficiency of the river reduced. In theory, this would have been a period of considerable estuarine sedimentation, and many low lying marginal areas are a product of this time.

The climatic factor

In considering the evolution of any coastal dune system, climate, both now and in the past, is the prime causal factor. The strength and direction of winds drive aeolian processes and generate waves and coastal currents. Vegetation responds to seasonal and long-term climatic cycles. Land use and drainage are also controlled by weather conditions.

With respect to modern conditions, wind patterns at the local airfield, Dyce, are shown in Fig. 3. This resultant diagram is calculated on the basis of wind speeds greater than 5.4 m/sec (10 knots), which is the approximate speed at which sand grains will be lifted and transported. There are two resultants – onshore winds at 153° and total winds at 255°. The onshore resultant shows close correspondence with coastal blowouts and other features of South Forvie and the total resultant

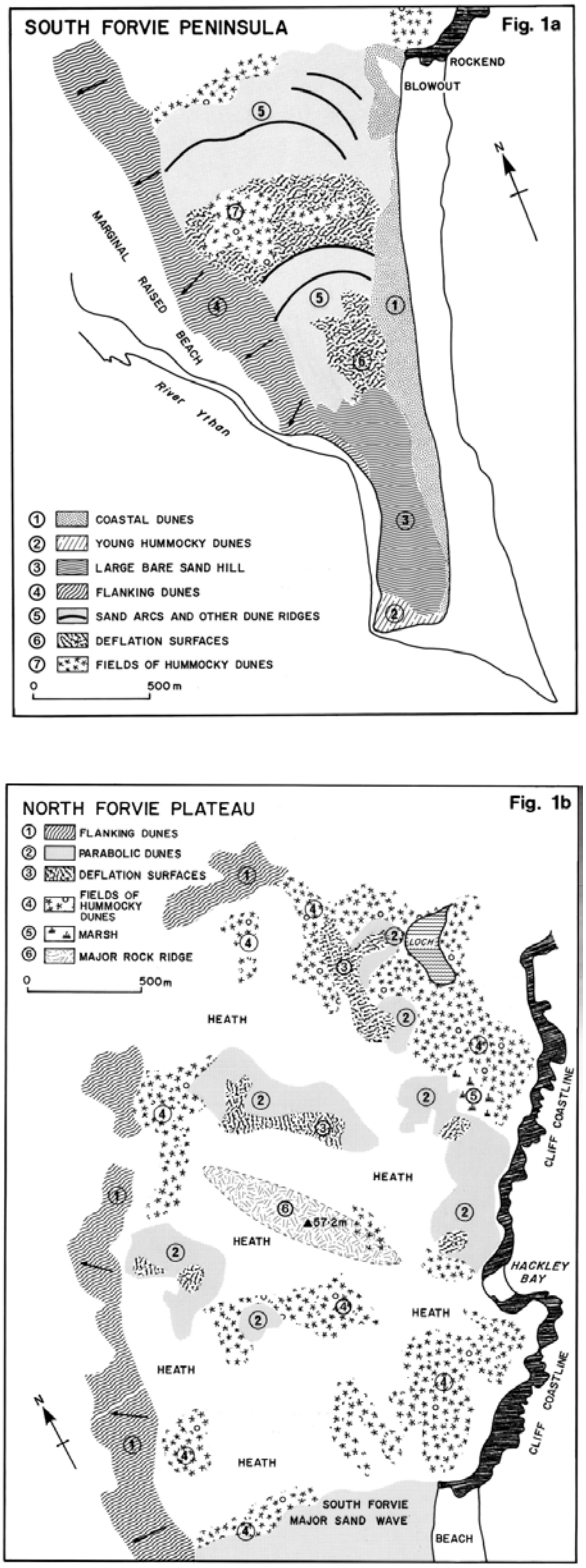

Fig. 1. General map of Sands of Forvie showing the main types of landforms and locational names. (Of necessity this map is divided into two sections, south and north.)

bears some relationship to the concentration of great masses of sand, including parabolic dunes, on the north-east part of the estate. The calculation of this direction-resultant diagram is based on percentage frequency and the wind speed, aggregated within the eight compass sectors (Ritchie et al. 1978).

At St. Fergus, 20 km to the north, in an area of similar coastal dunes, the frequency and amount of flooding have been recorded and analysed (Maizels 1990; Soulsby & Malcolm 1997). The results can be transferred to Forvie where similar winter flooding of low areas occurs, especially in South Forvie. The essence of the St. Fergus studies shows that flooding begins in October and persists until April in most years. Peak water table rise is in mid-February. Flooding is closely related to precipitation and reduced evapo-transpiration rates in winter. In contrast, there is often severe drying in summer due to the very low rainfall levels that characterize the climate of northeast Scotland. Absolute levels of rainfall in this part of Scotland are normally less than 750 mm with a conspicuous early summer minimum, but there is considerable year to year variability. Nevertheless high water table levels, marshiness and seasonal flooding are powerful controls of the patterns of sand movement in different parts of both North and South Forvie. In contrast, the combination of strong winds and summer dryness contributes to the considerable amount of aeolian sand transport from unvegetated surfaces. The variability of both factors on a month by month and year to year basis also contributes to short-term diversity in such morphological responses as the direction, extent and volume of active dune erosion and sand drifting.

Sediment sources and dynamics

Archaeological investigations of the north-central part of South Forvie by Kirk (1953, 1958) and Ralston (1992) who described the area as "Although stray finds indicate that there was recourse to this area during the Iron Age, the field remains date to the later part of the Neolithic and Bronze Ages" (p. 30). Ralston (1992) also states that "episodes of sand accumulation were taking place here well before 2000 B.C." (p. 32). Taking this date along with an approximate date of 6000 yr ago for the last significant movement in sea level it appears justified to believe that sand accumulation in this area has been occurring since at least 5000 yr ago with the prime sand source being at the mouth of the Ythan.

Stove (1978) and Weatherill (1980) described the Ythan Estuary as having a large inter-tidal basin with a small fluvial discharge and the estuary is dominated by marine and tidal processes with slow net sediment input. There is also a semi-closed sediment circulation between the dunes and beaches of the south end of the peninsula, the river outlet and the complex of sand spits and bars of this part of the coast. Buchan (1976) has also shown that, in general, the net sediment transport of Aberdeen Bay (and Forvie is the north part of this system) is northwards. Thus the accumulation of sand at the mouth of the Ythan and adjacent beaches were and are the sources of vast quantities of sand for dune building. Nevertheless Esler (1983) concluded that the modern coastline is characterised by erosion and foredune instability with little or no contemporary primary sand nourishment from the beach. This cycle of internal reworking of sand with net coastline retreat is no different from all other sections of the dune-backed coastline of Aberdeen Bay and has been attributed to the elimination of ongoing sand supply to the littoral zone. The best hypothesis for this abrupt change is to envisage the sand supply to the coastal zone of South Forvie as being a one-off legacy of deglaciation which, having been used, probably in a relatively brief period of time, has never been replaced.

The different types of sand dunes

The Sands of Forvie National Nature Reserve which contains depositional, redepositional, erosional and non-dune surfaces is a particularly complex system. Indeed it is this size and complexity which justifies its National Nature Reserve Status, and its landform diversity is reflected in a great variety of habitats which support the total ecology of the area.

The Sands of Forvie has two main divisions, the South Forvie peninsula (Fig. 1a) where the dunes overlie glacial till, raised beaches and estuarine terraces, and North Forvie, which, in contrast, consists of a rock plateau with a variable cover of glacial deposits and a scatter of dunes and sandhills (Fig. 1b). The greater part of the north area is heathland. The coastline consists of rock cliffs with one small cliff-foot sand and boulder beach. Nevertheless North Forvie has some of the best examples of parabolic dunes in Britain (Ritchie & Robertson-Rintoul 1990) and some sand hill complexes rise more than 20 m above the plateau surface (Fig. 4).

The classic block diagram, originally drawn by the late Professor Walton (Fig. 5), graphically illustrates these features. Detailed topographic maps (scale 1 : 7500, contour interval 2m) with accompanying geomorphological and vegetation maps were published in 1967 (Ritchie & Wright 1975). From these sources a long, south to north profile is provided in Fig. 6 which emphasises the gradual increase in elevation northwards and the considerable variations in relief consequent upon the alternating surfaces of deflation plains and massive sand waves, of which the sand wave, labelled 'Arc 3', marks the transition from South to North Forvie. This sand wave is critical to the understanding of the transfer of sand from the peninsula of South Forvie, with its estuarine and beach sources, to the dunes and sand hills on the cliff-bound north plateau, which is remote from any primary sand supply. The extensive sand dune complexes, including the parabolic systems, of North Forvie are superimposed on this uneven rock and till covered plateau at increasing altitudes and distances from the ultimate source of sand, the South Forvie peninsula and its North Sea beach and estuarine spit-bar complex.

In detail, the dunes of North and South Forvie form a complex patchwork, a palimpsest of old and new elements of ridges, hills, blowouts and deflation surfaces. Nevertheless it is possible to reduce these complex landforms into a generalised geomorphological map as illustrated in Fig. 1a.

The standard or 'textbook' dune landscape is usually portrayed as a simple sequence which consists of beach, dune ridge and a transitional area to a non-sand landscape, usually of agricultural fields, forests or urban areas. In reality, ancient, large dune systems such as Forvie are very complex, interlocking morphological and ecological units. In North Forvie, for example, stable acid heath with rich *Calluna-Empetrum* vegetation is juxtaposed with large migrating parabolic dunes with moderately shell-enriched highly mobile spreads of sand in the form of low hummocks, trailing sand ridges and occasional large amorphous sandhills.

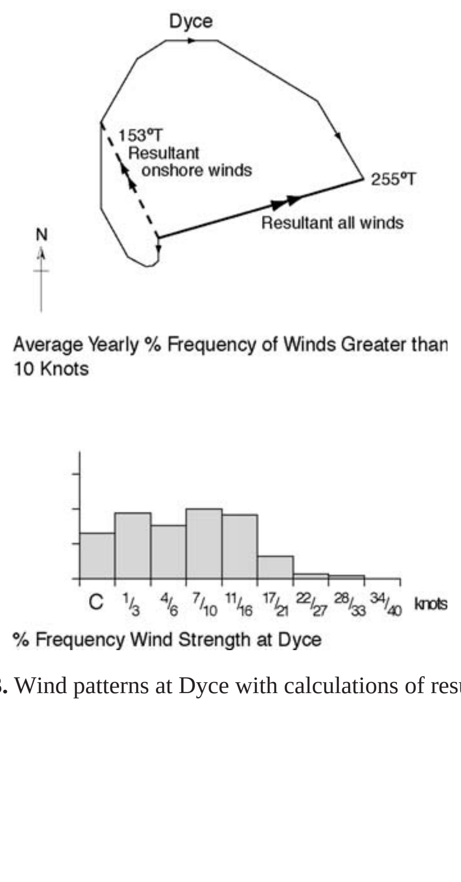

Fig. 3. Wind patterns at Dyce with calculations of resultants.

Fig. 2. The mouth of the Ythan at low tide with complex spits and bars. The south part of the peninsula of South Forvie contains very active dunes and large percentages of areas of mobile sands.

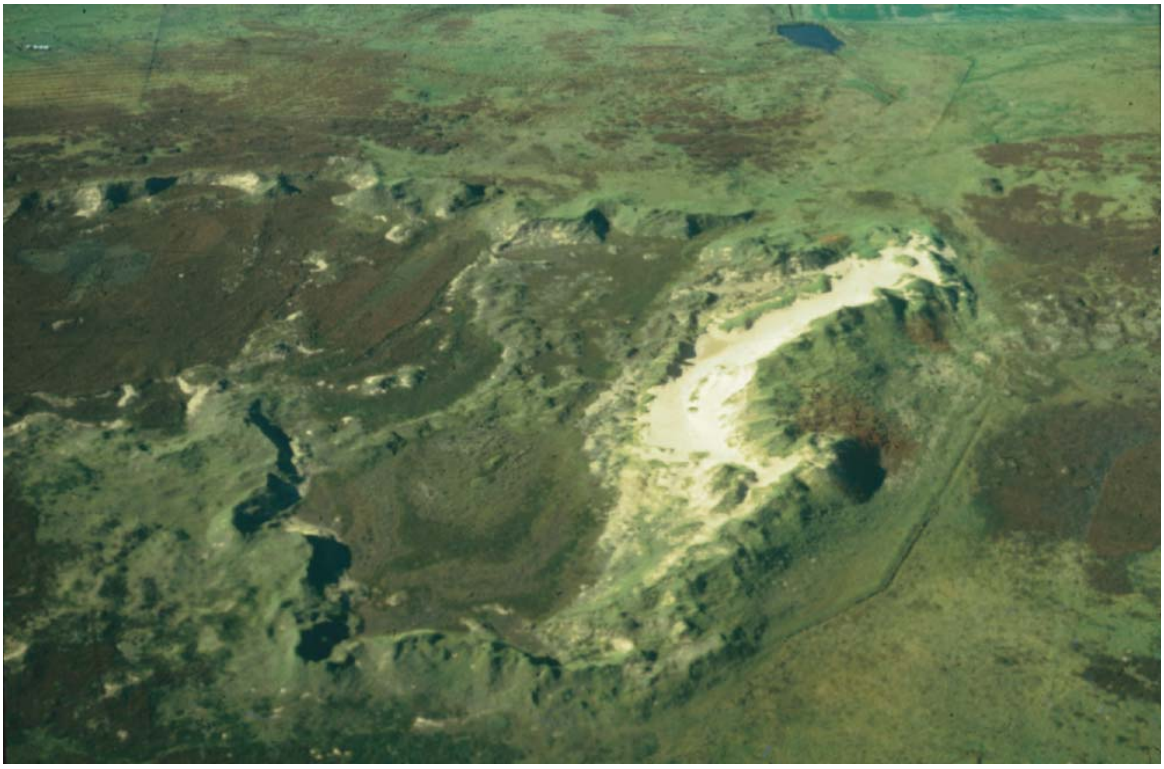

Fig. 4. This is a general view of North Forvie which shows the extensive area of heathland with a good example of a mobile parabolic dune complex.

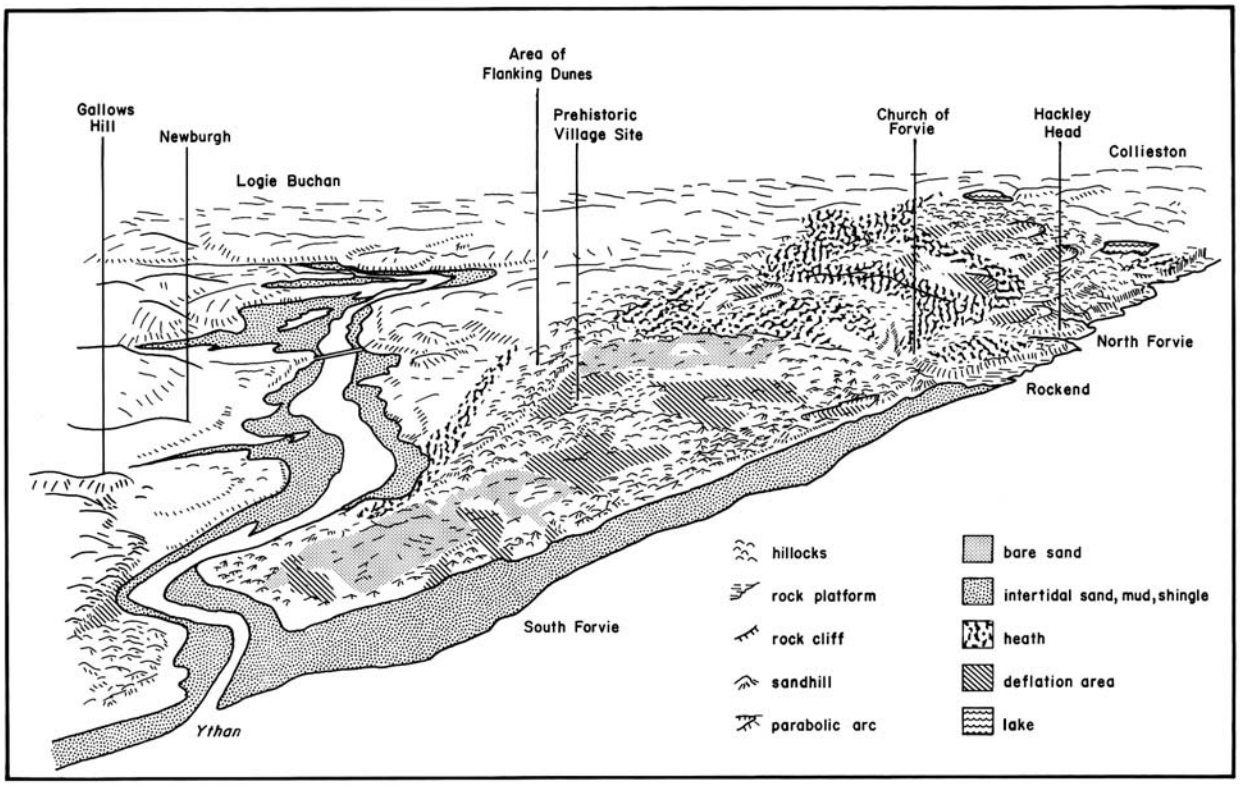

Fig. 5. Perspective block-diagram of Sands of Forvie and Ythan Estuary.

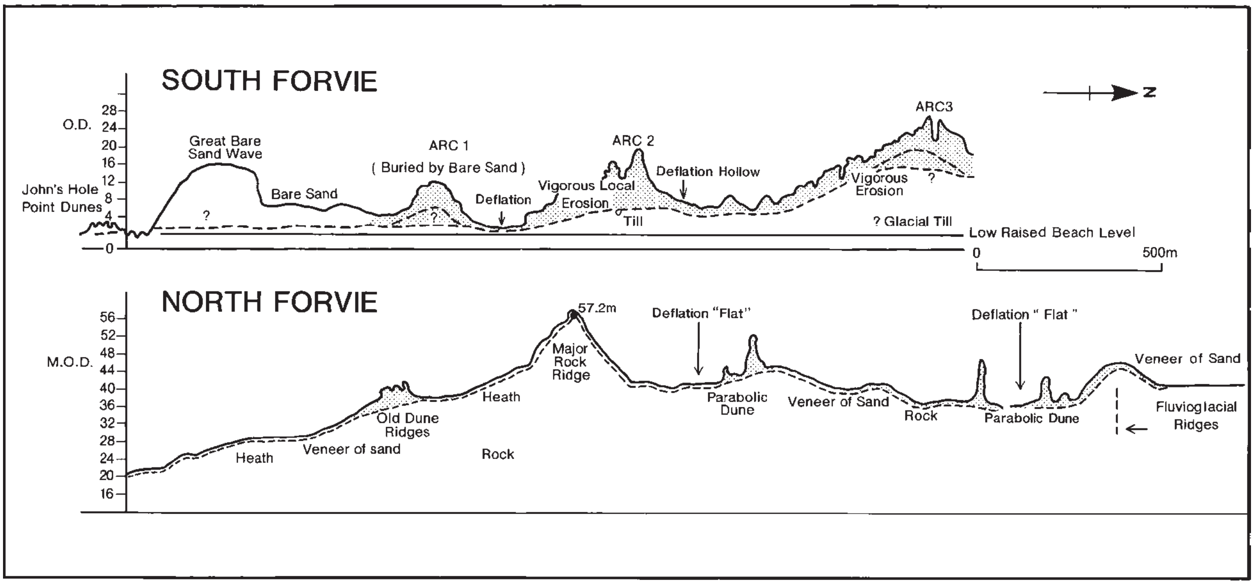

Fig. 6. Profile to illustrate both relief and general northwards increase in altitude.

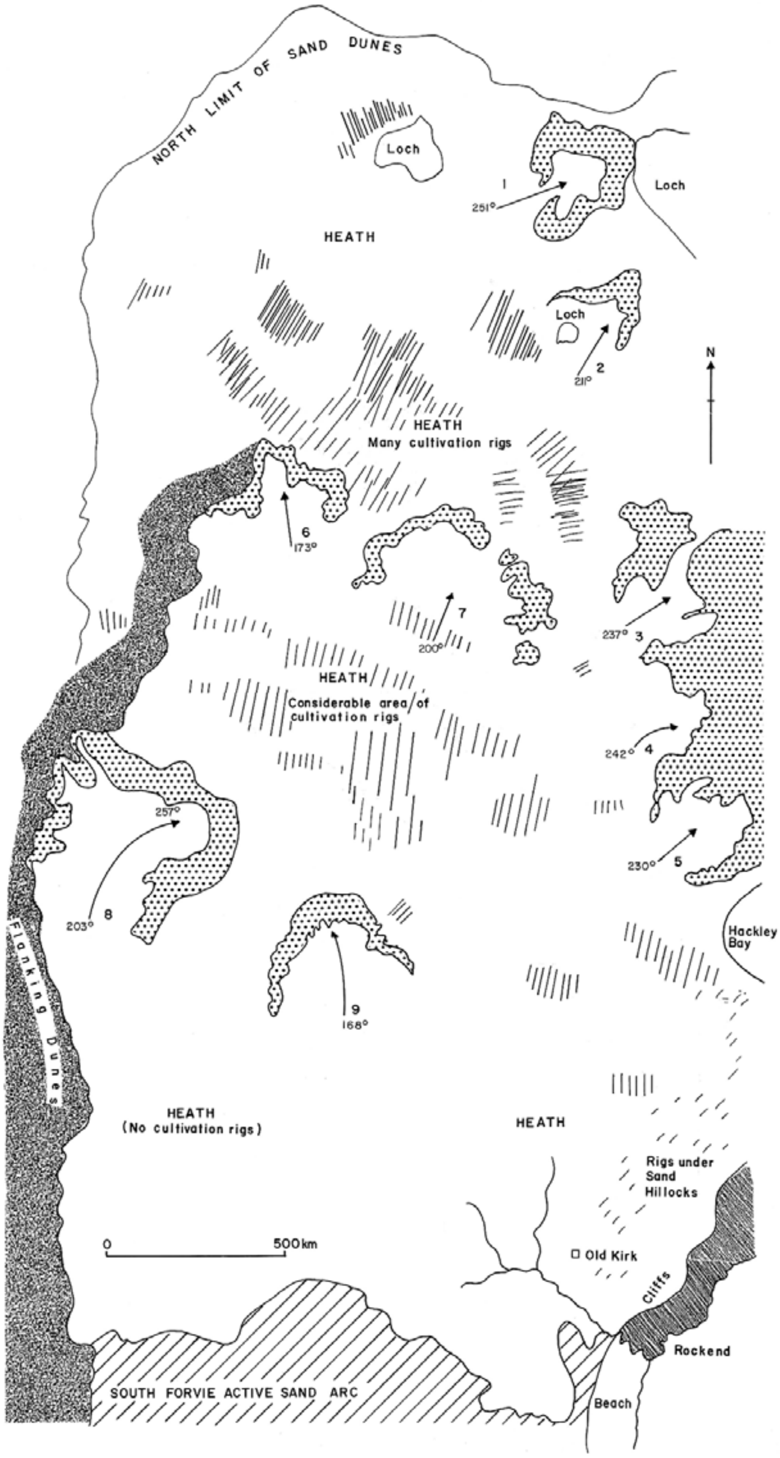

Fig. 7. North Forvie – Distribution and orientation of parabolic dunes and other landforms.

In South Forvie there is active beach-dune interchange, severe erosion in the form of linear blowouts and more general deflation, and the most southerly extension is strongly affected by changes in the position of the river outlet. Conservational management must recognise not only the intrinsic variety of the area but also the need to ensure that there is no restriction on the free-flow of the dynamic processes which continually reshape this enormously varied landscape resource.

A detailed taxonomy of these landforms emphasises the differences between South and North Forvie and also reveals clues which can be used to interpret both contemporary and historical sequences of development.

South Forvie (Fig. 1a)

Coastal dunes. These range in height from 2m to over 15 m in the north. Dissection is severe. Some dune ridges have been removed entirely. Esler (1976) analysed the extent of their instability which is due to a lack of sand supply, a narrow beach, and frequent onshore winds, mainly from the southeast. Large blowouts, especially near Rockend, are the reason for the increased height and extent of the dunes at the north end of the bay.

Active dune hummocks. These dunes may be remnants from more continuous foredune ridges. There is sufficient sand transport from the extensive beach and spit areas nearby to ensure accretion and vigorous growth. These dunes are rarely more than 4 m high and are among the most active dunes at Forvie.

The long whale-backed bare sand hill. This ridge with its superimposed sand waves and ripple forms, which trend in a consistent south to north direction, is a feature of remarkable persistence, having been described as existing in the 18th century. The absence of vegetation is a result of complete surface instability and continuous sand movement. From this ridge, sand spills westwards into the Ythan closed-cell circulation as described by Weatherill (1980) and northwards to encroach onto the adjacent deflation plain (Fig. 1a). It is difficult to envisage the permanence of this 20 m high ridge without suggesting that it has a core of rock or, more likely, glacial till with a perched water table. Indeed this core might be the reason for the southwards deflection of the mouth of the river Ythan. Such an exposed hill, if entirely composed of sand, would otherwise be eroded down to beach level unless a non-sand core exists. Less likely is a condition of dynamic balance where sand loss to north and west is continually balanced by fresh sand from the beaches to south and east. A series of boreholes would confirm the depth and stratigraphy of this prominent ridge but to date these have not been drilled.

Flanking dunes. The west margin of the Sands of Forvie consists of extensive, continuous flanking dunes which have steep, eroding, and actively dissected east-facing slopes. The west slopes are stable and grade relatively steeply to marginal farmland based on raised beaches in the south and fluvio-glacial ridges in the north. The sharp crest-edge of these flanking dunes is normally over 20 m O.D. (Ordnance Datum). Some of the best erosion features in Forvie, specifically V-shaped blowouts, occur in these flanking dunes. In South Forvie some blowouts have exposed the basement of glacial till, including areas of very large irregular boulders in a clay and gravel matrix.

Major sand arc or waves. The three main sand ridges are massive features, in the south 500 m wide and in the north about 1500 m. The north to south widths of these ridges are more than 200 m but the surface forms may be subdivided into various vegetated dune ridges and bare deflation surfaces. Parts of the south-facing slope are often at a stage of severe deflation and have been reduced to the base level of old soil horizons or the underlying glacial till basement. This is particularly true of the west side of the arcs which do not benefit from sand drift from the coastal dunes. There are also deep linear blow-out depressions and V-shaped hollows at various degrees of activity. Associated with wind erosion are redepositional forms of which the north-west side of the north ridge provides a good example of a mass of bare sand spilling northwards as a steep, partially vegetated talus slope. The surface stability of these massive sand waves changes rapidly. A detailed study by Wright & Harris (1988) of the west part of Arc 3, for example, demonstrated a complex and largely inexplicable series of rapid alterations from vegetated to unvegetated status within a decade.

It is these massive sand arcs that have been interpreted as the principal mechanism for sand movement northwards from the mouth of the Ythan to the north end of the estate during the last 5000 yr. The main crests of the south ridge reach over 20 m O.D. whereas the north ridge can exceed 35 m O.D. The distinctive rise and fall of the sand arcs with their intervening deflation plains are shown in the accompanying long profile (Fig. 6). All these arcs have a shape which is consistent with a south to north migration and the active edge on the north side is also encroaching in places onto older surfaces.

Deflation plains and hummocky dunes. The main deflation plains lie at low altitudes (5 to 10 m O.D.) between the great sand arcs to north and south, and the coastal and flanking dunes to east and west. These erosion plains are not flat but are characterised by smaller scale dune features, including fields of irregular hummocky dunes which are thought to be relatively recently formed, and are associated with small scale erosional processes and redeposition. The main deflation surfaces are marshy or flood in winter, having being reduced by deflation processes to the level of the water table, below which aeolian sand erosion is impossible. In a few places, there are dune slacks and seasonal stream-like features. The sub-sand basement of glacial deposits or raised beach gravels occurs at shallow depths below the sand. Deflation surfaces of all types are formed as a sand dune or a sand hill is eroded on the windward side. As the ridge of sand migrates, the deflation plain is left, abandoned, as an erosion surface. Later events may superimpose redepositional minor dune forms on it and, if there are successive sand waves moving in a consistent direction, the deflation surface which is expanding at the north margin could be compensated by migrating sand deposition at its south end. In South Forvie the main deflation surfaces are a product of erosion on both the north side (against the great sand arc) and on the west side (against the retreating flanking dunes). If the deflation and migration process were to continue there would be a parallel translation of deflation plains and sand arcs northwards. Since 1967 this has not occurred. This poses the question of balancing mechanisms such as short periods of exceptionally strong winds from the northerly quarter (which do occur each year) and/or net transfer of sand to the east and to the west, i.e. to the flanks of the peninsula. A general increase in dune and sand-hill heights would also help as a compensating process. Detailed long-term morphological and wind-analysis would help to answer these questions.

North Forvie (Fig. 1b)

Flanking dunes. These dunes continue the form and pattern of South Forvie but are at higher altitudes. They are equally dissected but have a more variable landward transition to the higher rolling fluvio-glacial topography west of the dune system. The flanking dunes are not continuous and, in the north, they curve to the east to form the northern limit of the estate where, in two places, they encroach into kettle-hole lochs in the kame and kettle fluvio-glacial deposits at the north end of the estate. They have active blowout-scalloped east-facing slopes. An area of dune hummocks and one of the major parabolic dune ridge complexes also merge with these flanking dunes to produce a more dissected topography than is found further south.

Parabolic dune complexes. Parabolic dunes are rare in Britain and the nine systems that can be recognised at North Forvie have been described as classic examples of this type of dune landform (Ritchie 1992a). The distribution of these features is given in Fig. 7, which shows a detached group of parabolic forms in the northwest of the area. A massive west-facing group is found north of Hackley Bay. Another group occurs north of this complex and extends as an irregular escarpment as far as the west side of Sand Loch in the extreme north of the Reserve. The remaining parabolic arc is found in the centre of the north plateau. A similar series of ridges and escarpments form the northern limit of the Sands of Forvie near Cotehill Loch, at a distance almost 6 km north of the mouth of the Ythan. These dune arcs face south, southwest and west and consist of several intersecting parabolic sections with trailing 'arms' of lower dune segments. There is considerable variation in geomorphological activity and, at any moment in time, most parts of the ridges are stable. Nevertheless, over a longer time scale cumulative erosion in the centre proceeds more rapidly than on the flanks and the parabolic shape is preserved as the dune migrates, leaving a deflation surface to mark its earlier positions. The movements of the parabolic dunes of North Forvie provide critical evidence for the elucidation of the historical evolution of North Forvie.

Heath plateaux. Between the parabolic and other types of dunes the most extensive surfaces of North Forvie are acidic heaths with characteristic *Calluna-Empetrum* vegetation. The sand cover is thin and the underlying red glacial clays are close to the surface. The areas of heath are normally undulating with some distinctive zones of marsh and small topographic basins. In a few places e.g. north of Hackley Bay, there is prominent stream drainage to the cliff edge. In many areas, there are extensive areas of old cultivation rigs. Within the area of heathland the most prominent single feature of North Forvie is a massive 2 km long oblique rock ridge which rises to 57.2 m O.D. This ridge exerts a strong influence on local wind patterns and must have been a major barrier to sand movements across the North Forvie plateau.

Fields of hummocky dunes. In several areas, notably near the Old Kirk of Forvie (Willis 1992) there are fields of rounded, stable vegetated hummocky dunes. These are thought to be relatively recent features which are superimposed on older surfaces, including some areas of old cultivation rigs which might date from medieval times. They have a relief amplitude of 2 to 4 m and have no consistent orientation. Their mode of development is unknown.

Historical development

Two main hypotheses exist for the general evolution of the dunes of the Sands of Forvie. The first hypothesis largely derives from the pioneering vegetation study of Landsberg in 1955. In essence, it postulates the migration over the last 5000 years of successive large sand waves from the south end of South Forvie to the northernmost limit of the estate. This hypothesis is dependent on archaeological, historical and cartographic evidence (Landsberg 1955; Kirk 1955; Ralston 1983; Burnett 1964). Within this chronology of sand drifting, 1413 is a key date. The Old Kirk of Forvie and surrounding areas of cultivation appear to have been inundated by sand at this time (Ritchie et al. 1978). This major sand influx of the 15th century has been described by Lamb (1991) as a single severe climatic event; this may or may not be true, since over-grazing and over cultivation may have been at least contributory factors. Nevertheless the location of the Old Kirk near Rockend (Fig. 1) is significant in that it lies at the south edge of the northern plateau. The historical record of the abandonment of the parish and evidence of later sand drifting in the 18th century has been described by Willis (1986, 1992) who concludes that relative stability was reached sometime in the 19th century.

The main question posed by this hypothesis of evolution is the probability of a particular major sand wave being followed after some period of time by a similar successive development and moving in a northward progression throughout the long formative period. The main criticisms of this pattern of development is the absence of recognisable sand waves or arcs in North Forvie compared with South Forvie, the fragmentary nature of the historical and archaeological evidence and the need to have consistent south to north aeolian transport mechanisms. It is also difficult to envisage how a single sand arc can migrate continuously the entire south to north length of the Reserve from the Ythan to the northern plateau. Also, little account seems to be taken of the importance of the long line of coastal dunes at South Forvie which are fed from the beach rather than from the mouth of the River Ythan.

The second hypothesis is more complex and recognises the physiographic difference between South and North Forvie. Essentially at some time, probably post 15th century, large quantities of sand moved under the dominant north-going winds of the region onto the plateau of North Forvie and proceeded to migrate as large discrete masses of sand according to particular wind regimes at the time. This 'scatter and break-up' evolution is supported by the fact that there are nine separate sand dunes and sand hills, including large parabolic dunes in North Forvie. They are scattered and face directions between south and southwest whereas the orientation of wind-aligned features in South Forvie is to the southeast; a direction which is closer to the resultant vector of all winds rather than the resultant of onshore winds (Fig. 2). Thus, to summarise, South Forvie is a complex but normal dune system which derives from the usual sequence of beach to dune to landward sand morphologies whereas North Forvie is essentially a scatter of discrete but separate sand hills which have their origin in migration of pulses of sand from the north end of the South Forvie system. A more detailed examination of the evidence for preferring the second hypothesis is given in Ritchie (1992b) from which the foregoing arguments have been abstracted.

Relatively few elements of this second hypothesis can be proved but it does not conflict with morphological, stratigraphic, archaeological and historical evidence. Dating of old soil horizons which outcrop in several parts of the area, more archaeological excavations, more boreholes to establish the nature of the sub-sand topography and a better understanding of both climatic and sea level changes over the last 5000 years would help to reinforce the validity of the hypothesis. In addition, one of the most durable axioms of geomorphology is that 'the present is the key to the past'. This hypothesis of the possible development of the dunes of South Forvie accords with the directional aspects of contemporary dune geomorphology but to extrapolate these processes backwards in time requires six assumptions i.e. (1) the pattern of winds was little different from today; (2) vast quantities of sand were available during the early part of this evolutionary period; (3) the sand supply ceased abruptly; (4) coastal and river mouth processes were similar to today and (5) there were slight changes in sea level, beginning with a fall from the time of the raised beaches, about 6000 years ago; 6) the transfer from beach to dune in South Forvie was more active. An advantage of this hypothesis is that it is consistent with normal patterns and processes of coastal dune developments elsewhere in Aberdeen Bay over the same time scale (Ritchie et al. 1978).

Contemporary use and management

Under conservational management, the Sands of Forvie National Nature Reserve which also includes the Ythan Estuary, is free from such damaging impacts as sand quarrying, grazing by farm livestock, artificial drainage and uncontrolled recreational use. Human impact is confined to footpaths, many of which are protected by wooden slatted walkways and bridges. Some areas, notably the south end of the peninsula are exclusion zones for nesting birds. Other land uses have negligible effects on the geomorphological and ecological interests.

In general, the present level of geomorphological development appears to consist of erosion of the coastal dune ridges; local extension of blowouts, especially in the east-facing slope of the flanking dunes; concentrated corridor, blowout and surface deflation in random parts of both the massive sand arcs of South Forvie and the parabolic dune complexes of North Forvie. For most of the area, however, there is relative stability and consolidation. Where there are larger exposures of unvegetated sand, some local drifting occurs and small areas, especially in South Forvie, are alternatively covered and exposed on short time scales. There is little primary dune accretion.

Recent developments which could affect the National Reserve include an oil pipeline from the Forties Field which was constructed in 1977 (McHugh 1992) which crosses the River Ythan more than 5 km from the mouth of the river. Environmental impact in the event of disruption and leakage would be minimal and, in its near quarter-century of existence, no such incident has occurred. In the event of an incident an oil spill contingency plan is in place and is tested in periodic exercises.

There is some growth in recreational activity in the Ythan Estuary but the effects are minimal. More concern has been expressed on the development of eutrophic algal blooms which might be associated with nitrates in agricultural drainage which could alter the ecological balance of the estuary and therefore the food-chain which contributes to the life cycles of fauna, especially birds, in the adjacent dunes.

On the whole however, the National Reserve is managed to preserve diversity, naturalness and a great variety of fauna and flora. Diversity is fundamentally the product of the complex history and rich mosaic of habitats which derive from the great variety and scale of dune and non-dune landforms. Naturalness is a relative concept but this area has been described as the least man-disturbed dune system in Britain (Ferguson et al. 1992) and although this statement is highly questionable, the area is free from most types of recreational, agricultural and commercial interference. For reasons that might be attributed to climate, to the absence of a large urban population nearby or to the abundance of other large sand dune systems throughout Scotland (Ritchie 1985), the Sands of Forvie have not become “battlegrounds for competing and diverse uses” (Carter et al. 1990).

As elsewhere in Europe, the status of a nature reserve is enhanced if there is a history of research and education. The Sands of Forvie satisfies both criteria. Many studies have been completed and are ongoing. Field studies are controlled and validated by a system of ‘permissions to do research’. This is an important development. It allows scientists of all disciplines to work in a relatively undisturbed outdoor laboratory. Field equipment, survey markers, experimental apparatus and other facilities can have a reasonable expectation that they are unlikely to be removed or damaged. The database of background information in the form of detailed large-scale maps with 2 m contours and of vegetation and landform maps from 1967 (Ritchie & Wright 1975) provide a secure platform to measure change. Recently it has been agreed to repeat this mapping exercise by taking new dedicated aerial photography for photogrammetric purposes. Nevertheless most scientific papers, especially on ornithology and more general studies of food-webs have been published as outputs from the long-established field centre and laboratories (Culterty) on the south side of the Ythan Estuary. Meteorological and hydrological data are recorded continuously. Archaeology is also a recurring source of information. Microstudies, including pioneering work on wind-flow patterns in parabolic dunes (Robertson-Rintoul 1990) are also available.

The Warden, employed by Scottish Natural Heritage, produces annual reports of activities and scientific work. The first management plan for Forvie was written in 1961 and its basic rationale has scarcely altered in the intervening years. In 1980 a revised management plan added “To develop the educational interest of the Reserve as far as this is compatible with other objectives” (Ferguson et al. 1992). More recently the linkages between the estuary and South Forvie have been a focus of attention. In the end, the future use and management of this remarkable natural resource which is also visually attractive as an outstanding coastal landscape, depends on allowing natural forces to prevail and on continuing to restrict potentially damaging activities. To permit erosion, to allow sand-drifting, to avoid coastal protection works, to prevent pollution of all types and to confine access solely to pedestrians who are controlled in a non-managerial and non-dictatorial way by improving footpaths and by using intelligent sources of information for guidance, must be the future for this remarkable heritage area.

The Sands of Forvie as a National Nature Reserve, one of the earliest in Scotland, can be used to epitomise trends and changes in the concept of conservational management. Coastal geomorphologists, especially those with interests in coastal dunes (which exist on the basis of rapid change and inter-change of sand within a relatively closed natural system) were among the first to promote a natural and dynamic approach to the conservational management of the basic resource; the mosaic of physical habitats which underpin the biological components of the ecosystem. Of late this approach has been formalised in the term ‘soft-engineering solutions’ which is a welcome advance from the belief that the answer to coastal erosion, flooding, damage and other types of adverse change was always to build groynes, seawalls and other fixed defences. Equally to fix most inland areas so that sand was stabilised and protected by some artificial means has also become questionable ‘good practice’. Conservation and its near-synonym preservation have now assumed a more dynamic rather than static meaning. Arguably coastal geomorphologists should seek credit for being early advocates of this attitudinal change which could also be described as a better understanding of the importance of dynamic equilibrium. Research in the Sands of Forvie has made a contribution to this debate both from the aspect of the establishment of a considerable body of environmental knowledge which is based on sound science but also in providing a model of the advantages of promoting naturalness. In some ways this was, and is, a bold strategy. To a visitor or to anyone examining an aerial photograph (Fig. 2) the overwhelming image of South Forvie is the high percentage of bare sand surfaces which tends to suggest excessive grazing or severe trampling or extensive burning or heavy tourist pressure – all of which are invalid. The Sands of Forvie is eroding, the sand is drifting and shifting elsewhere but this is the natural development of a 5000-yr old system under the stress of diminished sand supply. To allow these processes to operate without any constraint whatsoever is impractical and steps have been taken to monitor adverse effects on adjacent agricultural land but these are of minimal significance compared with the freedom of almost all of the remainder to evolve naturally. Nevertheless natural development should not be equated with *laissez-faire* – monitoring, guidance, education of users and non-intrusive practical assistance with footpaths, remote car-parking facilities, minor drainage works, signposting and prohibition of access to some sensitive areas continue to be important. Local managerial techniques which are practised at Forvie to enhance the continuing natural evolution of this exemplary coastal sand dune area can and have been transferred to other dune systems but few have its comparative advantages of size and location.

If one accepts the importance of landscape education as an important component for the designation of a National Nature Reserve, the Sands of Forvie provides an outstanding case-study of the development of interdisciplinary knowledge through research effort. The accolade implied by the title – national, nature, reserve is worthy of analysis. 'National' implies that the area is known for a sufficiency of reasons beyond its local region. This is achieved by a combination of visitors to the site and a substantial body of peer-reviewed academic and equally important popular writings. 'Nature' implies that the resource is not man-made, not cultural and not dependent on physical structures. In Forvie history can be seen in the ruins of a small church, in archaeological sites, in old maps and in ancient field and cultivation patterns but these supplement and give a time-perspective to the physical and biological resources. 'Reserve' as terminology has echos of its use elsewhere in the world as in 'Game Reserve' i.e. being kept for some special use, even to the extent of being unused but available for some future purpose. This concept cannot and should not be applied to the Sands of Forvie for to do so would fail to recognise the importance of *process*, both biological and physical, as being part of the understanding and therefore the wider educational value of the area. In conservational management it is relatively easy to explain the importance of forms or species or examples but more difficult to describe how and why change is occurring. The demonstration of change on various time and space scales can be done at Forvie and is another justification for both its intrinsic value and its potential as a model for other coastal areas which are under consideration for some type of conservational management.

Author's note. Substantial parts of this paper were published previously in 1992 in an essay on the Geomorphology of the Sands of Forvie in a *Festschrift* entitled 'The Ythan' and edited by Dr. M. Gorman of Aberdeen University. Additional information, including a greater emphasis on conservational management, has been added to this paper. The permission of Dr. Gorman, however, is gratefully acknowledged.

The help of the cartographic staff of the Universities of Lancaster and Aberdeen is also gratefully acknowledged. Photographs of Forvie were taken by Livingston of the Aberdeen.

References

Buchan, G.M. 1976. *Dynamics of a river-mouth spit-bar and related processes in Aberdeen Bay*. Ph. D. Thesis, University of Aberdeen, Aberdeen.

Burnett, J.H. 1964. *The Vegetation of Scotland.* Oliver and Boyd, Edinburgh.

Carter, W., Nordstrom, K. & Psuty, N. 1990. *Coastal dunes: Form and process.* Wiley, New York, NY.

Esler, D. 1976. *Coastal dune stability.* M.Sc. Thesis, University of Aberdeen, Aberdeen.

Esler, D. 1983. Contemporary morphology of the face of the foredunes at Forvie. In: Ritchie, W. (ed.) *Northeast Scotland Field Guide,* pp. 52-60. University of Aberdeen, Aberdeen.

Ferguson, M.P., Davis, B. & Matthews, M. 1992. Forvie National Nature Reserve: A time to take stock. In: Gorman, M. (ed.) *The Ythan*, pp. 172-183. University of Aberdeen.

Kirk, W. 1953. Prehistoric sites at the Sands of Forvie, Aberdeenshire. *Aberdeen Univ. Rev.* 35: 150-171.

Kirk, W. 1955. Sands of Forvie. *Discovery and Excavation, Scotland,* 2, Edinburgh.

Kirk, W. 1958. The lower Ythan in prehistoric times. In: Godsman (ed.) *History of the Burgh and Parish of Ellon.* Lindsay, Aberdeen.

Lamb, H. 1991. *Historic storms of the North Sea, British Isles and North-west Europe.* Cambridge University Press, Cambridge.

Landsberg, S.Y. 1955. *The morphology and vegetation of the Sands of Forvie.* Ph.D. thesis, University of Aberdeen, Aberdeen.

Maizels, J.K. 1990. Meteorological studies and water table fluctuations. In: Ritchie, W. & Kingham L.V. (eds.) *The St Fergus Coast. Environment*, pp. 15-35. St. Fergus Dunes Management Committee.

Ralston, I.B.M. 1983. Relationships between archaeological sites and Geomorphology in the coastal zone of north-east Scotland. *North-east Scotland Coast. Field Guide and Geomorphological Essays.* Department of Geography,

University of Aberdeen.
Ralston, I.B.M. 1992. The archaeology of the Sands of Forvie and Ythan Valley. In: Gorman, M. (ed.) *The Ythan*, pp. 19-37. University of Aberdeen, Aberdeen.
Ritchie, W. 1985. Some aspects of the provision of beaches and dunes in Scotland for recreation and amenity purposes. *Curr. Discussion Paper No. 24,* pp. 53-62. University of Glasgow.
Ritchie, W. 1992a. Scottish landform examples – 4: coastal parabolic dunes of the Sands of Forvie. *Scot. Geogr. Mag.* 108: 39-44.
Ritchie, W. 1992b. The geomorphology of the Sands of Forvie. In: Gorman, M. (ed.) *The Ythan*, pp. 5-8. University of Aberdeen, Aberdeen.
Ritchie, W. & Buchan, G.M. 1979. Aberdeen Beach and Donmouth Spit. *Scottish Geogr. Mag.* 95: 27-44.
Ritchie, W., Smith, J.S. & Rose, N. 1978. *The beaches of North-east Scotland.* Countryside Commission for Scotland, Perth.
Robertson-Rintoul, M.J. 1990. A quantitative analysis of the near-surface wind flow pattern over coastal parabolic dunes. In: Carter, W., Nordstrom, K. & Psuty, N. (eds.) *Coastal dunes,* pp. 57-78. Wiley, New York, NY.
Smith, D.E., Cullingford, R.A. & Brooks, C.L. 1983. Flandrian relative sea level changes in the Ythan valley, north-east Scotland. *Earth Surface Processes and Landforms* 8: 423-438.
Soulsby, C. & Malcolm, R. 1997. Hydrology of St.Fergus Dune System. In: Ritchie, W. & Kingham, L.V. (eds.) *The St. Fergus Coastal Environment*, pp. 75-90. University of Aberdeen, Aberdeen.
Stove, C.G. 1978. *The hydrology, circulation and sediment movements of Ythan Estuary.* Ph.D. thesis, University of Aberdeen.
Weatherill, P.J. 1980. *Hydrodynamic process, sediment movement, and coastal inlet morphodynamics at the mouth of the River Ythan, Aberdeenshire.* Ph.D. Thesis, University of Aberdeen, Aberdeen.
Willis, D.P. 1986. *Sand and silence: lost villages of the North.* University of Aberdeen, Aberdeen.
Willis, D.P. 1992. Forvie and the last settlements of North-East Scotland. In: Gorman, M. (ed.) *The Ythan*, pp. 38-43. University of Aberdeen, Aberdeen.
Wright, R. & Harris, T.A. 1988. Change detection in physically fragile coastal areas of Scotland by remote sensing. *Proc. of the Intern. Symp. on Remote Sensing of the Coastal Zone.* Brisbane, Queensland.

Received 11 October 2000;
Revision received 22 November 2000;
Accepted 22 November 2000.