A Guide to the Management and Restoration of Coastal Vegetated Shingle

By Dr Pat Doody and Dr Roland Randall

May 2003

Contract No. MAR 05-03-002 English Nature

A Guide to the Management and Restoration of Coastal Vegetated Shingle

Contractors:

Dr J. Pat Doody
***N**ational **C**oastal **C**onsultants*
5 Green Lane
BRAMPTON
Huntingdon
Cambs., PE28 4RE, UK
Tel: 01480 392706
E-mail: pat.doody@ntlworld.com

and

Dr Roland E. Randall
Monach Farm Ecological Surveys
St Francis Toft
HILTON
Huntingdon
Cambs,
Tel: 01223 338949
E-mail: rer10@cam.ac.uk

Nominated Officer:

Tim Collins
EN Headquarters
Peterborough

Frontispiece:
Dungeness - shingle extraction on the downdrift (eastern side) of the ness. The material is taken by lorries to nourish the beach to the west. Longshore drift moves it eastwards again providing protection for the nuclear power stations present on this tip of England - a never ending cycle of coastal protection?

Acknowledgements:

The authors would like to thank all the people who contributed to this report, most notably the local officers and site managers who gave freely of their time, including Mike Edgington, Simon Dunsford, Barry Yates, Rob Carver, Julie Hatcher, Brian Banks and Grant Lohoar.

Thanks also to English Nature staff at Peterborough Tim Collins, Sue Reid, Sue Watt and also to Pippa Sneddon, Ian Agnew, Robin Fuller and John Packham for past and present involvement.

A special thanks to Andrew Leader for sorting out the conflicts between PCs and Macs and for other IT help.

Contents:

Figure and Tables:

Annexes 01 - 09 Case studies:

01 Porlock;
02 Slapton;
03 Pagham Harbour;
04 Rye Harbour;
05 Dungeness;
Annex 05a 'Living with the Sea' Executive summary Dungeness - Pett Levels CHaMP;
06 Orfordness;
Annex 06a 'Living with the Sea' Executive summary Suffolk Coast & Estuaries CHaMP;
07 Cley-Salthouse;
Annex 07a 'Living with the Sea' Executive summary North Norfolk Coast CHaMP
08 Spey Bay;
09 Culbin.

Site locations are shown on the Map opposite.

Chapter 01 Introduction and aims

Definition and description

Shingle is the term applied to sediments larger in diameter than sand but smaller than boulders. A predominant particle size of over 2mm separates shingle from sand (King 1972). At much over 200mm diameter they may be considered to be boulders and in ecological terms approximate to cliff habitat, i.e. their surface is more significant than the spaces between the individual pebbles. Around Europe such coastal habitats are variously known as *galets* (France), *cascalho* (Portugal), *playa de cantos* (Spain), *stenstrand* (Denmark), *steinfelder* (Germany), *klapper stens felt* (Sweden).

Four environmental factors are responsible for the growth of a shingle beach. There must be an available supply of sedimentary material at the same time as conditions of waves, winds and tidal currents are favourable for its movement. Since this coincidence is unpredictable, conditions without movement occurring may exist for considerable periods, interspersed by times of marked activity resulting in stable and mobile shingle habitats varying both in time and space (Randall 1988).

Geomorphologists and ecologists have recognised five categories of shingle structures (Chapman 1976) which vary in their oceanicity and therefore in their ecology. The simplest and commonest type is the **fringing beach** forming a strip in contact with the land along the top of the beach. **Shingle spits** form where there is an abrupt change in the direction of the coast. They often contain recurved hooks and a recurved distal end, a result of deflection of waves by refraction. This recurvature may also be caused by waves approaching from two directions. **Bars** or **barriers** are effectively spits, which have formed across estuary mouths or indentations in the coast. Ecologically bars differ from spits in having a less maritime environment to their lee (Kidson 1963). These three structures are basically foreshores, regularly washed by spray and storm waves and therefore possessing ephemeral vegetation which will vary in extent and frequency of establishment.

Cuspate forelands and **offshore barrier islands**, on the other hand, are larger structures and have a more terrestrial nature. The former develop when shingle is available in large quantities and piles up in front of fringing beaches or spits and is then driven landwards by storm waves to form apposition beaches. If this process is repeated, a series of roughly parallel ridges may develop and an extensive area of stable shingle results. Where wave approach can be from two directions only, such apposition beaches will form into cuspate forelands. Large masses of shingle may also form offshore barrier islands under conditions of shallow water and low energy environments such as in the North Sea and the Baltic. In practise it is often impossible to treat these features as separate entities as they are frequently intricately linked with dune or salt-marsh habitats.

The type of vegetation assemblages that may recur on shingle beaches and structures is strongly influenced by stability. As stability increases the number of species able to colonise the shingle surface increases, helping to create a wide range of community types, which are at their most complex on the most stable sites. The relationship between the type of shingle beach or structures and the plant communities is indicated below. The first three categories all tend to be associated with fringing beaches, spits, bars and barriers; categories 4 and 5 develop on shingle structures:

1. unstable beaches - lacking vegetation. Common in high energy, west coast situations;
2. beaches stable between spring and autumn - summer annuals (e.g. *Galium aparine* and *Atriplex* spp.);
3. beaches stable over 3-4 year periods - short-lived perennials (e.g. *Sedum acre*, *Desmazeria marina*);
4. beaches stable over 5-20 year periods - long-lived perennials (e.g. *Crambe maritima, Suaeda vera, Silene vulgaris* ssp *maritima*;
5. beaches stable over very long periods with heath or grass-heath vegetation (e.g. *Arrhenatherum elatius, Festuca rubra, Rubus fruticosus, Cytisus scoparius, Prunus spinosa, Calluna vulgaris.*

Besides stability (or its converse mobility) beach composition is the other principal factor affecting vegetation. There are four major types of shingle beaches, depending upon the nature of the fine material present as a matrix within the shingle. These are:

1. shingle without matrix - relatively less common, is limited to a vegetation of encrusting lichens and the most tolerant angiosperms such as *Lathyrus japonicus*;
2. shingle with a sand matrix - ecologically having the hydrological conditions of foredunes but the stability of rear dunes, contains species such as *Lotus corniculatus, Honckenya peploides*;
3. shingle with a silt-clay matrix - ecologically related to salt-marshes but with freer drainage. The vegetation is similar to that of saltmarsh levées with *Halimione portulacoides* or *Glaux maritima*;
4. shingle with an organic matrix. Rotting seaweed is nutrient rich and will support large populations of species that arrive as seed within tidal debris, particularly *Beta maritima* or *Atriplex* spp. where drainage from inland is poor, humic soils may develop and reed or iris swamp may be present.

Shingle acts as a habitat for both fauna and flora. The fauna associated with shingle structures largely consists of invertebrates (Philp and McLean 1985) and avifauna. The importance of shingle as a habitat for breeding terns has led to the conservation of several sites (e.g. Blakeney, North Norfolk and South Walney, northwest England). Few vertebrates other than domestic herbivores are found on shingle sites except hares and rabbits (White 1967), though in places such as Rye, foxes are important predators of ground nesting birds.

Location

Shorelines dominated by clasts of the size considered to qualify as shingle are important mainly in high latitudes and in those parts of the temperate world that were affected by Pleistocene glaciation. The combination of sediment production and supply and the post-glacial storm wave climate have helped to create gravel beach concentrations in the areas shown in Figure 01-01 (Orford et al. 2001). The figure is derived from this paper and Pye (2001).

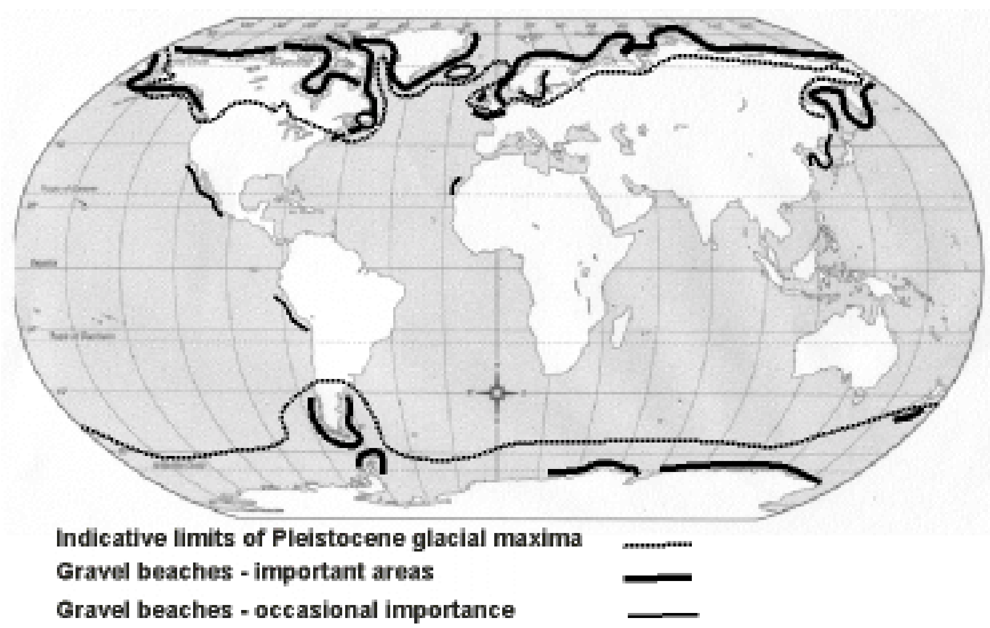


Figure 01-01 Approximate world distribution of gravel (shingle) dominated coastlines in relation to the limits of glacial activity

Europe

Within Europe, the occurrence of shingle structures has been documented for Britain (Randall 1989, Sneddon and Randall 1993). Géhu (1960 a, b, 1991) has described much of the shingle of western France; Bocher (1969) examined the vegetation of Danish shingle and Eklund (1931) gave an account of similar vegetation in southwest Finland. Nordhanger (1940) examined the vegetation of coasts of Norway where an organic matrix was present. Figure 01-02 provides an indication of their approximate location. A full literature review for the shingle habitat can be found in Sneddon & Randall (1989).

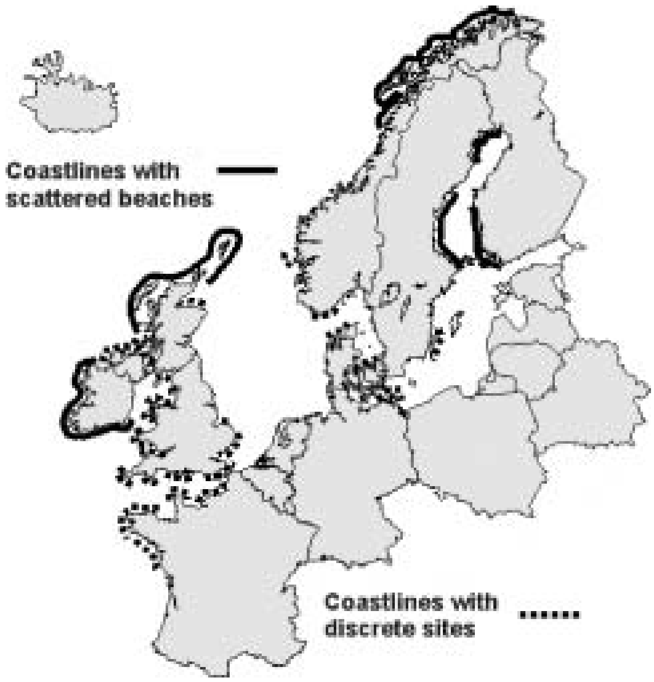


Figure 01-02 Approximate location of shingle beaches and structures in northwest Europe (various sources). Shingle also occurs in scattered localities around the Iberian Peninsula and in the Mediterranean

Systematic information is, as yet, lacking for much of Europe outside Great Britain (see below), but it appears that the most significant sites are on the Brest peninsula of France and the Rügen coast of Germany. Further detail is required. Coasts which are, or have been subject to glaciation or periglaciation often have plentiful supplies of rock fragments for the formation of shingle beaches; elsewhere other sediments predominate unless a shingle source (such as flint from chalk) exists locally.

Great Britain

Great Britain supports a significant proportion of European shingle shores structures, which are found extensively around the coast (Figure 01-03). The largest areas are in the northwest, south and southeast. The shingle in the northwest tends to be associated with beaches fringing sea lochs and in the south east major structures such as Dungeness in Kent. More detailed information on the location of shingle sites in Great Britain is presented in Chapter 04.

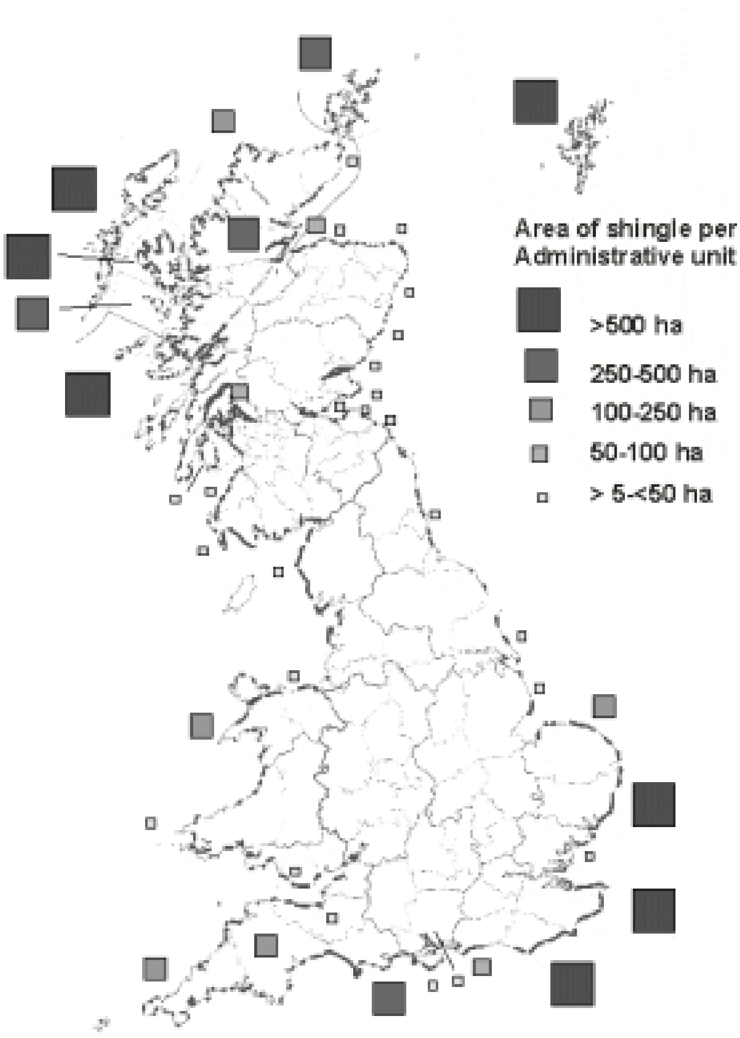


Figure 01-03 Distribution of shingle beaches and structures in Great Britain

Within the British shingle structures a series of distributional relationships (Table 01-01) can be seen among the major vascular plants, which are likely to be replicated and added to for Europe as a whole. If, however, the vegetation communities are analysed quantitatively, four major regional sectors are identified (northeast, southeast, south and west) with a less significant sub-set in the northwest.

Table 01-01 Distributional relationships of the major vascular plants of British shingle

Primarily southeastern	Southern	Western	Northeastern	Inland species with shingle ecotypes
Corynephorus canescens *Parapholis incurva* *Limonium bellidifolium* *Lathyrus japonicus* *Suaeda vera* *Frankenia laevis* *Lactuca saligna*	*Parapholis strigosa* *Limonium binervosum* *Rumex rupestris* *Trifolium scabrum* *Beta vulgaris maritima* *Tamarix gallica* *Glaucium flavum* *Eryngium maritimum* *Atriplex portulacoides* *Crambe maritima*	*Polygonum oxyspermum* *Sedum anglicum* *Coincya monensis* *Crithmum maritimum* *Polygonum maritimum* *Geranium purpureum* *Raphanus maritimus* *Lavatera arborea*	*Mertensia maritima* *Cochlearia scotica*	*Rumex crispus* *Solanum dulcamara* *Geranium robertianum* *Galium aparine* *Arrhenatherum elatius* *Cytisus scoparius*

Land Use, threats and conservation

In Britain, at least, most significant shingle structures are incorporated into Sites of Special Scientific Interest (SSSI), largely to protect the birds that frequent them and for their flora. Only about 10% of sites have no conservation designation. Approximately 200 Sites of Special Scientific Interest (Chapter 04) in Britain contain some shingle although in many cases this takes the form of a narrow fringing beach. Doody (1989) identified 22 as containing stable or semi-stable vegetation over significant areas. Three National Parks contain coastal shingle (Exmoor, Pembrokeshire and Snowdon). Several sites form part of National Nature Reserves, and several more are managed by local authorities as local nature reserves.

40% of the coastline of England and Wales is Heritage Coast and this assists in the protection of the north Norfolk shingle sites, the Suffolk coast and Dungeness. The north Devon coast and many of the Welsh sites are also proposed as Heritage Coast. In addition many shingle structures are part of Areas of Outstanding Natural Beauty (AONB) and the Royal Society for the Protection of Birds (RSPB) and the National Trust (NT) also own areas of shingle structures. The north Norfolk Coast and Bridgewater Bay are Biosphere reserves.

Despite these protection measures many sites are still at risk from development. Even within SSSI’s the major threats to vegetated shingle structures are gravel extraction, coastal defence works, building construction, military use, agriculture, forestry and recreational pressure (Chapter 05). Ownership by the country Nature Conservation Organisations within the Joint Nature Conservation Committee, RSPB, National Trust and the County Conservation Trusts provides the most effective protection (Gubbay 1986).

Doody (1989) ranked 22 vegetation shingle structures in Britain subjectively according to size and degree of successional development (Table 01-02).

Table 01-02 Vegetated shingle structures in Great Britain within Sites of Special Scientific Interest (SSSI)

A:	**Sites of national importance**	**Approx. SSSI Area ha**	
1.	Dungeness, Kent	2714	
2.	Orfordness Havergate, Suffolk	1602	
3.	Blakeney Point, Norfolk	581	
4.	Chesil Beach, Dorset	1281	
5.	Culbin Shingle Bar, Moray/Nairn	12295	*
6.	Rhunahaorine Point, Argyll and Bute	327	
7.	Kingston Shingles, Moray	500	
B:	**Other sites of significance**		
1.	Bridgewater Bay, Somerset	2460	*
2.	Slapton Ley, Devon	219	
3.	Browndown, Hampshire	64	*
4.	Pagham Harbour, West Sussex	384	*
5.	Rye Harbour, East Sussex	721	
6.	Colne Point, Essex	3806	*
7.	Landguard Common, Suffolk	31	
8.	Scolt Head, Norfolk	738	*
9.	Walney and Foulney Islands, Cumbria	1909	*
10.	Cemlyn Bay, Gwynedd	45	
11.	Traeth Tanbwylch, Dyfed	36	
12.	East Aberthaw Coast, South Glamorgan	68	
13.	Whiteness Head Iverness/Nairn	409	
14.	Copinsay, Orkney	152	
15.	Ballantrae Shingle Beach, Kyle and Carrick	34	

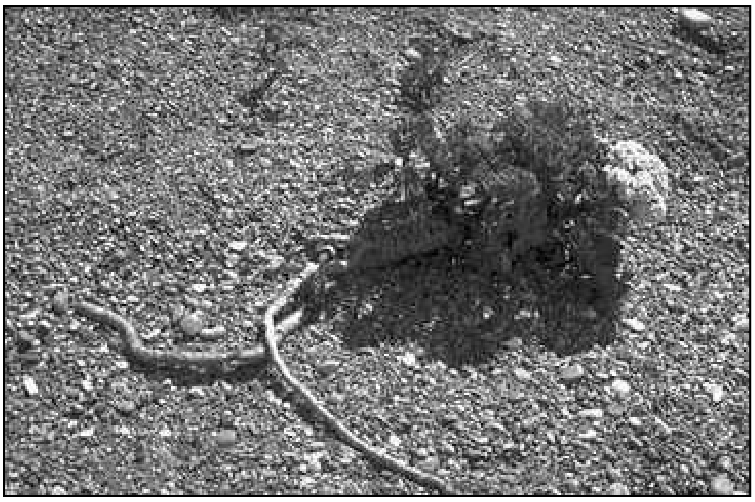
* Sites where the important shingle areas represent less than 10% of the total site area (After Doody, 1989)

If the most important sites are ranked objectively by floristic richness, size and disturbance factors (Sneddon 1992) it can be seen that the rank order changes quite significantly. In all three methods of ranking, however, Chesil Beach, Kingston Shingles, Rye Harbour, Slapton Beach and South Walney come into the top ten locations (Table 01-03).

Table 01-03 Shingle sites, the top 20, ranked by floristic richness (one most diverse), size (one largest) and disturbance (one least disturbed)

Rank	Floristic ranking	Floristic + size ranking	Floristic, size and disturbance ranking
1	Scilly Isles	Dungeness	Chesil
2	Dungeness	Rye Harbour	South Walney
3	Kingston	Kingston	Scilly Isles
4	Chesil	Chesil	Rye Harbour
5	Rye	Rhunahaorine	Blakeney
6	Slapton	Slapton	Kingston
7	Rhunahaorine	Snettisham	Whiteness Head
8	South Walney	Blakeney	Claymoddie
9	Snettisham	Browndown	Slapton
10	The Duver	South Walney	The Duver
11	Traeth TanybwIch	Orfordness	Orfordness
12	Browndown	Pagham Harbour	Snettisham
13	Blakeney	The Duver	Dungeness
14	Cemlyn	Whiteness Head	Colne Point
15	Crabhall	Scilly Isles	Pagham Harbour
16	Pagham Harbour	Traeth TanybwIch	Culbin
17	Orfordness	Claymoddie	Cemlyn
18	Whiteness Head	Colne Point	Rhunahaorine
19	Pwll du	Crabhall	Rascarrel Bay
20	Dougerie, West Arran	Shingle Street	Pwll du

Over Britain and indeed over Europe as a whole, climate is a major variable affecting shingle structures. Any form of climatic change would have implications for shingle communities. Associated hazards are related to accompanying sea level changes and increased frequency of storms. The loss of much of the raised shingle foreshore on West Arran in the storms of 1988 and the extinction of *Mertensia maritima* from the Isle of Man and Walney Island in 1967 (Randall 1986) are examples of this hazard. Boorman (1991) reports a median estimate of 0.8m sea-level rise over the next 100 years. Areas of British shingle which lie below 5m OD include all sites between the Suffolk coast and Browndown, Hampshire, along with the north Welsh coast, Foulney, Walney and the inner Solway Firth. Even if shingle is not lost, increased frequency of saline intrusion will lead to loss of heath species on terrestrial shingle as happened at Browndown and The Duver (Isle of Wight) in 1989.



A combination of factors have made rare or declining species quite characteristic of shingle structures with *Crambe maritima* (Scott & Randall 1976) Figure 01-04, *Lathyrus japonicus* (Randall 1977) Figure 01-05 and *Mertensia maritima* (Farrell & Randall 1992, Randall 1988) Figure 01-06 having been examined in detail.

Figure 01-04 *Crambe maritima.* Note the long tap root which helps stabilise the plant in the face of disturbance by waves.

Figure 01-05 *Lathyrus japonicus*, a plant of shingle beaches in the south and east of England

Figure 01-06 *Mertensia maritima* a species of undisturbed northern shingle beaches

Project aims

The aim of this contract is to produce good practice guidelines for the management of coastal vegetated shingle. It focuses on flood management works and their effect on shingle; covering the following broad subject areas:

- Physical and ecological attributes of coastal vegetated shingle;
- Importance of shingle structures in flood management;
- Nature conservation legislation;
- Threats to coastal vegetated shingle from flood management and other works;
- Guidance on managing threats to coastal vegetated shingle;
- Restoration opportunities;
- Monitoring.

The coastal vegetated shingle guide has been produced in two parts:

1. As a stand alone document - **The report**, which is reproduced here;
2. and as an interactive **Electronic guide**, which will initially be available on CD-ROM via English Nature in mid 2003.

1. The report

The report provides an introduction to the habitat, its attributes and guidance on management and restoration under the following Chapter headings:

Chapter 02 Describes the physical and ecological attributes of coastal vegetated shingle;

Chapter 03 Emphasises the importance of shingle structures in flood management;

Chapter 04 Provides information on shingle sites in Great Britain, including maps showing their location;

Chapter 05 Identifies the pressures on, and threats to coastal vegetated shingle;

Chapter 06 Provides habitat specific guidance on management;

Chapter 07 Highlights opportunities for habitat management and enhancement;

Chapter 08 Outlines monitoring requirements;

Chapter 09 Gives a summary of conclusions identifying any gaps in knowledge and provides recommendations for further work;

Chapter 10 Identifies sources of funding and useful contacts;

Chapter 11 Glossary and References;

Appendix 01 provides a summary of the legislation that may apply to managing and restoring coastal vegetated shingle

Appendix 02 provides a summary of the coastal vegetated shingle interest defined for the candidate Special Areas of Conservation in Great Britain

Appendix 03 give a list of invertebrates and their habitat preferences

Annexes 01-09 contain the site casework reports:

01 Porlock;
02 Slapton;
03 Pagham Harbour;
04 Rye Harbour;
05 Dungeness;
06 Orfordness;
07 Cley-Salthouse;
08 Spey Bay (Kingston shingles);
09 Culbin Shingle Bar.

2. An electronic guide

A contract has been let by English Nature to provide an interactive electronic guide to shingle habitat management and restoration. This will be linked to the Guide “Coastal Habitat Restoration, towards good practice” being prepared as part of the Living with the Seas LIFE Nature project. This will be available in July 2003.

Copies of the Executive Summaries of the CHaMPs within which sites 05, 06 and 07 are situated are included on the cd-rom.

References

Bocher, T.W., 1969. Stenstrandens plantverdun. *Danmarks Naturforening,* **4***:* 84-97.

Boorman, L.A., 1991. Coastal Habitats. In: *The Greenhouse Effect and Terrestrial Ecosystems of the UK.* Research Publication no. **4**. Institute of Terrestrial Ecology. Cannell M G R, Hooper M D, Eds., London, HMSO, 51-53.

Chapman, V.J., 1976. *Coastal Vegetation*. Pergamon Press, Oxford.

Doody, J.P. 1989. Dungeness **-** a national nature conservation perspective. *Botanical Journal of the Linnean Society* **101**:163-171.

Eklund, O., 1931. *Crambe maritima* in Nordbaltischen Gebeit. *Memo. Soc. Fauna Flora fem.* **7**: 41-51.

Farrell, L. & Randall, R.E., 1992. The distribution of *Mertensia maritima* (L.) Gray, Oyster Plant, in Ireland. *Irish Naturalist's Journal*, **24**: 135-140.

Fuller, R.M. & Randall, R.E., 1988. The Orford Shingles, Suffolk, UK – classic conflicts in coastline management. *Biological Conservation,* **46**: 95-114.

Géhu J.M., 1960a. La vegetation des levees des galets du littoral francais de la Manche. *Bulletin Societe Botanique Nord France*, **13**: 141-152.

Géhu, J.M., 1960b. Une site célèbre de la côte Nord bretonne: Le Sillon de Talbert (C-du-N). Observations phytosociologiques. *Bulletin Laboratoire maritime Dinard,* **46**: 93-115.

Géhu, J.M., 1991. Vegetations et paysages littoraux de type Cantabro-atlantique. *Berichte der Reinhold-Tuxen Gesellschatf*, **3**: 59-128.

Gubbay, S., 1986. Nature conservation in the coastal zone of Great Britain. *Journal of Shoreline Management*, **2**: 241-257.

Kidson, C., 1963. The growth of sand and shingle spits across estuaries. *Zeitschrift fur Geomorphologie* **7**: 1-22

King, C.A.M., 1972. *Beaches and Coasts.* London, Arnold.

Nordhagen, R., 1940. Studien uber die maritime vegetatin Norwgens I. Die pflanzengeselleschaften der tangwalle. *Bergens Museum Aarbheit,* 1939-1940: 1-123.

Orford, J.D., Forbes, D.L. & Jennings, S.C., 2001. Origin, development and breakdown of gravel-dominated coastal barriers in Atlantic Canada: future scenarios for North western Europe. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 23-55.

Philp, E.G. & McLean, I.F.G., 1985. The invertebrate fauna of Dungeness. In: *Dungeness: ecology and conservation*, eds., B. Ferry & S. Waters, Focus on nature conservation, **12**, Nature Conservancy Council, Peterborough, 94-135.

Pye, K., 2001. The nature of geomorphology of coastal shingle. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 2-22.

Randall, R.E., 1977. The past and present status and distribution of Sea Pea, *Lathyrus japonicus* Willd., in the British Isles. *Watsonia*, **11**: 247-251.

Randall, R.E., 1986. *The status of Mertensia maritima in Great Britain*. *An interim report*. Report, Nature Conservancy Council, Peterborough.

Randall, R.E., 1988 *The vegetation of shingle street, Suffolk in relation to its environment.*

Randall, R.E., 1989. Shingle habitats in the British Isles*. Botanical Journal of the Linnean Society*, **101**: 3-18.

Scott, G.A.M. & Randall, R.E., 1976. Biological flora of the British Isles: *Crambe maritima* L. *Journal of Ecology,* **64**: 1077-1091.

Sneddon, P., 1992. *Variations in shingle vegetation around the British Coastline*. PhD. Thesis, University of Cambridge.

Sneddon, P., & Randall, R.E., 1989. *Vegetated Shingle Structures Survey of Great Britain. Bibliography.* Report, Research & Survey in nature conservation series. No. **20**, Nature Conservancy Council, Peterborough.

Sneddon, P., & Randall, R.E., 1993. *Coastal vegetation shingle structures of Great Britain: Main Report*. Joint Nature Conservation Committee, Peterborough.

White, D.J.B., 1967. *An Annotated List of the Flowering Plants and Ferns on Blakeney Point, Norfolk.* National Trust, 2nd Edition.

Chapter 02 Coastal vegetated shingle, geomorphology, natural processes and ecology

Chapter 02 provides an outline of the geology, geomorphology and natural processes of coastal vegetated shingle. This is followed by a review of the main features of the ecology of vegetated shingle, its vegetation, invertebrate and breeding bird interests. [N.B. The locations of sites in Great Britain mentioned in the text are shown in Figures 04-01a, b & c.]

Geomorphology

Introduction

The term 'shingle' has been used for at least 400 years in Britain and some Commonwealth countries, to describe sediments composed of mainly rounded pebbles, larger in diameter than sand (>2 mm) but smaller than boulders (<200 mm). Elsewhere terms such as gravel, stone, levées de galets, playas de cantos, schotterwälle and steinstrand are used. A generalised world distribution of shingle coasts is given in Figure 01.01 (Page 2). In many locations shingle is mixed with sand, silt, clay or organic debris, resulting in a 'mixed' sediment beach but all shingle and boulder beaches can be regarded as different types of 'coarse clastic' beach (Carter & Orford 1993).

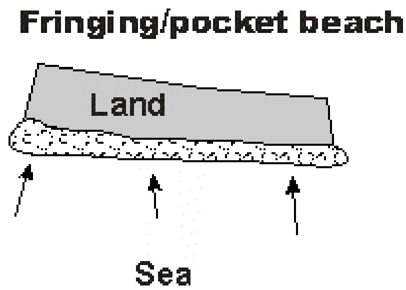
In general shingle coasts have received less scientific attention than sandy and muddy shorelines. In part, this reflects the fact that, at a world scale, they are much less common. However, in recent decades there has been an increasing awareness of the geomorphologic, ecological and engineering significance of shingle coasts in the contexts of sea-level change, flood defence and habitat conservation. Such coasts are now recognised as an internationally important, but disappearing resource (Packham et al. 2001).

Landform types and coastal processes

Shingle coasts form in wave dominated locations where suitably sized material is available. At a global scale they dominate high latitudes and those areas of temperate shores which were affected by Pleistocene glaciation (Figure 01-01). They are locally important in some other temperate and low latitude areas where high relief landscapes of suitable geology occur near the coast, near the estuaries of high-energy rivers, or where coral is present. Elsewhere they are of limited importance.

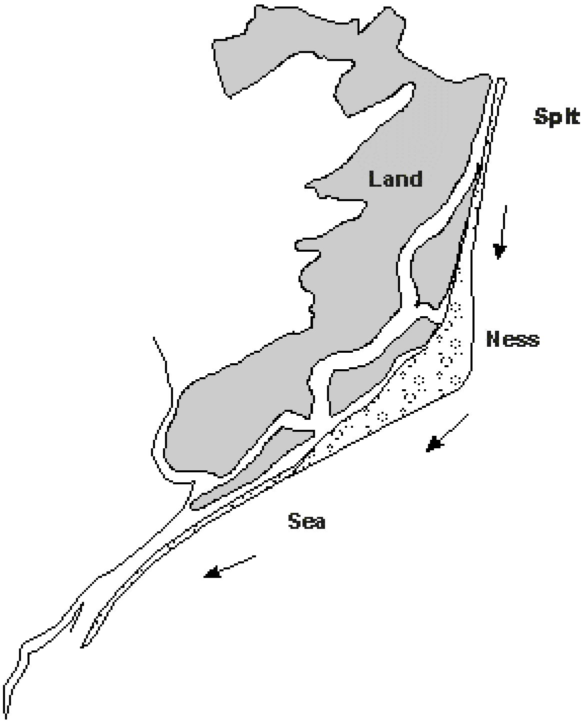
At a regional scale, lithographic composition determines shingle availability and durability. Hard materials such as flint, chert, granite, quartzite, and some metamorphic materials survive much longer at this clast size than sandstones, limestones or shells. Around Great Britain of the nearly 19,000 km of shoreline approaximately 30% has an important shingle component, with almost 3,500 km of these coasts being pure shingle (Sneddon & Randall 1993/1994). Many of the shingle-barrier systems occurring on present-day coastlines were initiated during the Holocene marine transgression and are currently sustaining considerable morphological change as a result of increasing sea-levels causing landward and longshore re-working of a finite sediment volume.

Shingle coasts can comprise several different landform types, which vary according to their history, mobility and oceanicity and therefore offer different habitats to vegetation, wildlife and man (Pye 2001, Sneddon & Randall 1993/1994).

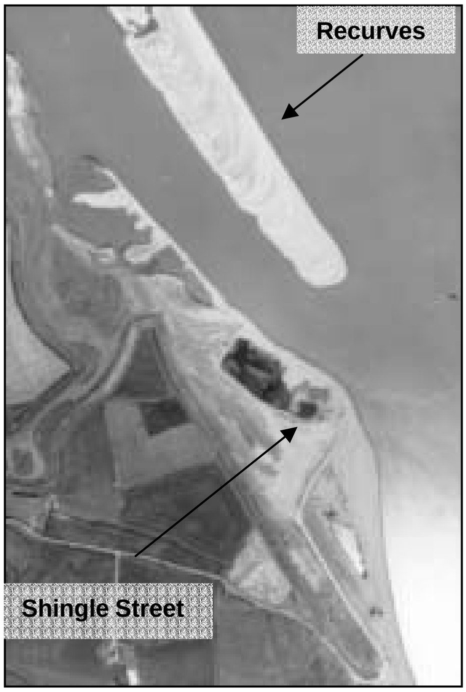


Fringing or **pocket beaches** are narrow strips of shingle coast in contact with the land along the top of the beach. These are usually subject to regular marine inundation. They frequently occur at the foot of sedimentary cliffs such as chalk in southern Britain, but may also occur in front of coastal dunes or salt-marsh cliffs.

Embayment beach-ridge plains, or apposition beaches, are comprised of a series of relict storm beach-ridges and an active front ridge system which together partly or totally infill a previous embayment. Such systems may be hundreds of metres or even kilometres wide and can be transitional to cuspate forelands or nesses see below.



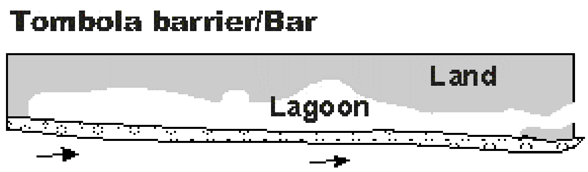
Shingle spits are strips of shingle, which grow out from the coast where there is an abrupt change in the direction of the coastline. They commonly occur, therefore, along coasts, which have an irregular plan. Spits often display recurved hooks along their length and at their distal ends, where the shingle is, or has been, subject to wave action from two or more directions. Indeed, in many cases, it is possible to trace the development of a spit's growth via recurved hooks, seen as lateral projections from the lee of the spit, which locate the position of the past distal points, (Randall 1973 and Figure 02-01). Paired spits are found at the entrance of several harbours on the south coast of England, including Pagham and Langstone. These may have originated as bars or tombolos, which have breached, but in other cases, independent growth of two spits may be due to bi-directional longshore drift.



On eroding coasts, shingle spits are transgressive and frequently overlay back-barrier marsh or lagoon deposits as at Shingle Street, Suffolk, and in some instances may be dissected to form barrier islands (Scolt Head, Norfolk also provides a good graphical example of this process). Transgressive ridges, often composed mainly of shell-shingle, are well developed on the saltmarsh coast of Essex. Similar features are also found in the Gulf of Mexico and in Auckland Bay, New Zealand. In Essex and the Gulf of Mexico they are known as ‘cheniers’ or chenier ridges respectively.

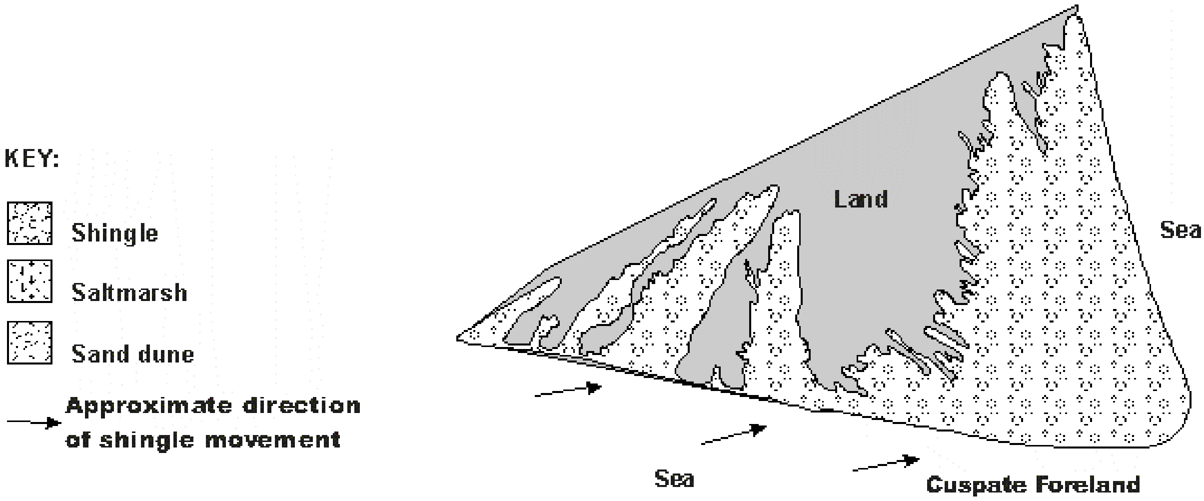
Figure 02-01 The shingle coast of Suffolk, UK. On the distal point of Orfordness and on the mainland opposite there are recurved hooks enclosing lagoons. At the mouth of the estuary of the River Ore longshore drift of shingle sediments can be observed. (Photograph RC8 D 121 - courtesy of University of Cambridge Committee for Aerial Photography.)

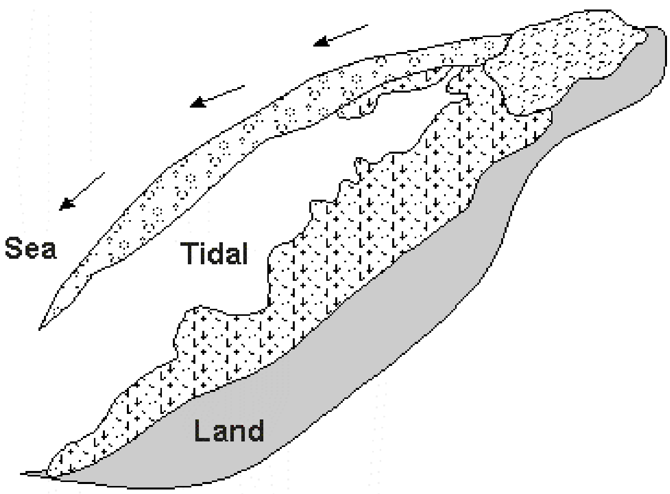
Tombolo barriers, or **bars**, are geomorphologically similar to spits, representing the extreme case where a spit has grown across an estuary or coastal indentation. This results in the formation of a lagoon behind the bar, which clearly affects the hydrology, and ecology of the leeward slope. Chesil Beach in Dorset is a prime British example. Rivers, which provide a source of shingle-sized sediment, may have prograded strandplains or deltas of shingle at their mouth. In Scotland the Kingston Shingles are found at the mouth of the Spey (Sneddon & Randall 1993/1994) and South Island, New Zealand has particularly good examples, such as at the mouth of the Waitaki River.



At points of littoral drift convergence the formation of a second set of apposition ridges deposited at a different angle, will lead to the formation of a ness or **cuspate foreland**, a triangular mass of shingle such as Dungeness, Kent, Rhunahaorine Point, Argyll or Cape Canaveral in Florida. The Island of

Rügen in Baltic Germany is effectively a cuspate foreland cut off from the mainland. Such features often support a terrestrial geomorphic system inland of the coastal ridges.





Offshore barrier Island

The final type of shingle formation is the **offshore barrier island**, formed where a large mass of shingle has been deposited offshore and which may act as the 'skeleton' for a coastal sand-dune system. Culbin Bar, Morayshire and Scolt Head Island, Norfolk, are prime examples.

Most shingle coasts have a steep upper beach slope and a relatively steep overall nearshore profile. Partial wave energy reflection results in the formation of edge-waves and rhythmic longshore features such as beach cusps. Shingle features are frequently of considerable ecological importance in terms of habitat diversity and play a vital geomorphologic role in determining the stability of adjoining 'soft' sediments of mudflats and salt marshes. Unless the shingle coastal features are mobile, a partial vegetation cover is the norm. The middle and lower beach are usually kept bare by wave action, but upper beaches are vegetated. The rate and extent of plant colonisation is dependent upon the degree of disturbance and shingle mobility, the presence or otherwise of a fine sediment matrix within the spaces between larger sediments and the hydrological regime of the shingle.

Sediment patterns

All shingle coasts contain a mixture of different sized sediments. Some are well sorted and consist entirely of pebbles, while others are poorly sorted and may also contain sand and/or boulders. Because there is frequently considerable temporal and spatial variation in shingle and mixed shingle/sand beaches, accurate determination of average textural qualities is difficult.

Most coarse sediment coasts become coarser up-beach, because backwash and gravity cannot move larger clasts. Hence many locations have shingle only on the upper beach. Discoid pebbles are sorted preferentially on the upper parts of the beach with spheres and rods occurring nearer the sea. Sediment grading along-shore also occurs due to selective transport of finer sediments in the down-drift direction as at Chesil Beach. However, other sites show much more complex patterns as a result of bi-directional currents of varying magnitudes.

Shingle coast micro-relief dynamics depend upon spring to neap tidal patterns and wind and wave conditions. The upper 50-80 cm of sediment is frequently remobilised forming berms and cusps that change from one tidal-cycle to another. More major changes occur seasonally as a result of spring to neap tidal fluctuations and especially at those times when storm-wave energy is higher.

The internal sedimentary architecture of shingle landforms reflects the process regime and net evolutionary trends of the structure (Randall 1973). The external structure of ridges vary depending on whether they are vertically accreting but laterally stable, laterally migrating or developing on a seaward prograding plain. The depressions between ridge crests may be partly filled by washover and storm-tossed deposits, so that there is often a marked difference in average particle size and shape between ridge fulls (crests) and lows (Randall & Fuller 2001). Sediment grading may also occur as a result of longshore drift with selective transport of finer sediments downdrift. However, on many coasts sediment grading has been found to be complex in relation to seasonal variation in the longshore current regime (Pye 2001).

Sea-level change

Sea-level rise has the tendency to move shingle landforms inland (Carter & Orford 1993; Forbes et al. 1995), but if sea-level rise is particularly rapid, shingle structures may be drowned in situ by overstepping. Normally, however, under moderate storm-wave activity, shingle is pushed to the top of the front-beach ridge (‘overtopping’); while in major storms the ridge is ‘overwashed’ (or even breached), creating shingle fans or aprons in the backbarrier area (e.g. Bradbury & Powell 1992). As this pattern is repeated, so the ridge migrates landward by rollover. Many of the major shingle formations present today formed in this way during the Holocene marine transgression, initiating at a time of lower sea-stand and reaching their present location by around 4000 BP. Most current shingle features are relict or dependent upon erosional sediments rather than glacial debris. Hence, there is currently a shortage of sediment at the updrift end of many transport cells and increasing risk of overwashing and breaching (Orford et al 2001).

Hydrology and soils of coastal shingle

Hydrology

Burnham & Cook (in Packham et al. 2001) reported that substantial areas of coastal shingle support a fresh water table that overlies saline water near the coast. Dungeness, Pevensey Beach, Blakeney Point and Shingle Street are good examples but there is little doubt that the hydrology is similar elsewhere. The significance of shingle as an aquifer is the great rate at which water passes through the coarse sediment. At Denge Beach, Dungeness (Annex 05) this ranges from 300-1000 m2/day. Such easy transmission means that any ‘doming’ of the water table is of low amplitude and water levels fluctuate with the tide. Penetration by sea water during storm tides can be equally rapid. Water abstraction from the Denge aquifer has taken place since the early years of the twentieth century. Following a report in 1984 that highlighted saline incursion this aquifer was seen as a finite and fragile resource. The abstraction licence was reduced to 3300Ml/annum and a management regime incorporated. Penetration by sea water during storm tides can be equally rapid.

Soils

Most shingle substrates do not develop a true soil. However, on shingle that has been stable for a very long period of time a ‘ranker’ or ‘ranker-like’ alluvial soil may develop. The fine component is primarily plant-derived and earthworms are normally absent. The development of vegetation seems to be associated more with the presence of fine shingle rather than elevation or exposure. The presence of fine particles is also important. Using the studies at Orfordness and Dungeness, Fuller (1987) suggests that the distribution of vegetated shingle is determined by a number of factors:

1. coarse shingle - seeds fall too deeply for germination and growth to the surface to occur. (*Note gardeners often use shingle to prevent weed growth*);
2. poor water retention of the shingle substratum inhibits germination and seedling establishment;

3. even if plants survive the initial stages of growth they may succumb to drought conditions and die, with the exception of a few highly specialised plants with long tap roots such as *Crambe maritima*;

Where plants do become established they help promote the build up of material through the decay of roots and above ground material. Mites and collembolans can help break down these plant remains to dark molder-like humus. At the same time the plant's ability to trap wind-blown debris increases litter accumulation. The soils so developed tend to be naturally highly acid, but can be nearer neutral if the shingle contains a large amount of shelly material. This accumulation of humus enhances moisture retention and with it the nutrient status of the soils and hence helps the establishment of more permanent plant cover. It is perhaps no accident that the more mature vegetation of the Culbin Shingle Bar (Annex 09) which is located in an area of high rainfall supports low-growing scrub in a matrix including *Salix repens*, *Empetrum nigrum* and *Calluna vulgaris* (see Figure 07-04). At Dungeness the soil mollusc fauna is substantial where calcium levels are higher as a result of input of shelly material.

Vegetated shingle

Vegetated shingle is recognised as an internationally important habitat. It is scarce in Europe with the UK supporting a high proportion of the European resource. Elsewhere, coastal shingle has few occurrences outside Japan and New Zealand. Coastal vegetated shingle is listed as a priority habitat in the UK Biodiversity Action Plan (BAP) and supports 9 BAP priority species. It is characterised by specialised plants that have adapted to survive in harsh coastal conditions where lack of fresh water and nutrients are compounded by fierce winds and impact by waves. Shingle habitats are also particularly important for invertebrates and for some breeding and roosting birds. Much has already been lost to housing developments, agriculture and coastal defence while the remaining area faces a number of threats including trampling and unnatural enrichment of the shingle substrate. One of the main long-term threats to vegetated shingle is as a result of man's intervention in natural coastal processes, with coast protection work changing the accretion rate of shingle to coastal areas. Trapped between urban development on the landward side and rising sea levels on the seaward side, vegetated shingle is also threatened by 'coastal squeeze'.

Shingle banks form a natural coastal defence, which may require replenishment in order to maintain the bank crest height and width. With coastal protection techniques moving towards a more integrated approach allowing natural processes to work where possible and relying more on 'soft' defences rather than 'hard' structures such as sea walls, there is an opportunity to create new, stable areas of shingle. If planned with care, these could be used to create new areas of shingle vegetation. However, it does not always follow that new areas of shingle will restore the plant and animal assemblages of areas that have been lost.

Vegetated shingle communities

The frequency with which shingle beaches are disturbed by the action of the sea varies according to wave fetch and prevailing meteorological conditions; and the resultant vegetation is similarly altered (Randall 1977). In practise the majority of shingle foreshores are unvegetated or have extremely sparse vegetation cover. Scott (1963) recognised three foreshore stability classes which can be observed on a vegetation basis, dependent on the length of time over which the shingle is undisturbed by environmental factors:

- no vegetation – disturbance too frequent to support plant growth: as at the foot of sea-cliffs, distal points of spits, high-energy beaches etc.;
- summer annuals – beach stable over growing season only: mainly *Galium aparine* and *Atriplex* spp. on drift line;
- short-lived perennials – beach stable for +3 years: considerable strand and foreshore vegetation *e.g. Glaucium flavum, Rumex crispus, Beta maritima.*

These three stability habitat classes, which are similar to those identified above in Chapter 01 in relation to the geomorphological types of shingle beaches, may occur at different levels on the same beach. For instance at Shingle Street, Suffolk, the exposed foreshore is unvegetated, the lagoon foreshores have drift lines supporting *Atriplex* spp., whereas the main ridge crest with more stable shingle supports growth of *Lathyrus japonicus, Beta maritima* and *Rumex crispus*. On some shingle foreshores as at Cley (Annex 07), Norfolk, mobility of the substrate results in accretion around plants of *Suaeda vera.* Various authors have discussed the role of this species in shingle stabilisation. Because of the instability of many shingle foreshores they usually have low volumes of animal life. However, numbers of amphipods and collembola may be high at a few sites, such as at Dungeness.

Although the geomorphic classification of shingle is determined by predominant particle size, the vegetation is primarily controlled by the proportion and size of the fine fraction material of the matrix under 2mm diameter. In fact, because this is the main source of nutrients, it is commonly recorded that, even on stable beaches, the absence of a fine matrix results in a marked reduction in vegetation. Early workers suggested the importance of the fine fraction and this has also been emphasised frequently since. The fine fraction is critical at germination and seedling stages (Chapter 06) since, without it, enough moisture may not be present for growth to be initiated or to continue. The matrix is usually composed of sand, silt or organic matter, each type having distinctive vegetation. Within the British Isles the matrix tends to vary regionally: silt and clay are dominant in the south and east, sand in the west and organic matter in the northwest. Randall (1977) showed the plant species most commonly found with different shingle matrices. These are listed in the following table.

Table 02-01 Species commonly found on shingle with different types of fine fraction matrix

None*	Sand	Organic	Silt/clay
Arrhenatherum elatius+	*Festuca rubra arenaria*	*Urtica dioica*	*Beta vulgaris ssp. maritima*
Mertensia maritima	*Sedum acre*	*Tripleurospermum maritimum*	*Glaux maritima*
Silene uniflora	*Elytrigia juncea*	*Galium aparine*	*Artemisia maritima*
Geranium purpureum	*Honckenya peploides*	*Potentilla anserina*	*Puccinellia martima*
Geranium robertianum+	*Corynephorus canescens*	*Rumex crispus var. trigranulatus*	*Parapholis strigosa*
Solanum dulcamara+	*Desmazeria marina*	*Iris pseudacorus*	*Limonium bellidifolium*
Limonium binervosum	*Calystegia soldanella*	*Armeria maritima*	*Suaeda martima*
Polygonum maritimum	*Polygonum oxyspermum*	*Atriplex* spp.	*Atriplex portulacoides*
Crithmum maritimum	*Eryngium maritimum*		
Sedum anglicum	*Hippophaë rhamnoides*		
Lathyrus japonicus	*Rosa pimpinellifolia*		
Vicia lutea	*Trifolium scabrum*		
Suadea vera	*Atriplex laciniata*		
Atriplex glabriuscula	*Cakile maritima*		
Crambe maritima	*Silene conica*		
Glaucium flavum			
Lactuca saligna			

Water availability is another basic factor in the ecology of shingle foreshores. This is likely to be extremely low because of the high porosity and low water-retention of the substrate. Inefficient capillarity in shingle usually rules out the water table as a moisture source for all but the deepest rooted of shingle foreshore plants. Thus, the principal source of supply must be pendulant water from precipitation. However, the speed of water movement is again related to fine fraction content and diameter. Early workers suggested that further moisture supplies are obtained within shingle by internal dew formation but it was demonstrated that it was no more important than in sand. Of greater significance is the ‘mulching’ effect of large shingle particles on the soil surface, which causes a reduction in the evaporation of any water present in the upper layers.

There are a few plant species that are more characteristic of shingle than of other environments, most of them being associated with the extreme mobility of the foreshore zone. One species apparently exclusive to maritime shingle in Britain is *Suaeda vera*, which is limited climatically to the southeast. The plant is unusual in shingle foreshore habitats in that it is woody and upstanding, reaching over 1m in height. It is also evergreen in the optimal parts of its range. Usually *S. vera* germinates in the driftline rapidly sending long roots deep into the shingle, so stabilising the plant. Overwhelming by shingle in storm conditions forces the plant to a horizontal position from which it sends out new roots and new vertical shoots.

In contrast, *Mertensia maritima* is a northern element in British shingle foreshore habitats. Typically it grows as a low cushion on ‘pebble-wrack-sand’ beaches on the north and west coasts of Scotland, where grazing does not occur. Good examples are The Churchill Barrier, Orkney and around the Castle of May, Caithness. An interesting change in the distribution of this species over recent years has been the decline or disappearance of its more southerly sites, possibly a response to climatic change. The fact that this species is highly susceptible to grazing and trampling may have also played a part. These factors have certainly been significant in the changing distribution of *Lathyrus japonicus. Glaucium flavum* and *Crambe maritima* are other characteristic species of shingle foreshores.

Although there is considerable variation in the assemblages of species found in shingle foreshore habitats, lists compiled from widely separated sites show some floristic pattern. Fringing beaches and the seaward slopes of spits and bars show constancy of several species, in particular *Tripleurospermum maritimum, Silene maritima, Atriplex glabriuscula, Rumex crispus* ssp. *littoreus* and, in the north, *Galium aparine.* Other species that are common in this habitat include *Festuca rubra*, *Beta maritima* and *Honckenya peploides.* Less common, but still locally important are *Potentilla anserina, Sonchus arvensis, Rumex acetosa, Elytrigia* spp., *Sedum acre* and *Senecio* spp. It will be noticed from this list of species that the majority, whether annual or perennial, are open ground nitrophiles. Their communities fall within the two Annex 1 habitats of the EU ‘Habitats’ Directive - the annual vegetation of drift lines and perennial vegetation of stony banks. However, as with more terrestrial shingle vegetation Sneddon and Randall (1993) showed that the communities around Britain are more complex than this twofold division suggests.

Landward slopes of spits and bars contrast with seaward slopes in that they are usually less mobile and have different nutrient inputs. Bars and spits, which have a poverty of drift material, are not so rich in flowering plants and many of the nutrient-hungry species are absent. On the north and west coasts where water tables may be higher, *Iris pseudacorus* and *Filipendula ulmaria* are common, whereas in drier conditions in the south and east *Geranium robertianum* and *Solanum dulcamara* occur in their coastal ecotypic form. On wider fringing beaches and some spits and bars on lower energy coasts *Tamarix gallica* and *Lupinus arboreus* have been introduced into this habitat. These species act as good protection for exhausted migrant birds on passage. In other areas, especially where spits are adjacent to salt-marsh, the reduced mobility and much-increased organic matter content of the substrate gives rise to narrow bands of halophytes: *Sarcocornia perennis*, *Salicornia* spp., *Suaeda maritima, Puccinellia maritima* and *Atriplex portulacoides* being the most frequent. Details of the variation around England, Scotland and Wales can be seen in Sneddon and Randall (1993/1994).

Much less common around Britain are the more terrestrial shingle formations of apposition beaches, cuspate forelands and offshore barrier islands. All these have typical foreshore habitats near the shoreline but further inland they are more stable. The largest apposition beach structures occur on the Isles of Arran and Jura; Dungeness, Kent has the most complete cuspate foreland and Culbin Bar and Scolt Head Island are the most studied barrier islands. Ecologically these features are of most interest because of the differences in the time-scales of their stability.

Because beach mobility is less of an ecological consideration on these larger-scale formations, Scott (1963) recognised two further vegetation classes relating to terrestrial shingle:

- long-lived perennial species – beach subject to occasional inundation, lichens present;
- heathland – beach entirely stable.

Vegetation succession

Understanding the factors determining the nature of vegetation succession is important when considering management and restoration options. This will be particularly significant when attempting to predict the outcome of a specific management operation. It is generally accepted that a greater expanse of shingle and a more stable formation result in a more complex ecological development over time. This has been studied by Ferry (in Packham et al. 2001) at Dungeness and Randall and Sneddon (in Packham et al. 2001) elsewhere in Britain. The quantity and composition of the matrix remains a vital factor throughout the successional sequence on stable shingle formations. It is of greatest importance at times of seed germination because, without it, enough moisture may not be present for growth to begin or to be sustained. The major difference between shingle foreshores and the larger, more terrestrial formations is that the latter do not have the advantage of external inputs of organic matter through tidal drift. Small quantities of nutritive material will be blown into these habitats by wind but most organic matter will be produced over long periods *in situ,* by the plants themselves. This hypothesis was first tested by Scott (1963) who later produced a tentative successional sequence based on Dungeness foreland (Scott 1965). Nine stages were recognised in an autogenic xerosere, ranging from bare shingle to climax woodland (Figure 02-02).

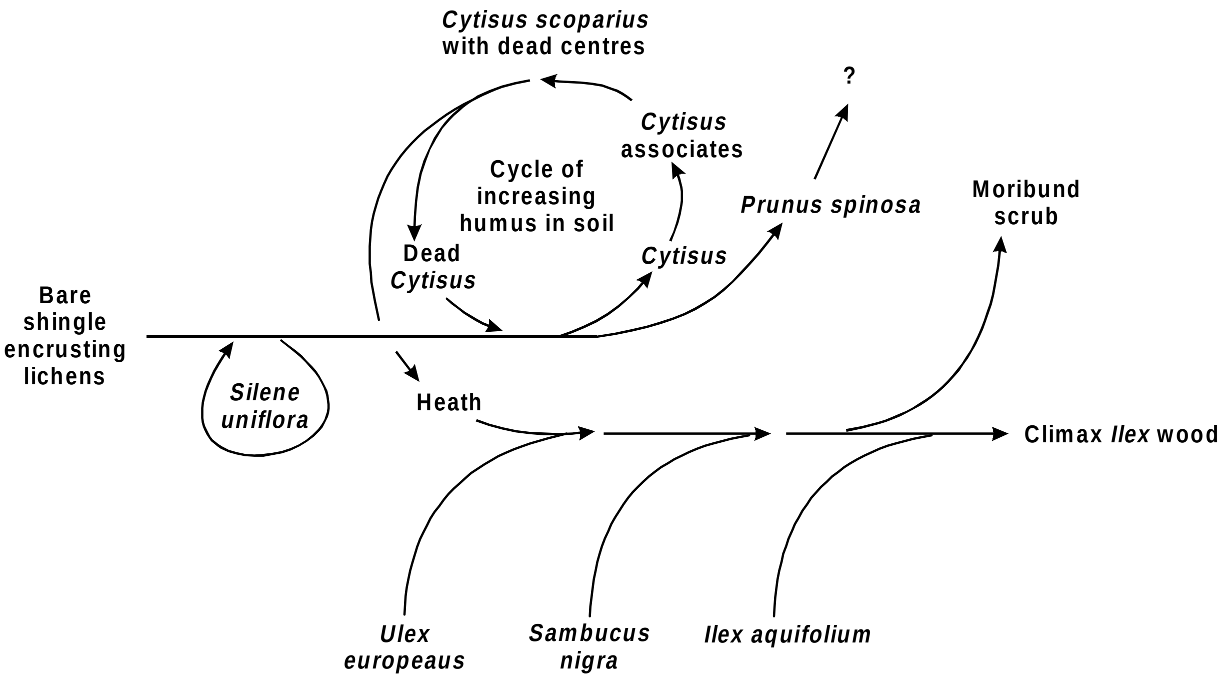


Figure 02-02 ‘Broom cycle’ at Dungeness leading to a supposed holly wood climax (after Scott 1965)

Scott (1965) identifies a small-scale patterning of vegetation confined to the ‘fulls’ of shingle ridges, which support patches of dry, acid heath. This patchiness is recognised as supporting Whittaker’s (1957) view of a sere as a general trend in vegetation change of ‘loosely ordered complexity’, conforming to Gleason’s (1926) ‘individualistic concept of the plant community’. Despite this, Scott notes a tendency for younger stages of succession to occur nearer the sea on more recently deposited shingle and older stages to landward, reflecting the known geomorphic sequence. Scott links the successional sequence to increasing humus within the shingle matrix, resulting from the dominant role of *Cytisus scoparius*, leading eventually to *Ilex aquifolium* woodland regarded as the climax (Figure 02-02). [*Teucrium scorodonia* is also important as a producer of woody humus.]

Peterken & Hubbard (1972), also working at Dungeness, question the status of *Ilex* and propose modifications of Scott's model in which various heathland species may increase humus within the soil and several scrub species are involved in the climax cycle dependent upon factors such as longevity, shade tolerance, fertility or dispersal mechanism (Figure 02-03).

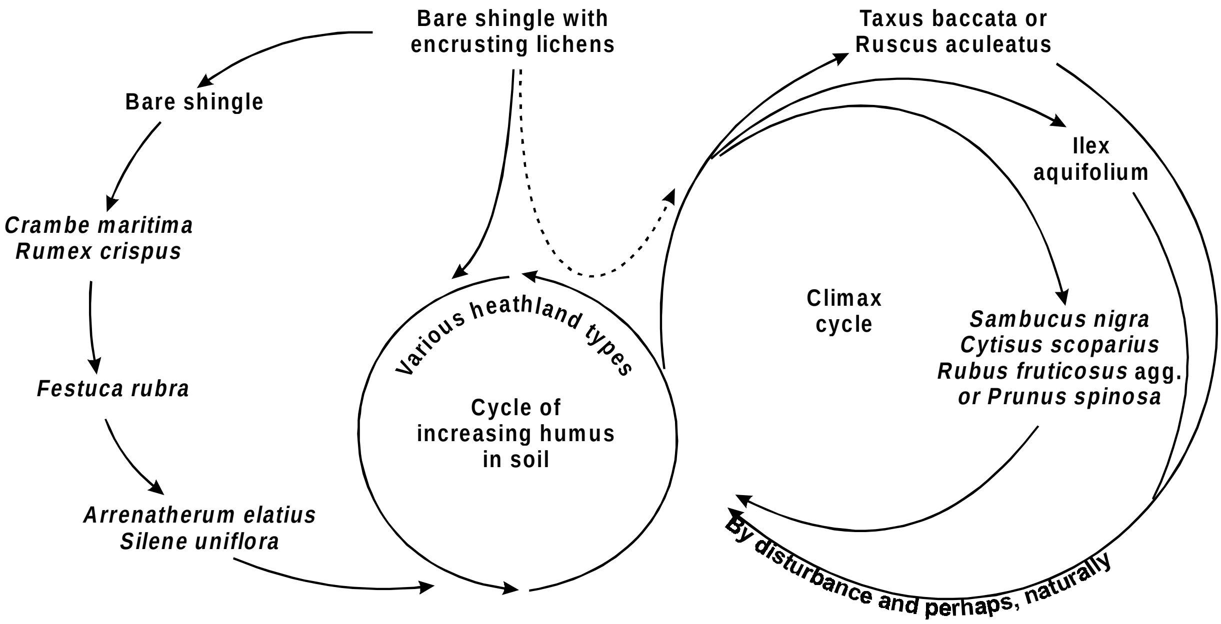


Figure 02-03 Cyclical and successional shingle vegetation at Dungeness (after Peterken & Hubbard 1972)

Ferry et al. (1989) refute these deterministic models and highlight the importance of stochastic events. Randall (1992), working in New Zealand also doubted the applicability of linear species models and suggests an anastomosing successional sequence with a development from herb to low, then taller, shrubs while the species differ considerably in each locality.

Connell & Slayter (1977) emphasise the *mechanisms* of succession, including 'facilitation', as being most significant, rather than the outmoded idea of climax. On shingle, pioneer vegetation has been shown to be particularly important in facilitating the provision of shelter for later species in the sequence. It also helps to stabilise the system and provides humus. The adoption of an 'anastomosing' sequence of succession, where the above ground plant material (of various species) breaks down to fill in the gaps between the pebbles, supports the development of a partially deterministic model. This model also allows for the incorporation of stochastic events. This type of model offers the best means of developing a useful predictive tool with wide applicability for management purposes. Full details are given in Randall & Sneddon (2001) and see also Figure 02-04 below.

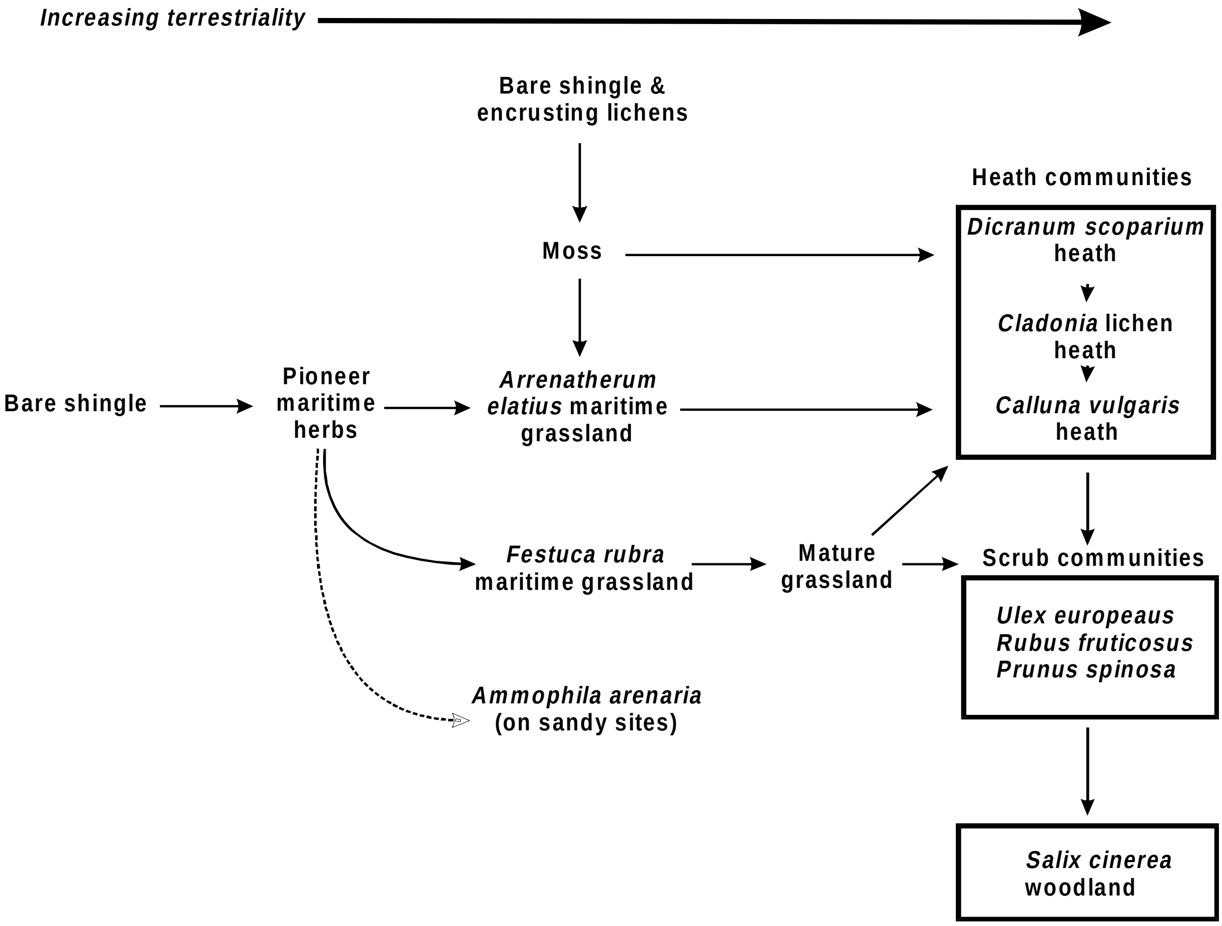


Figure 02-04 Proposed sequence of vegetation succession on shingle sites in Great Britain

Distinct communities also occur around artificial pits created by excavation and around lagoons that have developed naturally on shingle. The areas support a completely different flora dependent upon whether the water table is affected by fluxes of seawater or tidally related fluctuations in fresh-water level. Where seawater is able to seep through the shingle, lagoon waters are brackish and a limited number of saltmarsh species occur. *Artemesia maritima, Aster tripolium, Limonium spp. and Atriplex portulacoides* are the most frequent in these conditions. Where the water is less brackish there is usually a zonal sequence from open-water species through *Phragmites australis* to *Triglochin palustris* near the water's edge. Gimmingham (1964) also refers to 'shingle/salt-marsh communities' in western Scotland maintained by percolation of seawater through the storm-crest into shingle with a silt matrix. Here *Armeria maritima, Puccinellia maritima* and *Plantago maritima* form an intermittent, eroded turf over shingle.

A final community type is that of organic foreshores. These occur where, almost regardless of substrate, there is a very large algae deposit each winter, which does not fully decompose during the succeeding summer. Such conditions occur on high-energy coasts where the main constituent of the organic material is *Laminaria* spp. These areas mainly support communities of annual plants but some perennials can grow through further additions of organic debris. Over much of western Scotland *Atriplex glabriuscula* is the dominant species though *Potentilla anserina* is the major species in Mull. Such communities are dependent upon the chance input of seed and in different years many ruderal species may occur. The most frequent are: *Urtica urens, Poa* spp., *Polygonum* spp. and *Spergularia arvensis*. These strand communities are normally open, variable and ephemeral, without the more formal structure found elsewhere**.**

Invertebrate communities on shingle

Shardlow (in Packham et al. 2001) regards coastal shingle as a unique and fascinating habitat for invertebrates. He recognises two distinct habitats: saline-shingle beaches and terrestrial shingle. Some 390 species of importance to conservation have been recorded on shingle, including 15 Priority species, 18 species of Conservation Concern and 114 Red Data Book species. At least 11 shingle-specialist taxa occur in the UK, four of which are endemic. The current key factor threatening shingle invertebrates is thought to be changes in coastal sediment dynamics, related to management of the coastline and sea-level rise. In certain locations visitor pressure is also highly significant.

Barnes (in Packham et al. 2001) and McArthur (in Packham et al. 2001) look particularly at the ecology of shingle-enclosed lagoons, which are a priority habitat under Annex 1. Most lagoons are protected under legislation for other purposes but there is concern that our scanty knowledge of the inter-relationships between lagoonal organisms will make the long-term safeguarding of populations difficult. A list of invertebrates associated with coastal vegetated shingle is given in Appendix 03.

Birds of coastal shingle and lagoons

Birds associated with shingle can be divided into three groups. The first occurs on dry open shingle and is largely composed of about nine breeding species: oystercatcher, ringed plover, lapwing, grey partridge, and six passerines. Most of these occur more abundantly elsewhere. Stone curlew and Kentish plover formerly bred on coastal shingle but are no longer present. Wintering snow buntings use the east coast shingle beaches as a place to search for food.

Cadbury & Ausden (in Packham et al. 2001) regard shingle as more significant for two other groups: nesting colonial seabirds and waterfowl. Five species of gull, including the rare Mediterranean gull, four terns and cormorant breed on shingle. Many sites are particularly important for tern nesting and Orfordness has one of Britain’s largest colonies of lesser black-backed and herring gulls. Among the waterfowl, avocet is restricted as a breeding species to coastal lagoons. Nationally high numbers of little grebe, gadwall and, at Dungeness, smew congregate on shingle water bodies in winter and Chesil Fleet is famous for its large flocks of brent geese and mute swans which graze on the beds of *Ruppia* and *Zostera*.

References

Bradbury, A.P. & Kidd, R., 1998, *Hurst Spit stabilisation scheme – design and construction of beach recharge*. Proceedings of the 33rd MAFF Conference of River and Coastal Engineers, Keele University, 1-3, July 1998. 1.1.1-1.1.13.

Bradbury, A.P. & Powell, K.A., 1992. Short-term profile response of shingle spits to storm wave action. *23rd International Conference on Coastal Engineering.* American Society of Civil Engineers, 2694-2707.

Carter, R.W.G. & Orford, J.D., 1993. The morphodynamics of coarse clastic beaches and barriers: a short and long term perspective. *Journal of Coastal Research*, **15**: 158-79.

Connell, J.H. & Slayter, R.O., 1977. Mechanisms of succession in natural communities and their role in community stability and organisation. *American Naturalist,* **111,** 1119-1144.

Connell, J.H., 1977. Mechanisms of succession in natural communities and their role in community stability and organisation. *American Naturalist,* **111,** 1119-1144.

Ferry B. Lodge N. & Waters S. 1989. *Dungeness: a vegetation survey of a shingle beach*. Research & survey in nature conservation, **No 26**: Nature Conservancy Council, Peterborough

Forbes, D.L., Orford, J.D., Carter, R.W.G., Shaw, J. & Jennings, S.C., 1995. Morphodynamic evolution, self-organisation, and instability of coarse-clastic barriers on paraglacial coasts. *Marine Geology*, **126**: 63-85.

Forbes, D.L., Taylor, R.B., Orford, J.D., Carter, R.W.G. & Shaw, J., 1991. Gravel barrier migration and overstepping. *Marine Geology*, **97**: 51-86.

Fuller, R.M., 1987. Vegetation establishment on shingle beaches. *Journal of Ecology*, **75**: 1077-1089.

Gimmingham, C.H., 1964. Maritime and sub-maritime communities. In: *The Vegetation of Scotland,* Burnett, J.H. ed. Oliver & Boyd, Edinburgh, Scotland.

Gleason, H.A., 1926. The individualistic concept of the plant association. *Bulletin of the Torrey Botanical Club,* **53,** 7-26.

Kirk, R.M., 1980. *Mixed sand and gravel beaches: morphology, processes* and sediments. *Progress in Physical Geography*, **4**: 189-210.

Orford, J.D., Jennings, S.C. & Forbes, D.L., 2001. Origin, development, reworking and breakdown of gravel-dominated coastal barriers in Atlantic Canada: future scenarios for the British Coast; In: *Ecology &*

Geomorphology of Coastal Shingle, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 23-55.

Packham, J.R., Randall, R.E., Barnes, R.S.K. & Neal, A. eds. 2001. *Ecology and Geomorphology of Coastal Shingle.* Otley: Westbury Publishing.

Peterken, G.F. & Hubbard, J.C.E., 1972. The shingle vegetation of southern England: the holly wood on Holmestone Beach, Dungeness. *Journal of Ecology*, **60**: 547-571.

Pye, K., 2001. The Nature and Geomorphology of Coastal Shingle; In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 2-22.

Randall, R.E. & Doody, J.P., 1995. Habitat inventories and the European Habitats Directive: the example of shingle beaches. In: Healy, M.J. & Doody, J.P. eds. *Directions in European Coastal Management*. Samara Publishing, Cardigan, 19-36.

Randall, R.E. & Fuller R.M., 2001. The Orford Shingles, Suffolk, UK: Evolving Solutions in Coastline Management; In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 242-260.

Randall, R.E., & Sneddon, P., 2001. Initiation, development and classification of vegetation on British shingle beaches: a model for conservation management. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 202-223.

Randall, R.E., 1973 Shingle Street, Suffolk: an analysis of a geomorphic cycle. *Bulletin of the Geological Society of Norfolk*, 24: 15-35.

Randall, R.E., 1977. Shingle formations. In Barnes, R.S.K., ed., *The Coastline*. Wiley, London.199-213.

Randall, R.E., 1992, The shingle vegetation of the coastline of New Zealand: Nelson Boulder Bank and Kaitorete Spit. *New Zealand Journal of Geography,* **93,** 11-19.

Scott, G.A.M., 1963. The ecology of shingle beach plants. *Journal of Ecology*, **51**: 517-527.

Scott, G.A.M., 1965. The shingle vegetation at Dungeness. *Journal of Ecology,* **53**: 21-31.

Shulmeister, J. & Kirk, R.M., 1993. Evolution of a mixed sand and gravel barrier system in Canterbury, New Zealand, during the Holocene sea-level rise and still stand. *Sedimentary Geology*, **87**: 215-35.

Sneddon, P. & Randall, R.E., 1993/1994. *Shingle Survey of Great Britain. Final Report Appendix 1 Wales. Appendix 2, Scotland*. *Appendix 3: England*. Peterborough. Joint Nature Conservation Committee.

Whittaker, R.H., 1957. Recent evolution of ecological concepts in relation to the eastern forests of North America. *American Journal of Botany,* **44,** 197-206.

Chapter 03 Flood defence and coastal protection - the role of shingle beaches and structures

Introduction

Shingle beaches are mobile structures developed in dynamic high-energy environments. As such they are themselves highly efficient dissipators of wave energy and may form important sea defences, a role that has long been recognised. For example, discussions over shingle extraction during the 1907 'Royal Commission on Coastal Erosion and the reclamation of tidal lands in the United Kingdom' prompted exchanges such as the following:

"Do you recommend that the removal of shingle, whether for manufacture of concrete, road-making, or ship ballast should be stopped?"

"I think that any beach that can be shown in any way to protect the coast should be left alone .... I think that ought to be enforced very strongly indeed. In many cases shingle is taken from comparatively narrow, small masses of beach, the decrease of which leads to very serious results, that is to say, the damage done is many times the worth of the shingle taken." [Vol. 1(2); page 92; minute 2268].

Despite this understanding, building sea defence structures (e.g. sea walls and groynes) has occurred on or behind many shingle shores. These can cause major change to the sediment regime, reducing or preventing available sediment reaching the beach. In its turn erosion due to the interruption of long-shore drift can result in the need for protection further along the beach. Reprofiling the beach also takes place destroying any incipient vegetation. This last point is particularly important for designated sites as most problems occur due to ongoing beach recycling operations carried out by "competent authorities". These often involve activities, which have had a significant impact on shingle vegetation. In some cases the integrity of the structure is affected and low-lying land protected by shingle beaches or structures may become vulnerable to flooding. To some extent the value of shingle to coastal defence is not recognised until it is too late, as for example the case of Hallsands (Annex 02) vividly illustrates.

Shingle as a natural defence

Sea defence (the protection of land from flooding) and coastal protection (protection of land from erosion) can both apply to shingle beaches and structures. Most of the shingle types identified in this report provide some form of flood defence. The shingle beach itself is a buffer to waves absorbing the energy of storms. Often the height of the beach or shingle structure is above normal tidal levels and most storm waves. Taken together these provide a very effective barrier to incursions by seawater discussed above. However, despite this the spectre of eroding, or changing beach levels has resulted in many instances of artificial protection measures including building structures on the beach and offshore, re-profiling the beach and beach nourishment.

Shingle beaches by their nature tend to be robust and able to withstand sometimes massive and rapid change. They are particularly well adapted to changing environmental conditions responding to tides, waves and storms by absorbing their energy. The movement of shingle, which often accompanies particularly violent storm events, provides the means of adaptation. Thus natural beaches tend to be lowered and flattened by 'over-washing' as storm wave energy is dissipated (compare the 'natural' and 'engineered' beach profiles in Figure 03-01 below). Although more frequent overtopping and flooding can occur the violence and severity of these events is lessoned. Anyone who watches storm waves approaching a wide sandy beach or a shingle foreshore should need little convincing of their ability to withstand and dampen wave energy. At the same time the movement of material up the beach helps to rebuild the crest height and with it the ability to withstand the next storm.

Thus shingle beaches by responding to storms, and over the longer term to sea level change, by migrating alongshore or landwards can provide an effective and sustainable coastal defence. The issues surrounding this are discussed in more detail in relation to decisions taken at Cley-Salthouse.

Here reprofiling of the area shown in Figure 03-01a will cease and allow a more natural beach profile to develop (Annex 07 and 07a).

Figure 03-01a An artificially reprofiled beach at Cley North Norfolk, October 2001. The picture was taken looking southeast along the coast.

Figure 03-01b. A ‘natural’ beach profile Cley, North Norfolk, October 2001. The picture was taken looking northwest from the same spot as Figure 03-01a above.

Cheniers as natural sea defence structures

Some areas of the Essex salt marsh coastline are currently protected to some degree by the presence of shell and shingle ridges called ‘cheniers’. In Great Britain these features are largely confined to Essex. The ridges are transgressive, lying on a marsh surface, over which they are retreating, isolated by mudflat or marsh to seaward. They occur from Canvey Island to Harwich and vary in their composition from almost pure *Cerastoderma edule* shells in the south to mixed sand, shingle and shell further north.

Figure 03-02 Shell shingle forming a natural sea defence off Cuddy Point, Blackwater Estuary, Essex

Richards & Pye (2001) are currently investigating the composition of the Essex cheniers in relation to their effectiveness as ‘Natural Dynamic Coastal Defences’. Once the sedimentary and morphodynamic characteristics of different cheniers are better known, it is hoped to use this information in the construction of artificial cheniers at ‘at risk’ sites.

Sediment budgets and coastal defence

An important point to consider in relation to coastal defence is that many of the beach-barrier systems on the modern coast were initiated during the Holocene marine transgression and are now responding to changes in sea level, storms and tidal movement involving the reworking of an essentially finite sediment supply (Pye 2001). This poses the most significant management issue in relation to the sustainability of coastal shingle beaches and structures, especially for sea defence purposes.

The situation in Start Bay (Slapton, Annex 02) is summarised in the Futurecoast project as follows:

“There are no significant contemporary sources of material to this coastline. Landsliding in the vicinity of Brixham can occur in response to easterly storms and the removal of toe debris providing a local, although not significant, source of beach material. Toe-trimmed headland slopes fringed by some raised beach deposits are also potential sources in the north, but they are not presently significant. **This indicates that the sediments present in Start Bay were derived from the seabed during the Holocene period**. This is consistent with the high proportion of flint pebbles (75%), present on the barrier beaches, which have no local source.” (Halcrow 2003).

A project funded under Interreg II (Chapter 10) with matching funds coming from the relevant local authorities aimed to investigate the supply and depletion of shingle on ‘Rives Manche’ beaches under present day management regimes, and to determine the sustainability of the beaches in a period of rising sea level (http://www.geog.sussex.ac.uk/BERM/index.html). The study **BERM** (Beach Erosion in the Rives Manche) concluded that overall flint production on the English side of the Channel amounts to only 4,610m^3 per annum and may reflect the relatively low cliff heights and the lower flint content of the chalk (as compared to the French coast where the parallel study took place). The major source of flint on the English side is located between Cuckmere Haven and Birling Gap, which is towards the east. Limited observations from qualitative air photo interpretation suggest that beaches bound on the updrift side by engineering structures (such as the Seaford breakwater) have gained in volume over the past 26 years. However cliff fall analyses along the French coast suggest an increase in the number and frequency of cliff falls since the 1970s following the construction of groynes and jetties and associated reductions in shingle movement.

Comment: *It is not clear from this study, therefore, whether building structures to arrest longshore drift is beneficial or not, even in areas where new material is being delivered to the system. The increase in cliff erosion on the French coast suggests that a reappraisal of approaches, which seek to arrest shingle movement is needed.*

Other sediment sources may be important. Gemmell et al. (2001) have shown in relation to Spey Bay (Annex 08), for example, that it is vital to regard the coastal and riverine sediment processes as a dynamic continuum. Many previous *ad hoc* attempts to protect land from flooding and erosion have failed because of a lack of understanding of changes in the extent of shingle along the coast. Gemmell’s work has shown the need to conserve sediment transport and supply and to allow minimum intervention to type of sediment and rate at which it is supplied to river, coast or downdrift beaches.

Comment: *The situation in Spey Bay may be somewhat unusual in the British context as there is a relatively large volume of new material being fed to the system from the river, unlike those on the south coast of England.*

Groynes and artificial breakwaters

Groynes (Figure 03.03) of many shapes and sizes are specifically built to help hold material on a beach and slow down longshore drift. They can appear to be successful and in some instances are able to support the maintenance of a beach for some years. There are however caveats to their use:

1. storms, which can move material onshore and offshore may cause a rapid depletion of the beach. This may involve the pebbles either being moved offshore into deeper water where they can be effectively ‘lost’ to the system or onshore as the shingle beach ‘rolls-over’ the land;
2. as material is held up on one section of the coast it can ‘starve’ adjacent sections ‘down-drift’ of the groynes.

Figure 03.03. Wooden groyne creating a build up of shingle on the up-drift (left hand side) with a lower beach on the down-drift (right hand side), Porlock (Annex 01), Somerset.

Artificial breakwaters are normally built offshore and designed to shelter the coast by forcing waves to ‘break’ and lose much of their energy before they reach the shore.

Beach re-profiling sea defence activities

Reshaping shingle structures in order to enhance their sea defence function is a common activity. Although this alters the nature of beaches and shingle structures it does not cause their destruction. However, as with other forms of sea defence they can reduce the availability of material downdrift potentially exacerbating erosion trends there. At the same time the act of moving the beach material does have a profound impact on the vegetation and any invertebrates associated with stable or semi-stable shingle structures. Problems can occur where long-term works are carried out as this will prevent any natural beach profiles being allowed to develop. In some cases emergency repairs can be even more harmful, affecting beaches that have remained stable for many years as was the case on the south coast at Climping Gap, West Sussex in 1992, adversely affecting the Site of Special Scientific Interest.

The situation at Porlock (Annex 01) in Somerset and the along the North Norfolk coast at Cley-Salthouse (Annex 07) suggest that in some cases re-profiling may not be sustainable in the long term. It is also not clear if such activities may cause sediment loss from the beach in the long term and create a weaker internal structure to the beach. These issues are considered in more detail in the habitat guidance (Chapter 06) and discussed in relation to the pros and cons of undertaking ‘shingle beach protection’.

Beach nourishment

Beach nourishment is often seen as a more environmentally friendly ‘softer’ option for coastal defence. However the import of material foreign to the locality can bring with it its own pressures. Imported marine-dredged shingle can cause nutrient enrichment and adverse effects on local beaches when using shingle of unsuitable type/size.

The use of marine dredged material (see below) can be problematic. Excavation is carried out under licence from the Crown Estate and subject to the ‘Government View’ procedure (dealt with in Chapter 06 where the implications are considered in relation to marine mineral extraction). Economic factors, technical constraints and the occurrence of suitable deposits of sand and gravel dictate the location of dredging areas. Distance from the licence area to the point of landing and market is also critical in determining the commercial viability and competitiveness of marine aggregates. Thus suitability for use in a particular location may always be a secondary consideration.

Beach recycling

Shingle recycling such as takes place at Dungeness and Rye are less problematic than beach nourishment schemes as the material is almost always derived from the local source and ‘recycled’ to replenish the system. The scale of these activities on the south coast provides important information on the effects on existing beaches. At Dungeness (Annex 05), longshore drift is from west to east and the tip of the ness would naturally continue to move eastwards. The short-term consequence of this would be a deficit of material immediately in front of the nuclear power stations. Clearly the nuclear power station needs protecting and as a result, beach nourishment is carried out to build up the shore and protect the buildings from being undermined and possibly falling into the sea. This is undertaken by collecting material at the east of the site and moving it to the west. Longshore drift ensures the material is carried to the shoreline in front of the station and eventually back to where it was originally collected in the east. From here it is scooped up again and carried back to the west: a never-ending cycle of recharge. Although this protects the power station it prevents the accretion of ‘pioneer’ shingle ridges on the east side of the site.

At Rye Harbour the current defences are maintained by recycling shingle that has collected against the River Rother Harbour arm. It is thought that these could be breached as frequently as once in five years without the further beach recharge schemes that are planned or implemented further east. At Church Norton Spit, Pagham Harbour, the seaward side is also replenished, annually by the Environment Agency, who recycle large quantities of shingle from the foreshore over a two-month period in winter, usually January/February (see Annexes 03 & 04).

Offshore aggregate extraction

Gravel deposits suitable for commercial exploitation are relatively restricted around the UK coast. As a result the areas which are exploited are themselves limited. This together with access to ports for offloading the material have led to a concentration of dredging licences in areas such as the Outer Thames Estuary, off Great Yarmouth and around the Isle of Wight, and their absence in others, for example Lyme Bay and the western approaches.

According to the Crown Estate who license extraction these license areas cover a very small % of the total sea bed and even within the licensed areas only 15% is excavated in any one season. The location of the extraction sites is shown in Figure 03.04 below.

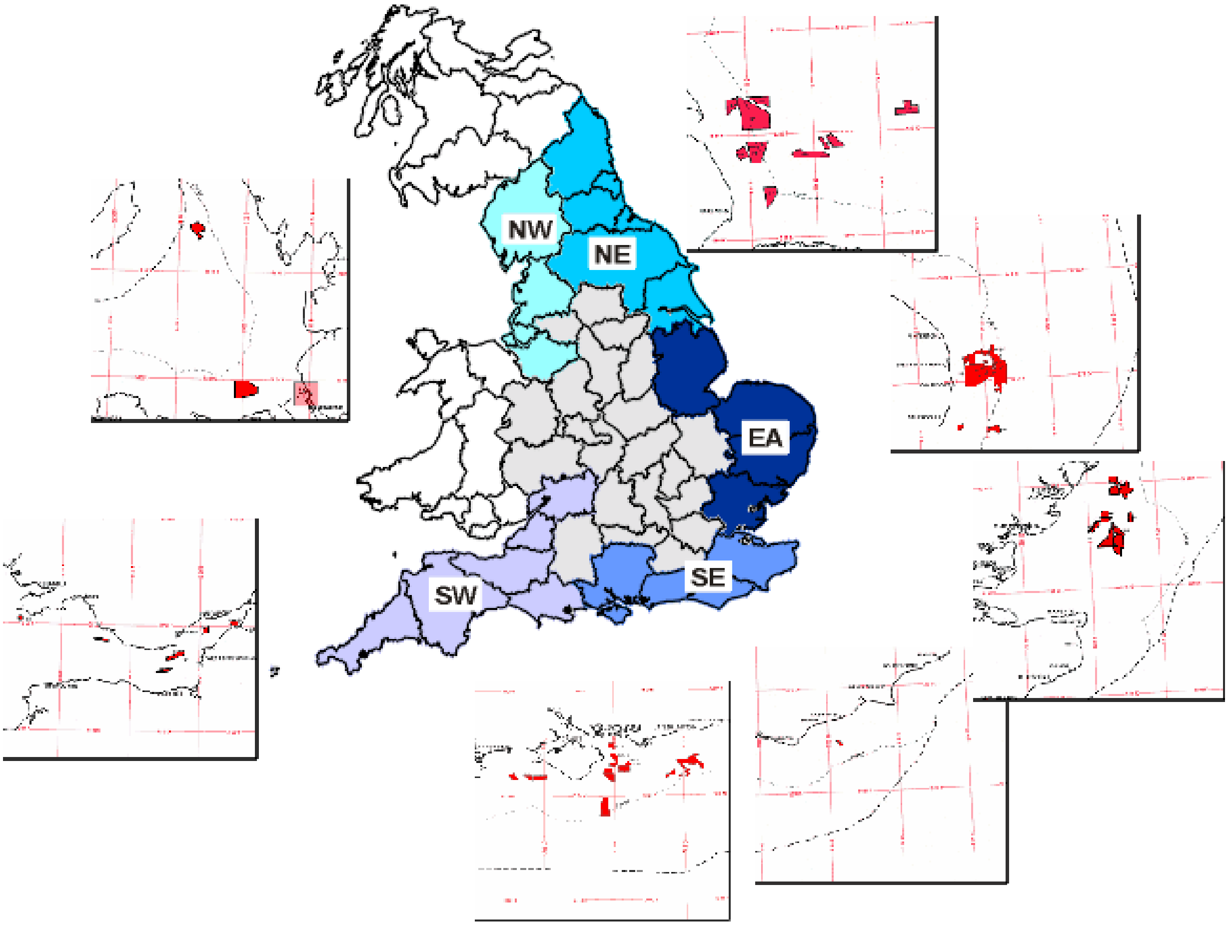


Figure 03.04 Location of sand and gravel licensed areas around the coast of England (DEFRA regions are shown in shades of blue). The extraction area maps are derived from the Crown Estates web site.

The effect of this offshore extraction on the coastal shingle beaches and structures is considered to be minimal as all applications are carefully vetted. Most extraction takes place at a depth of between 10 and 35 metres, though up to 50 metres is possible. At these depths it is generally assumed that there is no impact on adjacent shores. However the process of granting licenses for extraction has become more stringent over the years and Environmental Impact Assessments are now required. Amongst other things this includes the need to assess the physical impact on coastal erosion (through a Coastal Impact Study), see Marine Mineral Guidance Note 1 (MMG 1). Most of the rest of the assessment is concerned with the effects on the seabed and other marine factors.

Offshore dredging - marine aggregate licenses

Marine aggregate extraction has, in the past, been encouraged by Government policy, subject to detailed assessment of potential impacts, known as the “Government View”. Due to the localised occurrence of suitable material and the need for this to be readily exploitable and near to discharge ports the areas of exploitation are relatively small. The current procedure within each of the countries is summarised below and an attempt made to identify key elements which are important to coastal vegetated shingle.

England

In England the Crown Estate has been responsible for issuing licences. Since 1968 this has been preceded by a 'Government View' (GV) procedure which has tightened up the control of extraction. This procedure involved an analysis and consultation process co-ordinated by The Department of the Environment, Transport and the Regions (DETR). From 1989 all dredging applications have been screened as to the need for an Environmental Impact Assessment (EIA dealt with in Chapter 05) as part of this 'Government View' process and since 1993 all applications have required an EIA comprising a commissioned Coastal Impact Study and an Environmental Statement.

The Government intends to replace the non-statutory 'GV' procedure with a statutory process, with the introduction of the *Environmental Impact Assessment* and *Habitats (Extraction of Minerals by Marine Dredging) Regulations*. This will transpose the EIA and Habitats Directives into national law in so far as they relate to marine aggregate dredging. In 2002 a policy guidance note was published by The Stationary Office on behalf of the Office of the Deputy Prime Minister (available to download from the ODPM web site under planning policy guidance http://www.planning.odpm.gov.uk/policy.htm).

This guidance document "*Marine Minerals Guidance Note 1 Guidance on the Extraction by Dredging of Sand, Gravel and Other Minerals from the English Seabed*" includes detailed information in Annex A on Environmental Impact Assessment and what it should cover. It applies both to applications for dredging licences made under the 'Government View' procedure and for Dredging Permissions made under a new statutory system when it is introduced. The guide also indicates what should be assessed through the ***Coastal Impact Study*** (see Chapter 06).

Scotland

Although marine dredged sand and gravel has not contributed to the supply of aggregates in Scotland to date, the Scottish Executive recognises that it may do in the future. The National Planning Policy Guidelines 4 (NPPG 4) - Land for Mineral Workings - section *additional policy guidelines for individual minerals* includes a paragraph which states, in relation to marine minerals exploitation that:

"*…the potential to do so exists. Proposals are subject to the 'government view' procedure which is co-ordinated by The Scottish Office Environment Department. If favourable, licences are granted by the Crown Estate. Dredging of sand and gravel may be acceptable, provided it can be done without unacceptable damage to sea fisheries and the marine environment* ***or the stability of the coastline****. The operation of the 'government view procedure' is currently under review*."

Available via the Scottish Executive web site, publications @ http://www.scotland.gov.uk/publications/recent.aspx - search on NPPG 4.

Wales

The National Assembly for Wales (http://www.wales.gov.uk/index.htm) is also currently examining responses to its draft policy framework on marine aggregate dredging.

Impact on the marine environment

A number of other Key Issues and 'good practice' have also been identified which relate more generally to the marine environment (see boxes below). These are taken from the Marine Stewardship Report: "Safeguarding Our Seas: A Strategy for the Conservation and Sustainable Development of our Marine Environment". This report can be downloaded from the DEFRA web site http://www.defra.gov.uk/ under 'Environmental Protection in the Marine Environment').

'Regional Environmental Assessment'

The Crown Estate has recently granted prospecting rights in an area of seabed 20 miles south of the Sussex coastline, in the deeper (40 metres plus) waters of the eastern English Channel. Ten planning applications to dredge parts of the area have now been submitted by six companies to the Office of the Deputy Prime Minister. Recognising the need for an overall study of the cumulative impacts of their proposals, the companies involved have commissioned a comprehensive Regional Environmental Assessment (REA) and have joined forces as the East Channel Association to fund it. The REA was published in January 2003. A non-technical summary covering an area within which multiple extraction applications might be made; Eastern English Channel is available @ http://www.eastchannel.info/english/index.htm. This appears to be a new approach which fulfils the Government's requirements for an Environmental Statement whilst at the same time taking the wider sub-regional seas area into account.

Key issues an EIA needs to address:

- the coast and coastal processes;
- sediment transport pathways;
- marine ecosystems;
- commercial fisheries;
- water quality;
- navigation;
- marine conservation areas;
- archaeological sites;
- other uses of the sea.

Good practice in aggregate extraction will protect the marine environment through:

- the careful location of new dredging areas;
- considering new applications for Dredging Permissions in relation to the findings of a full EIA;
- minimising the overall impact of dredging by reducing the risk of cumulative impacts from multiple dredging operations and other human activities, minimising the area being dredged at any one time, and minimising the total area permitted for dredging;
- controlling dredging operations through the use of legally enforceable conditions attached to dredging permissions;
- requiring operators to monitor, as appropriate, the environmental impacts of their activities during and on completion of dredging.

The increasingly important issue for shoreline management is the extent to which offshore extraction potentially impacts on nearshore and coastal processes. This is discussed in more detail and in relation to the procedures identified above, in the guidance given in Chapter 06.

References

Gemmell, S.L.G., Hansom, J.D. & Hoey, T.B., 2001. River-coast sediment exchanges: the Spey bay sediment budget and management implications. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 159-166.

Halcrow, 2003. Futurecoast. A 3 CD set comprising reports and interactive map browser and two CDs with oblique aerial photography of the shoreline of England and Wales, Department of Environment, Food and Rural Affairs.

Pye, K., 2001. The nature of geomorphology of coastal shingle. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 2-22.

Richards J. & Pye K., 2001 The cheniers of the Essex coast: sedimentology and management for flood defence. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 167-172.

Chapter 04 Protected sites

This chapter deals with the protection of coastal vegetated shingle sites in Great Britain. In the UK there are a hierarchy of designations, which are applied to sites deemed by the statutory countryside agencies to be important for their wildlife (flora and fauna), geological or physiographical features. These include:

Site of Special Scientific Interest (SSSI)

The Wildlife and Countryside Act 1981 (as amended by the Countryside and Rights of Way Act 2000) is the principle legislation under which actions affecting the wildlife interests of designated shingle sites are controlled. It is under this Act that Sites of Special Scientific Interest are designated. Sites are assessed, identified and designated by English Nature, the relevant countryside agency in England (Countryside Council for Wales; Scottish Natural Heritage).

Notification as a SSSI is primarily a legal mechanism to protect sites that are of particular conservation interest because of the wildlife they support, or because of the geological features that are found there. SSSIs can be found all over Great Britain and help to form a national network of areas with the greatest value to wildlife or geological conservation.

The legislation was further strengthened by the Countryside and Rights of Way Act 2000 which amends the 1981 Act provisions and improves protection for SSSIs in England and Wales.

[English Nature has produced an excellent booklet explaining the role of SSSIs and the obligations on owners and occupiers and on the statutory bodies. It includes supporting information on more technical aspects of the process and can be downloaded from the EN web site @ http://www.english-nature.gov.uk.] Details of each SSSI in England can also be obtained from the English Nature web site or via the Department of Environment, Food and Rural Affairs 'Magic' @ http://www.magic.gov.uk/, for most sites pdf files provide the SSSI description (Figure 04-01a shows the location of important sites in England).

Similar information will be available on the Countryside Council for Wales web site during 2003 see http://www.ccw.gov.uk/ (Figure 04-01b shows the location of important sites in Wales). Information for sites in Scotland should be available via the Scottish Natural Heritage web site http://www.snh.org.uk/; though at the time of writing this was inaccessible (Figure 04-01c shows the location of important sites in Scotland).

National Nature Reserve

National Nature Reserves (NNRs) are established to protect the most important areas of wildlife habitat and geological formations in Britain, and as places for scientific research. NNRs are 'nationally important' and among the best examples of a particular habitat. They are either owned or controlled by English Nature (CCW in Wales, SNH in Scotland) or held by approved bodies such as Wildlife Trusts. The management of these sites has as a first priority the conservation of those natural or semi-natural features for which the site has been designated.

Local Nature Reserve

Local Nature Reserves (or LNRs) are designated under Section 21 of the National Parks and Access to the Countryside Act 1949 by principal local authorities (county and district councils). Parish and town councils can also declare LNRs but they must have the powers to do so delegated to them by the principal local authority.

Natura 2000 sites

At the centre of the European Union policy is Natura 2000, a coherent network of protected areas across the EU. These areas are made up of Special Areas of Conservation (SACs) and Special Protection Areas (SPAs). [The location of the candidate SACs and SPAs in Great Britain are shown in the maps below (Figure 04-01a, b c). A description of the interest, as provided by the JNCC web site is reproduced in Appendix 02 for each of the SACs.]

An overview of legislative implications of these designations and the various regulatory controls that may affect proposals to manage or restore coastal vegetated shingle habitats is provided in Appendix 01.

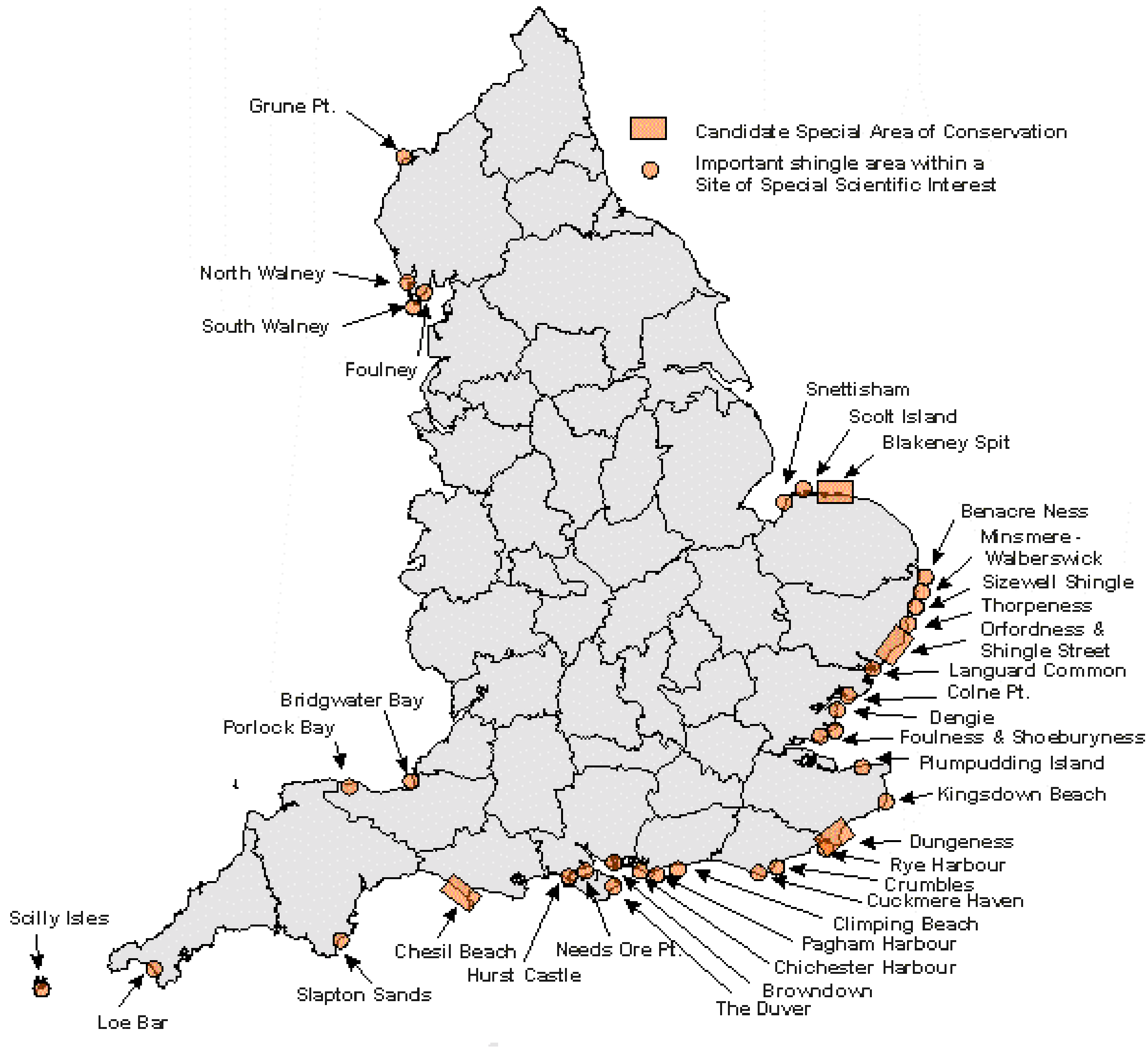


Figure 04-01a Important shingle sites in England. NB The Crumbles is the only site mentioned which is not a Site of Special Scientific Interest

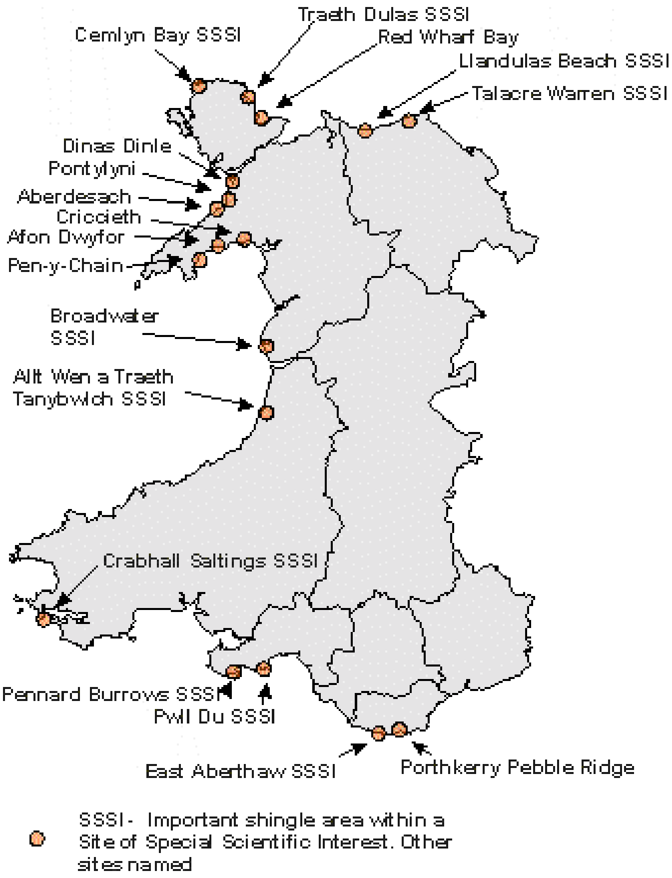


Figure 04-01b Important vegetated shingle sites in Wales

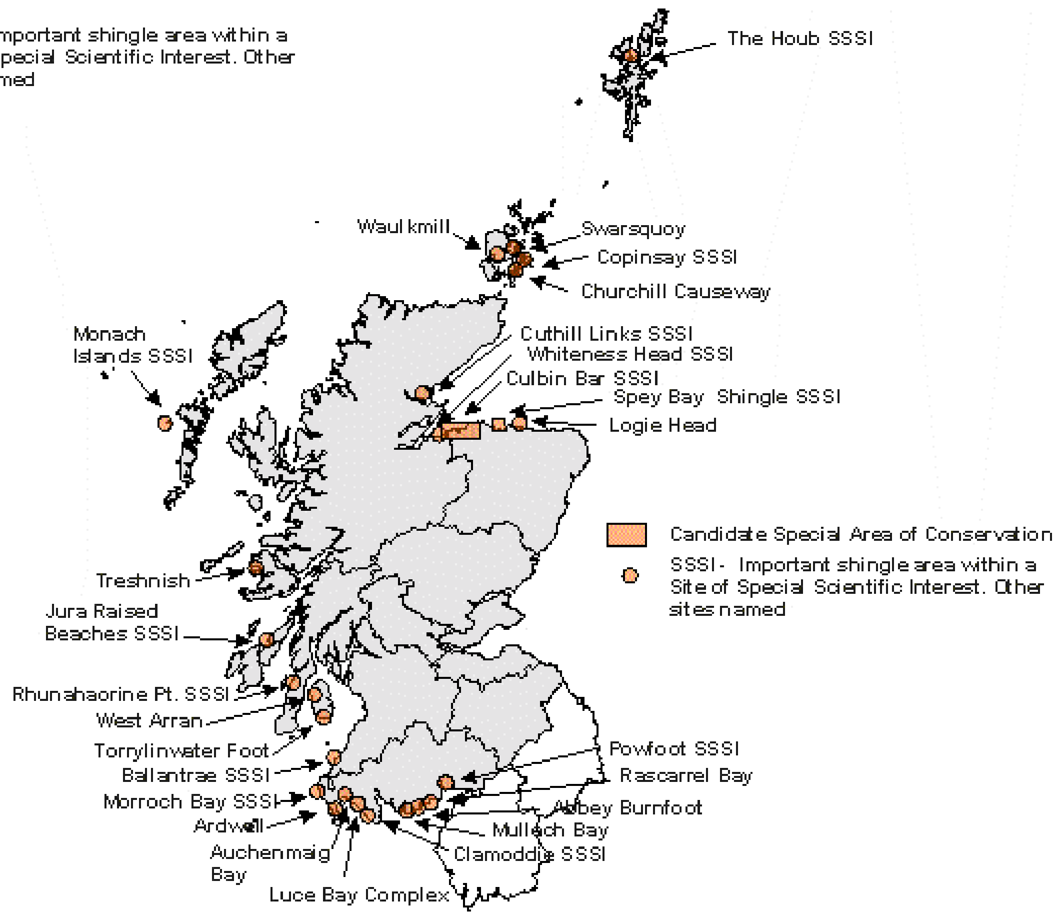


Figure 04-01c Important vegetated shingle sites in Scotland

Chapter 05 Pressures and threats

Introduction

Shingle beaches by their nature are ephemeral and prone to sometimes massive and rapid change. As has been described in Chapter 02 the plants and animals which survive there are therefore usually tolerant of periodic disturbance. However, once the ridges become stabilised and out of reach of storm waves, a gradual build-up of interstitial sediment takes place and with it the development of more mature and stable vegetation. At this stage the communities, which become established are adapted to highly stressful conditions involving lack of water and substantial temperature fluctuations not dissimilar to those of some deserts. Although such species are highly tolerant of such conditions they are much more sensitive to disturbance.

The most widespread and damaging activity is the removal of gravel either from the beach or more significantly the structure itself. Gravel extraction destroys the vegetation and associated fauna which, due to the complex structure of the matrix in which these communities develop, is impossible to re-create. Infrastructure development is equally damaging and the simple act of driving a vehicle across a series of mature shingle ridges can cause damage which remains visible for many years until the next 'natural' change takes place and the structure is reformed.

The Habitat Action Plan summarises the problems facing the conservation of this priority habitat under the European Union Habitats and Species Directive as follows:

"2.3 Exploitation. *Shingle structures have been regarded as a convenient source of aggregates, and have been subject to varying degrees of extraction resulting in severe alteration of morphology and vegetation (e.g. Dungeness and Spey Bay) or almost total destruction of major parts of the feature (e.g. Rye Harbour). Industrial plant, defence infrastructure and even housing have been built on shingle structures (e.g. Dungeness, Orfordness, Spey Bay), destroying vegetation and ridge morphology. At Dungeness water is abstracted from the groundwater system; there is some evidence of drought stress on the vegetation, but it is difficult to distinguish the effects of water abstraction from those of gravel extraction*."

Thus there are a number of key areas where pressures on shingle beaches and structures have caused significant, direct and irreversible loss of shingle habitat (nearly 100% in the case of the Crumbles, see Figure 05-02 below and more than 40% of the surface of Dungeness, Annex 05). These losses and the impact of activities associated with coastal defence have had a major impact on the habitats and led in part to the need for this guidance manual. Other activities alter, rather than destroy the habitat and some of these changes can be reversed, offering opportunities for habitat restoration. A summary of the most significant issues is given below:

1. aggregate excavation both:
    - onshore;
    - offshore [**Dealt with in Chapter 03**].
2. habitat loss due to structures built on the surface shingle including:
    - infrastructure development, industry, housing and roads;
    - power stations including nuclear facilities;
    - military use, car parks, airfields;
3. sea defence and coastal protection [**Dealt with in Chapter 03**] involves creating:
    - groynes and artificial breakwaters;
    - reprofiling fringing beaches;
    - beach nourishment.

4. recreational use involving:
    - trampling, destroying vegetation and ground-nesting birds;
    - disturbance of nesting birds;
    - boat mooring;
    - fishing;
    - vehicle access.
5. other issues:
    - grazing (loss of rare plants);
    - water abstraction;
    - military training;

Habitat loss - excavation

Gravel is a rare material highly desired by the construction industry. As a result, large quantities are obtained by extraction from both onshore and offshore deposits. The former provide a ready source of easily accessible material but can cause long term damage to the surface shingle. The latter is more difficult to exploit and impacts on the marine environment can also be significant. Knock-on effects on ,in particular, coastal shingle beaches and structures should also be considered.

Onshore excavation

The most widespread and damaging activity is the removal of gravel either from the beach or more significantly from within the body of the shingle structure itself. Deep excavations create a void which can rapidly become filled with water, creating gravel pits (Figure 05-01). Several large sites have been adversely affected in this way. Dungeness, the largest shingle structure in Great Britain covering some 1600 ha of exposed surface, is the most disturbed site with some 43% of its surface affected by a wide variety of adverse impacts. These range from relatively minor incursions into the intact vegetated shingle ridges by vehicles (which break up the vegetation), to the complete destruction of the vegetation and ridge structure through the extraction of gravel (Fuller 1985).

Figure 05.01 Dungeness, Kent. Gravel extraction and the resulting gravel pit in the body of the shingle structure. Note the nuclear power stations in the background.

A similar and even more complete loss has overtaken the Crumbles in southern England where a 160 ha site, immediately east of Eastbourne, has been destroyed. Building works, including erection of houses and gravel extraction have destroyed most of the shingle surface and the remaining vegetation on intact ridges has been broken up by heavy visitor pressure. Figure 05-02 depicts the situation at Pevensey Bay Shingle (the Crumbles), southeast England, showing damage to shingle ridges from buildings, gravel extraction and recreation.

Extraction may not always be so destructive. Shallower excavations, which do not reach the water table can, if left undisturbed become recolonised. In some cases this may increase local biodiversity of the site, as species associated with damp to wet conditions become established (see parts of Dungeness and the coastal river shingles at Kingston, Scotland, Annex 08). Such changes, however, must be viewed in the light of the fact that coastal vegetated shingle cannot accommodate further losses, without significant impacts to its overall extent and distribution.

Shingle beaches may also suffer loss through localised excavation. This may be by individuals who remove small quantities for personal use or larger scale operations for sale. It has not been possible to find information on the extent of these activities, which are both illegal, thus assessing their impact has not been possible. Whatever the cause the removal of surface shingle destroys the vegetation and associated fauna, further degrading the habitat.

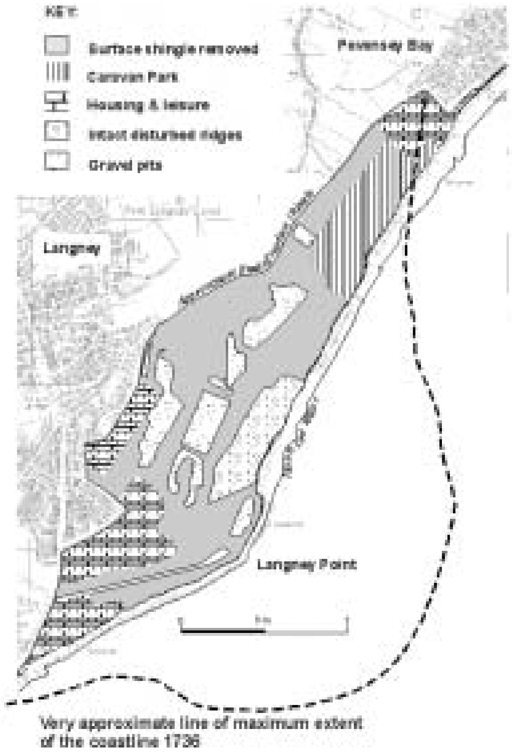


Figure 05-02 Pevensey shingles (the Crumbles) showing the extent of the destruction of the surface shingle. The limit of the original shingle structure which has been eroded over many years. Another example of a 'coastal squeeze'.

A similar story can be told for many other areas. For example, much of the surface shingle west of Rye Harbour, again in southern England, has also been destroyed by gravel extraction. Kingston shingle, which lies to the west of the River Spey in Scotland, is another important area where shingle extraction destroyed much of the ridge structure, probably during the 1940s (Annex 08). Though less information is available French sites have been similarly affected "The small sand and gravel ridges of Basse Normandie (south of the Seine) have in large part been urbanised" (Géhu & Géhu-Franck, 1979). Other sites in France such as Cayeux sur Mer (Côte d'Opale), Sillon de Talbert (one of three locations on the north Brest peninsula) and two more to the south have also been degraded and diminished from gravel extraction.

Offshore aggregate extraction

Offshore aggregate extraction is not an obvious and direct pressure on coastal shingle formations. However the extent of gravel extraction offshore poses a potential threat if it diminishes the supply of material onshore. The precise effects are difficult to determine. The issue has been covered in some detail in Chapter 03, sea defence and coastal protection issues.

Habitat loss to infrastructure

Shingle structures have suffered much damage both in the UK and abroad from direct destruction of the surface shingle. Infrastructure development includes buildings such as housing, recreational facilities, access roads and railways and in a few instances nuclear power stations (Dungeness) and military buildings (Orfordness). Even the simple act of driving a vehicle across a series of mature shingle ridges will cause lasting damage, which remains visible for many years. Several large sites have been adversely affected by gravel extraction and other damaging activities; these are included in the site studies annexes.

Industry, housing and roads

Major industry is not normally built on shingle. The area of land is often too small or too remote. However there are numerous examples of housing and other buildings built on the more stable upper shores as in Pevensey Bay, East Sussex; Shingle Street, Suffolk and Lydd-on-Sea, Kent (Figure 05.03). Other areas may be built on shingle such as the town of Brighton (where there is a substantial shingle beach) but it is not clear the extent to which these have resulted in major losses of habitat. At Shoreham Beach a village was developed for the film industry on the spit in the early 20th century. This has now expanded to take over much of the shingle spit other than the foreshore. At Pontlyfni, Gwynnedd, much of the northern part of a high quality shingle beach has been lost to the construction of a sewage works (Randall, Sneddon and Doody 1990).

Figure 05.03 Lydd-on-Sea, Kent. Housing and a road interrupting the transition from shingle beach to more stable vegetated shingle ridges. Note the parallel ridges on the right and *Crambe maritima* the large glaucus plant in the foreground.

Power stations including nuclear facilities

The need for a coastal location for power stations, providing access to cooling water, has led to the construction of some substantial facilities on shingle. The most notable in the UK is the nuclear power station complex on Dungeness, although there are other examples of development on or near other coastal and some shingle sites (e.g. Sizewell, Suffolk, East Aberthaw in South Wales and Hinkley Point, Somerset). Whilst power station construction leads to an obvious loss of the surface shingle, such facilities can also result in additional damage. This is particularly true at Dungeness where access roads, power lines, vehicle access associated with their maintenance and ironically attempts to improve the biodiversity of the adjacent shingle habitat have all caused loss of, or damage to the shingle surface and its wildlife.

A secondary and in some ways more important consequence of building a nuclear power station on shingle, lies in the need to retain buildings in situ for many years. In the case of Dungeness this is particularly important as it has been built in an area where the shingle beach is attempting to move eastwards as it has done for centuries. This has resulted in the need for a continuing cycle of beach nourishment with material being moved from the beach to the east of the building and transported to the west where it is deposited back on the beach. The natural process of longshore drift then carries the material back to the east. [Annex 05, Dungeness]. This process also prevents anything other than the rudimentary foreshore shingle communities from developing because of the continued disturbance of the shingle. In this sense it is similar in effect, to beach nourishment and reprofiling.

Military use, car parks and airfields

Most shingle structures are not big enough to accommodate major military use for the provision of airfields; the exceptions are Orfordness and Dungeness. At Orfordness military activity has destroyed, or seriously disturbed a major part of the site (see site issues report). At Dungeness both military use and an airfield have also affected the area of surface shingle (see site issues report). At many other sites (unquantified) formal and informal parking has caused loss or compaction of the surface shingle. This is especially the case at many of the shingle beaches in Scotland. This problem is examined in detail for the Solway coast by Randall (2001). The reports prepared by Sneddon & Randall (1993 a, b, and 1994 a, b) also contain a considerable amount of information about pressures on the sites included in their study.

Sea defence and coastal protection

The construction of coastal defences can have potentially serious implications for shingle habitats. In summary defence works may result in changes to the movement of material both on and offshore and alongshore. This has important consequences for the natural dynamics of the habitat. The structures themselves can also lead to a loss of overall extent in habitat. Beach nourishment, feeding and re-profiling are also significant activities, the former having both positive and negative impacts on the habitat, the latter almost always having negative effects. Beach recycling represents an ongoing negative impact on many designated sites. (The issues surrounding these activities are discussed in some detail in Chapter 03 on flood and coastal defence.)

Recreational use

Recreational activities can affect both shingle beaches and structures. In places in Baltic Germany and Norway extensive ‘flintstone fields’ occur extending inland to *Calluna* heathland and birch/juniper scrub similar to those in Kingston, Scotland. Several of these have suffered severe recreational damage. On the most mature structures even relatively small incursions into the surface layer may remain visible for many years. The impact of off-road vehicles ranges from relatively minor incursions into the intact vegetated shingle ridges, which break up the vegetation, to prolonged use and total destruction. Wheel tracks created by vehicles during the 1940’s at Dungeness, for example, are clearly visible today. Many of these actions can be cumulative leading to long term and irreparable damage to the shingle surface. Both recreational activities may also have an impact on other important features such as bird nesting survival and behaviour.

Several Scottish sites, including Rhunahaorine, west Arran and Auchenmalg have official camping and caravanning sites either on, or immediately adjacent to the shingle. Many of these sites are located on raised beaches or forelands and therefore damage may occur on the more terrestrial parts of a site.

Vehicle access

As already indicated above, driving vehicles onto shingle causes considerable disruption of the surface. Vehicles can create swaths of damaged and destroyed vegetation. The structure of the shingle may be completely destroyed and its ability to hold water and hence support plant and associated animal life. Elsewhere, beaches and smaller sites can be greatly affected by uncontrolled vehicle access. Even where the surface remains intact, compaction can lead to changes in drainage and plant community composition. Sites on the west coast of Scotland, for example, are often readily accessible from the road and as a result have suffered from vehicular damage. This takes the form of track marks across the sites with destruction of vegetation on areas which are habitually used for parking.

Trampling

Some of the most susceptible communities on shingle structures are those with abundant lichens. These slow growing species are very sensitive, especially in dry weather, when they are particularly easy to damage. Even the passage of one person walking (or cycling) on an established vegetated shingle ridge can leave ‘footprints’, which may never be repaired. Compaction of the surface may also affect the seed bank making it more difficult for some species to germinate. Control of visitors at Orfordness has helped to rehabilitate communities of the rare *Lathyrus japonicus* (Annex 06).

Disturbance of nesting birds

In areas where ground-nesting birds, including terns occur, then potential damage to nests and their eggs is obvious. Even where direct destruction of nests does not take place repeated disturbance may discourage or displace nesting species. As several of these (notably the terns) are rare and protected and depend on isolated sites where their eggs blend in with the shingle substrate, impacts can be severe.

Boat mooring (including fishing)

Shingle beaches are popular areas for providing access for small fishing boats. Pulling boats up a beach, as frequently occurs on the south coast can lead to loss of vegetation or surface damage. The process of hauling the boats onshore, whether by fixed winches or tractors can cause localised damage to the shingle, which can vary in severity depending on the size of vessels and the intensity of use. Rhunahaorine has a fish farm on the northerly part of the foreland, which creates pressure on that site.

Other issues

Grazing (loss of rare plants and invertebrates)

Grazing of domestic stock is a relatively restricted activity even on the larger shingle sites. The sparseness of the vegetation and limited growth rates combine to make the available herbage limited and unpalatable. Hares may frequent these areas and are especially plentiful on Orfordness. Only in Scotland where sheep and cattle from adjacent areas can have access to beaches are they likely to have adverse effects - in this case the loss of *Mertensia maritima* a rare plant of beach shingle in the north. (Figure 05-04, Randall 1988).

At Rhunahaorine Point, western Scotland heavy grazing of much of the foreland by cattle and sheep with relatively high stocking levels has reduced the area of heath. This is not only because of the direct effect of grazing on the vegetation but also the indirect effect of the fertilisation it supplies to an otherwise nutrient-poor environment. Rhunahaorine also has a fish farm on the more northerly part of the foreland. Grazing pressures can also reduce structure and diversity of the vegetation and with it losses of invertebrate fauna.

Figure 05-04 Cattle grazing *Mertensia maritima* Treshnish beach Isle of Mull

Arable cultivation

At several raised shingle beach sites in Scotland the rear part of the beach has been reclaimed for arable agriculture with the total loss of topographical features and the more terrestrial components of the vegetation. A classic example of this is the site at Claymoddie (Figure 05-05 below), which is otherwise one of the most undisturbed along the Solway Firth (Randall 2001). Much of the land on the lower, younger ridges at Rhunahaorine has been reseeded with agricultural leys, which has resulted in a loss of natural vegetation. Arable farming also occurs on the raised gravel beach at Browndown, Hampshire (Randall et al. 1996).

Figure 05-05 Loss of shingle to arable cultivation at Claymoddie, Dumfries and Galloway

Plantations

The major loss of natural vegetation on the shingle at Kingston Shingles has resulted from the planting of pine on the western part of the site (Annex 08). This has not only caused a direct loss of native vegetation but also has major implications for species composition in undisturbed areas where seedlings of *Pinus sylvestris* have established. A similar problem is occurring on Culbin Bar where seeding *P. sylvestris* have spread from the plantation on the mainland (Annex 09).

Water abstraction and reservoir use

Water abstraction can lead to lowering of the water table and saline water intrusion. This is an issue at only one site, Dungeness where water is used for domestic purposes. The shingle aquifer here was first used to supply water to Littlestone-on-Sea at the end of the nineteenth century. Abstraction has continued ever since and rates have increased substantially in the last 50 years leading to some problems with saline water intrusion (Annex 05 and Chapter 02, section on hydrology, page 13).

Dumping of waste

Because the value of shingle areas is not always apparent to some members of the public, they are frequently used as dumping grounds for rubbish. Kingston Shingles, Grampian has been used as a tyre dump and Philip and Mary, Dumfries and Galloway has been severely damaged by the dumping of waste road metal. In several sites such as Ballantrae, Strathclyde and Shore Cottage, Dumfries and Galloway the dumping of farm organic waste has caused local eutrophication.

Military training

The direct effects of habitat loss due to military infrastructure are visible at Dungeness (Annex 05) and Orfordness (Annex 06). In at least one part of Dungeness, the undulating nature of the ridges was considered an obstacle to military training. These were flattened and any vegetation destroyed. The presence of a 'holly wood' was respected and individual bushes now survive on a flat shingle plain (Figure 05.06). The Training Camp at Browndown has also witnessed significant damage to the shingle vegetation, but sympathetic management by the MOD in conjunction with the Browndown Conservation Group has resulted in a more careful policy being adopted (Randall et al. 1996). The fragile lichen communities are readily damaged by military use and recovery can be very slow an important consideration.

Figure 05.06. The 'holly wood', Dungeness, Kent. Note the bare, flat nature of the intervening shingle (and the 'wind-pruning' of the holly bushes).

References:

Fuller, R.M., 1985. An assessment of the damage to the shingle beaches and their vegetation. In: *Dungeness: ecology and conservation*. Eds. B. Ferry & S. Waters, Focus on nature conservation, No. **12**. Nature Conservancy Council, Peterborough, 25-42.

Géhu, J.M. & Géhu -Franck, J., 1979. Sur la vegétátion nord-Allantiques et baltiques à *Crambe maritima*. *Phytocoenologica*, **6**: 209-299.

Randall, R.E., 1988. *A field survey of Mertensia maritima (L.) Gray, Oysterplant in Britain during 1986 and 1987.* Contract Survey Report Series, **20,** Nature Conservancy Council, Peterborough.

Randall, R.E., 2001. *Solway Firth: inventory of shingle vegetation, [CD-ROM],* Commissioned Report, Scottish National Heritage, Edinburgh.

Randall, R.E., Sneddon, P. & Doody, J.P., 1990 *Coastal shingle in Great Britain: a preliminary review.* Contract Surveys, No. **85,** Nature Conservancy Council, Peterborough.

Randall, R.E. & Fuller, R.M., 2001. The Orford shingles, Suffolk, UK: evolving solutions in coastline management. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, pp. 242-260.
Randall, R.E., Sneddon, P & Aitcheson, J., 1996. Plant Communities of Browndown South Training Area. *Sanctuary,* **25,** 29-30.
Sneddon P, & Randall R.E., 1993a. *Coastal vegetation shingle structures of Great Britain: Main Report*. Joint Nature Conservation Committee, Peterborough.
Sneddon P, & Randall R.E., 1993b. *Vegetated shingle structures survey of Great Britain: Appendix 1 - Wales*. Joint Nature Conservation Committee, Peterborough.
Sneddon P, & Randall R.E., 1994a. *Vegetated shingle structures survey of Great Britain: Appendix 2 - Scotland*. Joint Nature Conservation Committee, Peterborough.
Sneddon P, & Randall R.E., 1994b. *Vegetated shingle structures survey of Great Britain*: *Appendix 3 - England*. Joint Nature Conservation Committee, Peterborough.

Chapter 06 Habitat guidance (management and sea defence issues)

This chapter is concerned with two areas of guidance:

1. management of vegetation in a more traditional sense including the control of invasive species, grazing etc. and the adverse effects of human use, notably for recreation;
2. the guide identifies problems and opportunities associated with sea defence maintenance including recharge schemes.

Before considering any guidance on habitat management or restoration a primary concern must be the conservation of the remaining areas of relatively intact and undisturbed areas of vegetated shingle. All damaging activities must be prohibited on all sites where important areas of this extremely rare habitat exist. The UK has a particularly important role to play here by virtue of the extent of the shingle (gravel) banks that occur here and their world significance (Chapter 01).

Management, including vegetation management

Before discussing the management of shingle in relation to sea defence operations, a more general discussion of management is appropriate. Many of the plant communities supported on shingle are unique to this substrate and this must be taken into account for the management of vegetated shingle. In particular whilst pioneer communities of vegetated shingle can begin to recover naturally from damage within a few years, as long as the seed bank remains intact and further damaging activities are halted, more mature communities will not.

The development of unusual bryophyte - and lichen-rich communities, unique to shingle (Lambley & Hodgetts 2001) has high conversation value. These and other closed-turf communities are unlikely to recover quickly as the lack of soil development, on many shingle substrates mean the vegetation requires many decades to reach maturity. Some can take hundreds of years to establish. It is important that these types of vegetated shingle communities are not damaged, as they are extremely rare.

Traditional forms of management

Varying degrees of management intervention are required to conserve differing successional stages of shingle structures. Though unlike other coastal habitats (notably saltmarshes, sand dunes and sea cliffs) where grazing provides a significant determinant of the plant and animal communities, which develop; for vegetated shingle this influence is relatively limited. Minimum management is required to maintain scrub or woodland communities on shingle but heath, grassland and pioneer communities may require more active management. The presence of lichen heath is indicative of remote areas with limited public access (e.g. Orfordness, Annex 06; lee slopes of Chesil Beach). To allow the development of lichen or moss-rich heath, access should be restricted to such areas, thus protecting the fragile structure of these communities. *Calluna vulgaris* heath on the other hand may require low-level grazing management to maintain age and species diversity.

Edaphic and environmental conditions peculiar to shingle seem to serve as natural limits on cover for *Calluna* (and other plant communities). Grazing management may be all that is needed to restrict scrub invasion on grassland and to a lesser extent heathland. However, following cessation of grazing pressure, maintenance of a variety of grassland (and a few heathland) communities may require clearance of invasive scrub and heath. Reintroduction of grazing may then be required to maintain certain grassland assemblages such as the herb-rich *Holcus lanatus* grasslands of Arran. It must be remembered that, away from the drift-line, shingle structures are usually very nutrient-poor so that the introduction of grazing herbivores on traditionally ungrazed sites will almost always cause vegetation change both as a result of structural effects and nutrient enrichment and is potentially damaging (see for example Rye Harbour, Annex 04).

Soil conservation on shingle is also highly significant. Mechanical clearance of scrub invasion as has been carried out at Slapton (Annex 02) and Rye Harbour (Annex 04) will bring about soil removal and a competitive advantage for ruderal species rather than earlier stages of shingle succession. Because of the long timescale of soil development on shingle, fire, whether accidental or deliberate can affect the full depth of the soil including any seedbank. Locally, ground nesting birds (notably gulls) can also influence the vegetation composition by increasing levels of nitrogen in what is a nutrient poor substrate (see for example Annex 06, Orfordness).

Summary guidance - traditional management

Traditional management notably by grazing animals is a requirement for the maintenance of some more mature grasslands and heath. However, because of the low productivity of these areas introduction of grazing where none has occurred traditionally should be avoided. Limited intervention by way of scrub control may be appropriate in a few cases.

Control of visitor and other pressures

It almost goes without saying that the first requirement in the conservation of any shingle beach or structure must lie in its protection from damaging work. This will include the building of any structure which destroys and covers the surface shingle. Equally damaging is gravel extraction (see for example Dungeness, Annex 05). On top of these activities further pressure is put on areas of shingle by public use. Trampling, in particular, can compact the fragile substrate and damage the vegetation. Access to certain sites should be restricted to boardwalks rather than footpaths. All of the activities causing loss or damage to the surface shingle should be avoided as repair and restoration is often difficult. Solving these problems involves a combination of physical control measures and education.

Public access

The fragile nature of the shingle habitat makes it important that the public are directed in their movement as much as possible. Public access maps should be produced and explanations given why general access is not recommended. One successful way of limiting general public access is to provide an information board and a nature trail from the nearest parking site. Public access is limited to a certain extent by car-parking provision but in some areas off-road cycling and the illegal use of motorbikes and four-wheel drive vehicles over vulnerable areas of vegetated shingle may cause irreparable damage. Where this occurs this can be prevented by forging links with the local police and where physically possible, such as at Orfordness (Annex 06), access points can be blocked. Once the damaging activity is prevented, successful regeneration of rare plants can take place. However, in areas where access needs to be provided for emergency coastal defence works, it can be difficult to restrict access.

Trampling

Because of the succulent nature of many of the pioneer plants they are particularly susceptible to trampling. Well situated boardwalks across the backshore to the beach front are an efficient means of reducing this problem, as proposed for Dungeness (Annex 05). Locations where this has been successfully carried out are Walmer, Kent and Portland Harbour at the eastern end of Chesil Beach cSAC.

Off-road parking/unauthorised dumping

At Dungeness the judicious positioning of small ‘grips’ or dykes by the roadside or placing bollards protects rare plants growing near the road. Along the Luce Bay shingle, in Scotland, designated access points for parking have been improved while other possible vehicle access points have been made more difficult to use.

Reducing recreational pressures

Trampling disturbance is significant on shingle due to recreational pressure; sometimes grazing animals can also influence the substrate in this way (e.g. Randall 1977). This is particularly true among pioneer and lichen-rich communities which have a very long recovery time. Regional distribution patterns exhibited by some shingle communities highlight the importance of regional management policies for this habitat. In Britain the Moray Firth emerges as a particularly distinct floristic unit, as do the pioneer communities of the south east which are threatened by recreational pressure.

Signage

Signage and information boards such as those employed at Pagham and Rye Harbours (Annexes 03 & 04 respectively) are a significant element in helping to control damaging activities on sites used extensively by the public. Whilst this may not stop damage, especially that undertaken as a wilful act of vandalism it does go a long way to alleviate some of the worst aspects of damage. When coupled with educational activities a body of knowledge and respect for the areas of interest can be built up.

Environmental education strategy

Shingle sites frequently have a ‘wow’ factor because of the dynamic nature of the site, the classic nature of the geomorphology and the unusual vegetation communities and wildlife that are present. They are important locations both for formal education (school visits) and for outreach to the general public. Where possible leaflets and interpretation boards should be produced and links made into local and regional networks.

The Nature Coast Project and East Sussex Coastal Biodiversity Project have produced an awareness raising/educational video on vegetated shingle, entitled “Life on the Edge - wildlife of a shingle beach”. It is only 7 minutes long but shows what an extraordinary and attractive habitat vegetated shingle is. It also shows the problems it faces. This video would be ideal for use at meetings, training courses, presentations etc or as a continuous display in a reception area/ visitor centre etc.

Summary guidance - controlling damaging human activities

These problems can best be solved by education of local people about the wildlife value of shingle sites. The variety of approaches summarised above can be employed in different combinations, at different times and with greater or lesser emphasis. A key element lies in the approaches being as flexible as the habitats and species which they are trying to protect.

Nest disturbance

Temporary fencing

Nesting sites for certain shingle species such as terns and oystercatchers are typically in beach locations much frequented by walkers and their dogs. Work at Rye Harbour LNR (Annex 04), among other sites, has shown the value of temporary fencing in these locations to reduce nest disturbance.

Identification guides

As with plants, a great deal of disturbance is accidental and unintentional, even by scheduled workers in shingle areas. Laminated identification guides of bird species and their eggs/nests can be provided for machinery operatives and others working in ‘at risk’ areas.

Seasonal wardening

Because of the dynamic nature of tern nesting patterns, it may be necessary to consider temporary wardening of some sites, as occurs at Blakeney Point.

Summary guidance - protecting nesting birds

Simply delimiting an area sensitive to nesting birds can provide the necessary protection in most places and for most of the more sensitive periods of the year. Identification guides and seasonal wardening also play their part.

Pest control

Pest control is a very sensitive issue and what might be considered pests at one site may be harmless or even regarded as an asset at another. Hence any form of control must be carefully researched before implementation, always remembering that there is a legal requirement to control some pest species (Ground Game Act 1880 as amended 1906, Weeds Act 1959). Be aware of Health and Safety and Control of Substances Hazardous to Health Regulations 2002 (COSHH) which require employers to control exposure to hazardous substances to prevent ill health. Pest control should take place in conjunction with Habitat Action Plans, Biodiversity and Species Action Plans.

Control of alien plants

Because shingle structures are usually ‘open habitats’, it is easy for alien species to invade and establish in those areas where the abiotic environment is less harsh. This is particularly the case on the south and east coasts where houses and gardens abut the shingle, often resulting in enrichment of the habitat and the spread of non-native garden species. This can often be a sensitive issue as local people enjoy the showy species and some such plants can be particularly important for invertebrate species, e.g. red valerian *Centranthus ruber*.

At Pagham LNR (Annex 03) there are plans, in conjunction with English Nature, to determine the most effective way of controlling a particular alien species by establishing trial plots / quadrats to be treated in a variety of ways, including hand pulling, herbicide treatment and incineration. As the work will be carried out adjacent to houses, awareness-raising among the local residents about the necessity for selective vegetation control will form a fundamental part of the project.

Summary guidance - controlling invasive alien plants

The following techniques are suitable:

- *Senecio jacobaea* (Annex 03 Pagham). Pull individuals in May-June or spray clumps with Clopyralid in April & September;
- *Cirsium arvense.* Top in August or spray in May-June with Clopyralid;
- *Urtica dioica.* Strim when required or spray from April with Glyphosate.

Control of animals

Rabbits - Shooting or ferreting both give limited control. Fumigation by trained contractors is recommended so long as no other species are sharing the warrens. An alternative is to fence those areas in need of protection with wire or electric cable (Annex 04, Rye Harbour). Recommended wire is 19 gauge with 31 mm mesh.

Mink, **brown rat** and **fox** may all become pests where ground-nesting birds are important. Mink are best trapped in early spring, foxes shot from August to February and rats poisoned all year round. Contractors should be used and due care taken that other species are not affected.

Corvids can be trapped in the breeding season and shot at other times (Larson traps were used at Pagham Harbour, Annex 03).

Summary guidance - controlling animals

Traditional approaches of shooting, gassing and poisoning may be applied, subject to the normal procedures for undertaking these operations.

Harrowing

Cultivation with tractor and harrow has been used as a technique to knock back vegetation in areas where rampant vegetation is detrimental to ground-nesting bird species (see Annex 04, Rye Harbour). Bare shingle is a favoured nesting habitat for several rare birds, notably terns; it can also host some rare and highly specialised plant communities and their associated invertebrates. Any decision to remove vegetation must be taken in the light of a full understanding of the conservation consequences including the geomorphic implications of removal of sediment from the shingle supply location.

This management technique also highlights another central dilemma for conservation particularly on vegetated shingle sites i.e. **should management be for nesting birds or vegetation**? Although successful in maintaining open areas of shingle it also results in an unnatural appearance to the topography and may seriously disturb plants and invertebrates that are also important to the site.

Summary guidance - maintaining un-vegetated open shingle surfaces

Re-creation of island sites such as Tern Island at Pagham Harbour (Annex 03) can clearly be effective for the protection/relocation of tern nest sites.

Caution: Problems associated with location of the new construction, implications for sediment regime and the balance between the values of these areas for birds as opposed to other interests need to be addressed. NB There was a problem of plant growth on the newly created tern island at Pagham partly due to the importation of shingle, which already included an amount of small fraction material and seed of ruderal species.

Coastal defence

Providing guidance for coastal defence operations presents a complex series of issues. One of the most obvious is the provision for reducing the impact of engineering works on shingle beaches and structures themselves, as well as any vegetation and associated species. Where reprofiling is undertaken on a regular basis this will prevent the establishment and growth of anything other than the most ephemeral of plant communities and the regular movement of heavy machinery can compact the shingle. At the other extreme beach nourishment or the erection of some coast protection structures (groynes and breakwaters) can help to create conditions where more stable forms of shingle develop and with it typical vegetated shingle communities. However, beach nourishment can be detrimental in increasing the amount of fine sediment within the shingle, hence changing the conditions required by pioneer species. Between these two extremes lie a series of options for reducing or avoiding damage and destruction of this rare habitat.

Issues surrounding the implications of offshore gravel extraction (which may be used for beach nourishment) on the stability of the shoreline are considered in Chapter 03. Chapter 03 also discusses the value of shingle beaches and structures as sea defences in their own right. It is this value which leads to an increasing recognition that allowing the sea to reprofile beaches and move structures landward is as effective a sea defence strategy as one which seeks to retain the beach in its current location. The case of Porlock (Annex 01) lends credence to this approach. The issues surrounding the protection of the Slaughden sea defences at Orfordness (Annex 06) and the reappraisal of the Cley-Salthouse scheme (see Annex 07 and the Living with the Sea Executive Summary included as Annex 07a) are important to the wider debate about managed realignment as an appropriate policy response to eroding shingle coastlines.

In the event that it is decided that intervention is required and acceptable on cost-benefit analysis then there are many ways in which the operation of the works can be managed to reduce the environmental impact. These are considered next.

Conservation during coastal defence engineering works

Vegetated shingle can be damaged in a number of ways when coastal defence and other works are being carried out on the beach. It should be noted that damage could be done not only by vehicles and machinery but also by trampling, especially on the older communities.

Damage can be in a variety of forms:

- physical damage to plants;
- physical damage to shingle communities (including pioneer, intermediate, closed-turf, moss and lichen etc);
- disturbance to breeding birds;
- movement and/or compaction of shingle;
- destruction of the seed bank;
- imported marine-dredged shingle causing nutrient enrichment;
- imported shingle of unsuitable type/size[1] for vegetation development;
- nutrient enrichment through mixing of the shingle and soil layers.

Practical measures to prevent damage or to offset unavoidable damage

There are a number of measures that can be taken, both before the commencement of coastal defence operations and while the work is being carried out. It is important that all contractors are informed in advance of the procedures they must follow to limit any impact on the vegetated shingle.

Preventative measures that can be taken are:

- brief the works unit/contractors before commencement of work to ensure that each individual is clear about the measures being taken;
- require contractor to appoint environmental supervisor to oversee environmental issues (as condition of planning approval);
- limit the number of beach access points for vehicles and if possible, ensure vehicles keep to a limited track;
- clearly define beach access points avoiding any vegetated areas where possible. If the loss of some vegetation is unavoidable, ensure that it is limited to those communities which will be able to re-establish in the relatively short term;
- demarcate any particularly valuable or important area of vegetation prior to commencement of operations to ensure its protection. Use old groyne timber, tape or any other highly visible barrier laid around the perimeter. Keep all vehicles, machinery and people out of the marked area;
- if possible, wash imported marine-dredged shingle to prevent nutrient enrichment;
- if possible, use imported shingle of a suitable type/size[1] for vegetation, at least in those more stable areas where plants are likely to recolonise;
- if possible, limit vehicle movement along the beach to below High Water Mark to prevent impact to vegetation or compaction of shingle on the ridge;
- limit work to the period outside the bird-nesting season. Shingle nesting birds generally nest between March and August;
- include information about the shingle vegetation protection measures that are being taken, in any interpretation on the site.

Trenching on shingle

Experience at Dungeness (Annex 05) has shown that demarcating significant shingle vegetation along the line of any trenching activities with stakes and brightly coloured plastic rope and highlighting the least damaging route ahead of contractors pays great dividends in avoiding disturbance.

Vehicular access

Unprotected vehicular access onto shingle will virtually always cause long-term damage. However, access for water authority or other utilities vehicles will often be necessary. This can be mitigated by the use of temporary trackways across the surface which may well result in bleaching of the vegetation but will markedly reduce geomorphic damage and allow the vegetation to recover in the short to medium term (Dungeness, Annex 05).

Work programming

Work programming is very important. Where possible both sea defence and management works should be carried out at times when disturbance of plants and wildlife are at a minimum. Most vegetation will be least disturbed out of the growing season. Areas of significance for ground-nesting birds such as terns should be avoided even for survey work until reproduction is complete.

[1] Land-sourced shingle tends to have sharp edges and be more angular than marine-sourced shingle, making it less suitable for coastal shingle vegetation. Pebble size is very important in determining which plants can grow. Pebbles with an average size greater than 8cm diameter are normally unsuitable for vegetation. Shingle species generally prefer an average diameter of up to 4cm. Patches of different sized pebbles are the most desirable as they allow a mosaic of vegetated and bare shingle areas to develop. A variety of pebble sizes will also allow a greater number of species to colonise and a series of different matrices to be held in situ.

Coastal defence guidelines and vegetated shingle identification guide.

Many of the above points are contained in the “Good Practice Guide for working on Vegetated Shingle beaches” produced by the West Sussex Vegetated Shingle Project (http://www.pebbledash.org.uk) to help those planning work on shingle areas. In addition, an A5, waterproof, colour identification guide has been produced jointly by the West Sussex Vegetated Shingle Project and East Sussex Coastal Biodiversity Project to enable easy identification of the shingle communities to be protected, by contractors working on site. Similar guidance should be made available for other areas of significant vegetated coastal shingle. These guides have been distributed to all Environment Agency offices nationally with shingle coastlines, and have been widely distributed around the south-east beyond East & West Sussex via the two relevant coastal groups and Standing Conference on Problems Affecting the Coast (SCOPAC).

Emergency works

It is possible to provide guidance, as above, which will help to overcome the damage to shingle habitat during planned operations. However, it is much more difficult to prevent damage when emergency repair work takes place, especially when storms occur and property (and life) is threatened. There are two other points which are important:

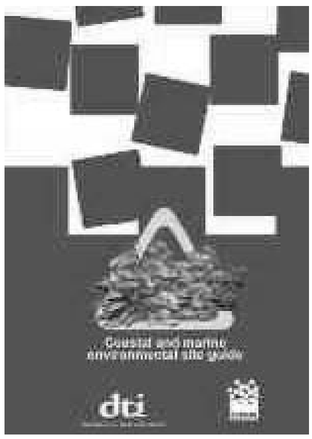
Summary guidance - emergency sea defence operations

1. early identification of potential problems, presence of stable mature shingle vegetation, rare plants or animals or breeding birds will help ensure that these interests are taken into account;
2. under emergency circumstances not only is good, accessible information required on the nature of the interest likely to be affected, but this also needs to be available to those undertaking the work. This requires contingency planning including the establishment, in advance, of close working relationships with relevant utility companies, regulatory and other authorities (especially local Environment Agency staff).

Construction Industry Research and Information Association (CIRIA) - the CIRIA guides

The Construction Industry Research and Information Association is an independent, UK-based research association concerned with improving the performance of all involved in construction and the environment. It provides information and advice on best practise and has produced several guides of relevance to this report, including:

- “Environmental Good Practice on Site”. This is a very general guide aimed at site managers, site engineers and supervisors (Coventry & Woolveridge 2000) available from CIRIA;
- “Coastal and marine environmental site guide” Research project 646 (Budd et al. 2003).



The coastal and marine guide is specifically designed to inform front-line construction staff working on coastal and marine projects about the environmental impacts associated with a range of common construction operations. The work, funded by (DEFRA and the Environment Agency) provides guidance on avoiding or mitigating these impacts. It is presented in a format suitable for use on site and easy to use in an emergency situation (see above).

The guide is available from the CIRIA Bookshop and can be ordered from their Web Site: http://www.ciria.org/ price £40. CIRIA, 2 Storey’s Gate, Westminster, London, SW1P 3AU.

Guidance on environmental impact assessment in relation to marine minerals dredging applications

The potential effects of marine aggregate extraction have been discussed in Chapter 03. A recent review of the Government approach to the control of licensing of marine minerals dredging applications has resulted in greater consideration being given to their potential effect on onshore coastal systems. The following text is taken from MMG 01 and provides guidance on issues that should be considered when assessing the environmental impact of any proposed offshore dredging project. Of particular relevance are Article 6 "Assessment of the Potential Effects of the Dredging Activity" and the requirement to assess the physical impact of aggregate extraction for coastal erosion (through a Coastal Impact Study). In particular they suggest the following should be addressed:

- "*the proposed dredging is far enough offshore for there to be no beach drawdown into the deepened area;*
- *the proposed dredging will interrupt the natural supply of materials to beaches through tides and currents;*
- *the likely effect on bars and banks which provide protection to the coast by absorbing wave energy, and the potential impact on local tidal patterns and currents which could lead to erosion;*
- *likely changes to the height of waves passing over dredged areas and the potential effect on the refraction of waves which could lead to significant changes in the wave pattern*."

This issue is discussed in more detail in Chapter 03. For further guidance on assessing the effects of dredging on the coastline see Report (C505) '*Regional seabed sediment studies and assessment of marine aggregate dredging*' produced by CIRIA (Brampton & Evans 1998). It provides a structured approach to studies of regional seabed sediment mobility, plus guidelines for studies needed to assess the impact on the coastline of proposed dredging operations.

Issues surrounding the use of coastal defence measures to help re-create and restore vegetated shingle are given in Chapter 07.

References:

Brampton, A. & Evans, C.D.R., 1998. *Regional Seabed Sediments Studies and Assessment of Marine Aggregate Dredging*. CIRIA Report **505**, Construction Industry Research and Information Association, Storey's Gate, Westminster, London

Budd, M., John, S., Simm, J. & Wilkinson, M., 2003. *Coastal and marine environmental site guide*. Construction Industry Research and Information Association, Storey's Gate, Westminster, London.

Coventry S. & Woolveridge C., 2000. *Environmental Good Practice on Site*, Construction Industry Research and Information Association, Storey's Gate, Westminster, London .

Randall R.E., 1977. The past and present status and distribution of Sea Pea, *Lathyrus japonicus* Willd., in the British Isles. *Watsonia*, **11**: 247-251.

Chapter 07 Opportunities for habitat restoration/creation

This chapter sets out to provide some generic guidance on shingle habitat restoration. It builds on the discussion in the previous chapter and identifies a number of States in which shingle can exist. These range from mobile shingle beaches to stable shingle structures and transitions to other habitats. Shingle beaches are precursors to shingle structures, which become stable over time. The beach in its normal state responds to the action of waves and storms, existing in a highly dynamic environment. Once stable the larger shingle structures may remain so for many years, in some cases lying undisturbed for centuries. As has been shown in Chapter 5 human actions have modified or disturbed many shingle beaches and destroyed the surface of large areas of stable shingle.

The first section of this chapter deals with shingle beaches and more stable shingle structures and efforts to re-create more natural, stable forms of the habitat. Where management potentially provides opportunities for restoration of degraded areas of stable shingle, such as in managed realignment schemes, this is also considered. Opportunities for the restoration of shingle areas on the landward side of existing ridges are also discussed in areas where there are transition zones between vegetated shingle and agricultural land. This section of the guide thus deals with the essentially dynamic process of restoration, including areas where extraction of aggregate and/or recycling is taking place. It also addresses the value of natural cycles of erosion by the sea as a means of stimulating restoration.

The second section looks more closely at enhancing biodiversity through artificially creating shingle surfaces suitable for plant and animal colonisation in areas of dry aggregate extraction. Restoration of areas where shallow extraction has resulted in damp conditions is reviewed in relation to the development of semi-natural communities such as those associated with fens. The chapter also highlights the importance of planning ahead before projects i.e. to facilitate seed collection.

Shingle beaches

Restoring shingle beaches and structures is considered for the purposes of this guide separately and in relation to their original stability. Thus two states are identified for **shingle beaches**:

State 1 (erosional) - where a dynamic beach is moving alongshore or landward under the influence of the sea and there is an overall deficit in the sediment supply

Figure 07 - 01 Erosional beach, Porlock, Somerset. Note the complete absence of vegetation on this exposed part of the beach.

State 2 (accretional or semi-stable) where there is no sediment deficit. The beach moves in response to the prevailing wave and tidal regime

Figure 07 - 02 Semi-stable beach, Berridale, Scotland. The beach may accrete and/or retreat but stays more or less in the same location.

Both states are typically associated with shingle beaches and movement between the states forms part of the natural processes associated with this dynamic landform, in which plants can perform a limited role.

The erosional state is often the predominant form and where the shingle represents an important line of sea defence, action to help stabilise the beach is frequently undertaken with management aimed at moving the beach from State 1 - State 2.

The mechanisms involved can include some of the following:

- the construction of sea defence structures;
- beach reprofiling;
- beach nourishment.

The direction of movement is as shown in the Figure opposite. The preferred direction of movement from a sea defence perspective is shown in the figure in blue. Note that in a few cases, and for the restoration of more natural shingle forms, a reversal of the process to restore shingle movement may be considered i.e. State 2 to State 1 by allowing natural processes to dominate. This issue is discussed below and by reference to several cases studies reviewed in the guide: Orfordness (Annex 06); Dungeness (Annex 05) and Porlock (Annex 01).

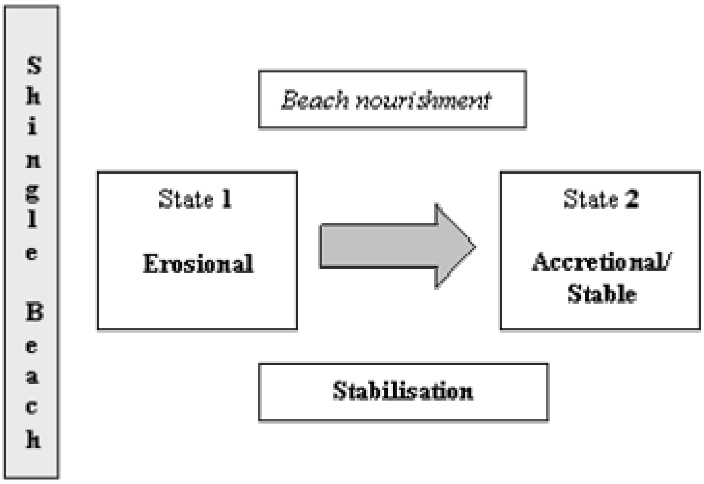


Figure 07 - 03 Principle direction of preferred movement of shingle (from an engineering and vegetation development stand point)

Creating stability - State 1 to State 2, engineering approaches

Undertaking engineering works designed to prevent erosion can, potentially at least, provide the means for creating more stable areas where vegetation becomes established. Both toe protection along the base of the sea walls and breakwaters can be used to reduce scour. Buried revetments, e.g. at Sovereign Harbour in Eastbourne have helped to build up the base of the beach. As a result less material is needed to build the shingle up to a level suitable for flood protection. The top of the ridge is broader, and hence more suitable for the development of vegetation communities. At Pevensey investigations are taking place into the use of tyre bales for a similar purpose. These may have the added advantage that the bales are not solid structures and can provide gaps for the shingle to penetrate and hold the beach together, as well as voids for root systems.

The construction of the Brighton marina in 1972 provided opportunities for a newly deposited shingle beach to form between a groyne and the western breakwater. Detailed studies of this area (Black Rock Beach) showed, for example, how vegetation can develop once engineering activities cease (Packham & Spiers 2001). Between 1975 and 1996 the beach remained relatively stable and both typical and rare plants colonised, helping to create an unusual community which included the sea knotgrass, *Polygonum maritimum* (a plant of the Mediterranean, rare in Britain and at or near its northern range here). This community persisted until a storm in 1996 washed it away.

The study at Black Rock provides some pointers to future approaches where construction is used to protect a beach. If left undisturbed once construction is complete, then it is possible for important and rare plant communities to develop. Increasing the period of beach stability allows the development of a type of matrix and hydrology suitable for the establishment and survival of the vegetation.

The case of Black Rock is unusual, in that access to the beach by machinery was limited. More usually sea defence structures are associated with nourishment and/or reprofiling and such development is not possible. This leads to consideration of the implications of artificially engineered approaches to beach protection and their impact on coastal vegetated shingle. The implications of these approaches for the maintenance or restoration of coastal vegetated shingle are discussed next.

Creating beach 'stability' with beach reprofiling

Generally, reprofiling beaches destroys any vegetation in the areas where work takes place. The nature of the beach slope is important, as is the height above sea level. In sea defences conventional approaches involve raising the crest height, which at the same time tends to steepen the foreshore. This has happened at several sites where loss of vegetated shingle has occurred, e.g. Porlock (Annex 01) Cley-Salthouse (Annex 07) and the sites on the south coast (Annex 03, 04 and 05). The evidence suggests that this approach is not wholly sustainable from a sea defence point of view. This is particularly illustrated by the work at Porlock (Annex 01) and Cley-Salthouse (Annex 07).

Comment: *A major question arises about the use of coastal defence structures and beach reprofiling/nourishment as to their appropriateness within important nature conservation sites. Sites with a dynamic balance between stability and instability allows for a variety of communities to develop, including those associated with both ephemeral and more stable structures (Chapter 02). Thus creating stability must be considered in relation to compliance with the 'Habitats' Directive and in relation to the Habitat Regulations (dealt with in Chapter 04). The designated sites have fixed boundaries, with lines on maps used to define the protected areas. This can impose a rigidity on restoration activities, which is not commensurate with the inherent dynamism of the systems. This is particularly important where shingle beaches or structures move in response to tidal energy and storms, beyond the boundary of the designated site. These issues are discussed in more detail in the general guidance in relation to the coastal vegetated shingle Habitat Action Plan below.*

Beach profile

The creation of a natural beach profile is crucial to the establishment of shingle vegetation. A study of regeneration of vegetation (Walmsley & Davy 2001) suggested that recontoured beaches should be left to allow natural reshaping by winter storms before any attempt to plant vegetation is made.

As a guide, the slope and sediment size best for restoring vegetation on shingle beaches, based on a natural beach profile, has the following characteristics:

Feature	Size and range	Comment
Slope	1:100 - 1:15	Natural range of slope
Sediment size	2mm - 200mm	Range for shingle used to define habitat (Randall 1977)
Sand content	10 - 20% sand content	Best for vegetation establishment (Walmsley & Davy 2001)

Beach nourishment

Beach nourishment with shingle is frequently used to improve its sea defence capability. There are numerous examples, especially on the south coast of England where the Environment Agency and others are undertaking such work. If a suitable source of material exists nearby, beach nourishment with shingle is a relatively easy process. It can also, if the new or replenished beach is allowed to develop without interference through reprofiling and the material is washed to reduce nutrient enrichment, provide the foundation for restoration of vegetation. In many instances this is not the case and continued bulldozing of beach material to increase crest height and 'improve' the sea defence capability prevents such colonisation.

Successful and long term effectiveness of beach nourishment without environmental damage and with opportunities for colonisation can occur. These will depend on the nourishment process taking into account the following:

- the nature and type of beach appropriate to the location (slope, width, sediment type and sediment size, see Chapter 06);
- the role of nearshore tidal currents in moving shingle across the shore and in a longshore direction i.e. the beach response;
- the long term wave climate and extreme storm sea-states, which combine large waves and high water levels;
- the relative rate of sea level change.

Under most circumstances the value of the beach to the protection of life and property is the primary reason for nourishment. Thus most schemes depend on an assessment of the following:

- risks (human, economic, environmental), both locally and along adjacent frontages;
- costs of the scheme, including initial placement and long term maintenance; the availability of appropriate material (dredged aggregate, quarried gravel, crushed rock) in the volumes required (both short and long term) and the influence of different recharge sediment gradings on the cross-shore and long-shore processes;
- potential impacts of the scheme on the human and natural environment (e.g. recreation, archaeology, nesting sites, fisheries, outfalls).

Assessment of the appropriateness of such schemes also depends on the suitability of the material used (grain size, freedom from pollutants etc.). Where material is derived from marine sources they are also subject to a Government View procedure, which controls the extraction of aggregates from offshore. This procedure requires an assessment of the potential impact of extraction on nearshore and coastal processes (dealt with in more detail in Chapter 04).

Problems potentially arise from a conservation perspective with all of these solutions to preventing erosion. This is particularly acute in areas where more stable beach forms exist, which have both ephemeral strandline plant communities (with associated and sometimes rare species of both plants and invertebrates) and more stable structures and their communities. Thus although engineering approaches to stabilising shingle areas can help to create or re-create vegetated shingle habitat, it rarely does so! Recently other approaches are being investigated, e.g. the use of buried tyre bales at Pevensey as noted above.

However the socio-economic imperative for the protection of life, land and property remains a dominant one. Opportunities for using the natural predilection for shingle beaches to respond to tides and waves including storms and by so doing provide opportunities for habitat re-creation have only recently been considered at all, except in a few circumstances. This issue is considered in more detail in the section on the implementation of the Habitat Action Plan aims below.

Summary guidance - creating stability, engineering approaches

It is clear that beaches can be stabilised using artificial structures. Because these are associated with coastal protection measures, other activities usually take place, such as beach replenishment and/or reprofiling. As a result the establishment of new shingle communities is very rare and the case of Black Rock above may be an isolated example.

Restoration of stable shingle and vegetation

The natural process of beach ridge formation (Chapter 02) can result in the development of large structures as former beaches are piled against each other. These structures may take a variety of forms depending on strength and direction of the waves, storm conditions and availability of sediment in a suitable size range. Shingle structures may enclose estuaries and embayments as a result of material being moved by long shore drift and form spits, bars and barriers. Major accumulations of successive ridges piled on shore under storm conditions can develop into cuspate forelands. Nesses and recurved spits form where there is a convergence (or divergence) of littoral drift. Cheniers are a special form of shingle which is driven onshore as a series of low shell deposits (Chapter 02).

In the absence of human interference these all provide essentially stable surfaces on which other factors come into play, which influence the development of vegetation. The action of the waves and storms that create the ridges help sort the pebbles (Chapter 02). Subsequently material is washed into the spaces between the pebbles and can result in sufficient water retention to facilitate plant growth. Over long periods of time stable communities develop, which can range from lichens growing directly on the pebbles (as at Orfordness), to grassland, heath and scrub (State 3, Figure 07-04 below).

State 3 - (Stable). Shingle ridges removed from the influence of storms and where the build up of material between the pebbles helps support plant establishment

Figure 07 - 04 Stable shingle ridge and hollows, Culbin Shingle Bar, Highland Region, Scotland. Note the build up of vegetation on the sides and hollows of the ridge, where the spaces between the shingle become filled with organic and other material and improve moisture retention opportunities.

This state provides geographically the widest and most diverse expression of the vegetated shingle habitat in Great Britain, as described in Chapter 02.

As we have seen in Chapter 05 human action can seriously damage or disrupt this surface vegetation. Typically large expanses of shingle provide a ready source of accessible gravel for a variety of building purposes. Excavation of the shingle destroys the surface vegetation and any associated interests. The extent and nature of any restoration depends on whether the excavation is above or below the water table. Where disturbance or excavation remains above the water table for most of the time (State 4, see below) then vegetation can, potentially at least, be restored on the shingle surface, although stable communities are likely to take a considerable time to revert to their natural state.

State 4 (Disturbed/Excavated) A state where the depth of the disturbance / excavation is above the water table

Figure 07-05 Disturbed/excavated shingle at Kingston, Moray Firth, Scotland dominated by herbs including *Shoenus nigricans* in the foreground, a species of damp places.

NB. A distinction is made here between disturbed shingle surfaces which remain dry and those where the surface is close enough to the water table to provide opportunities for good plant establishment and growth. In such instances such as at Kingston (Spey Bay Shingle Annex 08) and at Dungeness (Annex 05) species-rich secondary communities can develop.

Restoring these stable surfaces essentially revolves around attempts to re-establish vegetation on stable shingle surfaces. Restoring the physical shingle structure (ridges and lows) is a precursor to re-establishing vegetation, but is difficult, especially on dry well drained shingle. Figure 07-06 gives a summary view of the direction of the main restoration opportunities. Several approaches for restoring vegetated shingle (moving from State 4 to State 3) are considered next.

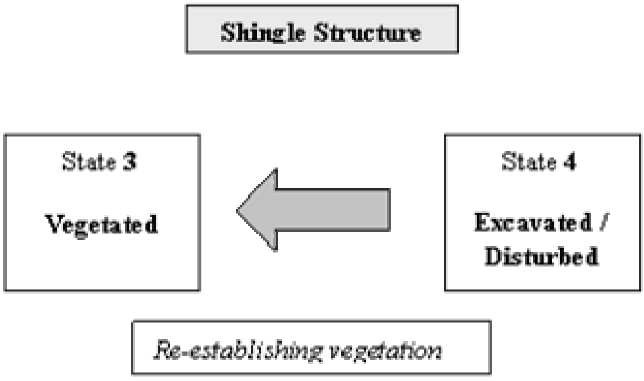


Figure 07 - 06 Principle direction of preferred movement of shingle (from a conservation perspective, which aims to restore vegetated shingle habitat)

Re-grading disturbed shingle

As a first stage in restoring vegetated shingle, re-creation of a suitable shingle matrix is needed. Few attempts have been made, as far as can be ascertained, to artificially re-create the surface shingle form of ridges and hollows. One project carried out at Orfordness involved the grading of shingle to mimic the process undertaken by the sea (Annex 06).

The damage to the shingle at Orfordness has been considerable. Although excavation has been relatively restricted, loss and damage of the surface has been extensive at the northern (ness) end of the structure. This has destroyed the vegetation and severely degraded the morphology, such that natural regeneration of the vegetation is very slow or non-existent. [A requirement for the development of vegetation on the extremely porous shingle surface lies in the presence of fine fractions between the pebbles, which allow the retention of moisture and facilitates plant seed germination. This fraction is lost with the surface disturbance of the shingle.]

The National Trust undertook to test, experimentally, whether it was possible to regenerate shingle flora on some of the worst degraded and damaged sites. The project was carried out in 2000 as part of the European Union LIFE-Nature project ‘WILD NESS - The Conservation of Orfordness, Phase 2’.

The chosen site was selected in an area substantially degraded by military use. Initial work on the ridge to be restored involved the scraping off of the surface shingle to a depth of approximately 18-20cms (below the depth to which germinating seeds will reach).

“The shingle was graded, using an adapted small commercial screener, into four nominal sizes <5mm, 5-15mm, 15-25mm and >25mm. These measurements are representative of the natural sizing recorded on adjacent ridges. This material was then manually and mechanically replaced onto the scraped area in order to reproduce the height, width, spread and size ratios of a section of undamaged ridge adjoining the test area.” Five treatments were tried; see Table 07- 01 below:

Section 1	Restored sizing and grading plus added fines and added *Silene maritima*/*Arrhenatherum elatius* seed
Section 2	Restored sizing and grading plus added fines
Section 3	Restored sizing and grading plus added *Silene maritima*/*Arrhenatherum elatius* seed
Section 4	Restored sizing and grading only
Section 5	Existing ‘undamaged’ ridge - possible source of colonisation

Table 07 01. Five experimental treatments to restore shingle vegetation.

Recolonisation

The work at Orfordness is being monitored using presence or absence linear transects and fixed point photography. There was no evidence of recolonisation by October 2002 when the photograph opposite was taken (see Figure 07-07), some 2 years after the work was undertaken.

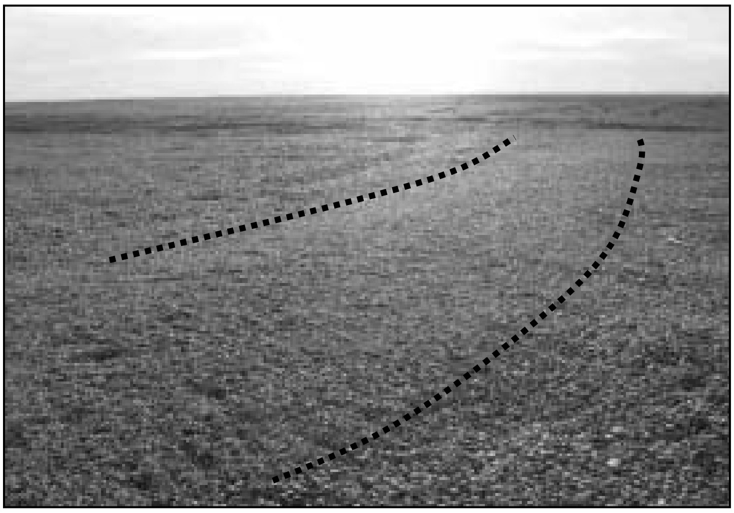


Figure 07 - 07. Site of experimental shingle restoration. The location of the restored ridge is indicated in the picture.

Part of the LIFE Nature funded project: “**Wild Ness**: the conservation of Orfordness, Phase 2 (LIFE97 NAT/UK/004245)”.

Summary guidance - re-creating shingle ridge profiles

The evidence so far suggests that regrading shingle is feasible but costly in time. The re-establishment of vegetated shingle does not seem to readily occur even with the introduction of seed (note this comment relates only to this experiment, but see also below, “Restoring Vegetation”). From this work it appears the natural forces of tides and waves are much more efficient tools for sorting coastal shingle than anything human restoration can achieve.

Restoring vegetation - free-draining shingle surfaces

Research has also been applied to recreating shingle vegetation without the grading of the shingle substrate. Restoring vegetated shingle surfaces is principally a nature conservation issue. Unlike sand dunes (and to some extent saltmarsh) plants play a limited role in stabilising the structure itself. There is little information available on how to re-establish plants on shingle, though a recent series of studies at Sizewell in Suffolk has elucidated several approaches, namely:

- natural regeneration;
- use of the natural seed bank;
- use of sown seed for restoration (Walmsley & Davy 1997);
- use of container grown plants (Walmsley & Davy 2001).

[*These methods are discussed in more detail in the "Good Practice Guide for habitat restoration, re-creation and creation on the coast". Note small-scale projects are being trialled in East & West Sussex; see also reports for Pagham, Annex 03 and Rye Harbour, Annex 04.*]

Much is still to be learned about vegetation restoration on shingle. Walmsley and Davy (2001) in reviewing the work of the 'Sizewell B' Vegetation Restoration Project where mature, container-grown plants were able to survive best because they possessed extensive root or rhizome systems. Trials are being undertaken on several sites on the south coast. On a small area at Bognor Regis planting was carried out successfully in 2001/2002 and seeding in 2002 (results are not yet available). Following extensive coastal defence work in the early 1990s, seeding was carried out at Elmer, Middleton-on-Sea. Although not scientifically monitored, the beach rapidly developed a vegetated shingle community. However, it is uncertain exactly how much was due to the seeding application and how much to natural re-colonisation. The site is now being regularly monitored but unfortunately too late to observe the early stages of colonisation. Other trials are proposed at Selsey Bill near Pagham with a variety of seeds and at Dungeness with *Cytisus scoparius* but the outcomes of these studies will not be available for 2-3 years (Annexes 03 and 05).

Whether or not seed or other plant material is introduced the structure of the shingle surface is all important. The creation of a natural beach profile is crucial to the establishment of shingle vegetation. Recontoured beaches should be left to allow natural reshaping by winter storms before any attempt to plant vegetation is made (Walmsley & Davy 2001). In this context the development of soils with water retention characteristics cannot be over emphasised (Chapter 02, soils).

Overall this approach can help with the re-creation of vegetated shingle though the success is relatively limited when compared with the cost of undertaking the restoration. At the same time storms can (as might be expected) undo the work in a short space of time, on the most seaward sections of the restored beaches.

Summary guidance - re-creating vegetation on dry shingle surfaces

Natural regeneration of plant communities takes place over time and a variety of techniques have been tried to encourage the establishment of vegetation on dry degraded/disturbed surface shingle. These do not appear to have been particularly effective, to date. Hence restoring vegetation to stable shingle (moving from State 4 to State 3) may largely be a matter of 'leaving nature to take its course', see below.

Restoring shingle vegetation - waterlogged surfaces

Although there are no specific examples of active intervention to create or restore vegetation on shingle surfaces which have been excavated to levels at or near the water table, there are a few sites where such conditions exist. At Kingston (Spey Bay, Annex 08) on the south shore of the Moray Firth excavation has created depressions in the surface shingle that have become colonised by a variety of plants typically associated with damp hollows. These communities may be particularly rich in species including the rare coralroot orchid *Corallorhiza trifida*. At Dungeness (Annex 05) shingle spoil and areas of shallow excavations have also been colonised by a variety of communities more typical of damp conditions, including some similar to those of wet sand dune slacks. Some highly disturbed shingle; with an input of fine-grained material along road verges, can have a much richer complement of plant species than natural undisturbed grassland on shingle (Ferry 2001).

Summary guidance - re-creating vegetation in damp hollows on shingle

Restoring vegetation on shingle surfaces at or near the water table is more readily achievable, based on the limited examples from sites in the UK. The presence of moisture (a limiting factor in most undisturbed stable shingle) and the apparently more rapid build up of humus help to create suitable conditions for plant establishment and growth. Although there are no known examples, an approach which seeks to lower the level of already disturbed shingle at the margins of these areas could help create transitional communities such as those found on the shingle at Kingston, Scotland (Annex 08) and Rye (Annex 04) where they resemble dune slack communities. The disturbance associated with mixing shingle with fine-grained material as has occurred at Dungeness provides another potential method for habitat enhancement see Ferry (2001).

These examples suggest that it may be possible to create or re-create these communities which are reminiscent of transitional zones between open dry shingle and other habitats sustained by springs or with soils with water retaining properties.

The role of gravel pits

A fifth state has been included in this guide (rolled into State 4 above in the “Good Practice Guide for habitat restoration, re-creation and creation on the coast”) which takes account of those areas where excavation is at or below the water table, for all or most of the time.

State 5 (Excavated) Below the water table helping to create coastal gravel pits (Figure 07-08)

Figure 07 - 08 Newly excavated gravel pits at Dungeness, Kent on land owned by the Royal Society for the Protection of Birds (RSPB). A large part of these areas have subsequently become part of an extensive wetland nature reserve. The picture was taken in 1980 before the RSPB stopped selling gravel-winning concessions at the site.

As we have seen in Chapter 05 pressures on the excavation of onshore deposits of shingle are enormous. This is the most usually encountered and often most extensive form of habitat loss. In these cases the shingle void, because it is excavated to below the water table, results in open water ‘gravel pits'. Generally, excavated shingle areas are considered to have a reduced value for nature conservation because of the loss of the specialist and rare plant communities that make up the vegetated shingle habitat. There are, however, replacement values associated with the open water and the creation of new wetland habitat such as the creation of roosting, feeding and breeding habitats for birds, and the creation of saline lagoons. Restoration of the gravel surface and vegetated shingle (including those communities defined in the 'Habitats' Directive) is not possible. The replacement values associated with developing this habitat are thus not comparable with the restoration envisaged in moving from State 4 (Disturbed/Excavated) to State 3 (Stable).

Information on restoring gravel pits is available, see particularly the Royal Society for the Protection of Birds' publication "Gravel Pit Restoration for Wildlife: a Practical Manual" 1990 (ISBN 0 903138 603, RSPB Code 24-015, Price £12) and the "Gravel Pit Restoration for Wildlife: Site Managers Guide" 1990 (RSPB Code 24-014, Price £5).

Summary guidance - gravel pits

The replacement of stable and undisturbed vegetated shingle ridges with excavations, which result in areas of open water, is almost always a retrograde step. The new habitat and coastal bird populations that can colonise the areas do not represent an acceptable trade off for the loss of the rare coastal vegetated shingle habitat.

General guidance and the UK vegetated shingle Habitat Action Plan (HAP)

Naturally, shingle coasts are dynamic and tend to migrate along the coast or landward. They have at the same time become a major source of material for the construction industry, sites for building infrastructure such as nuclear power stations and houses and as a recreational resource. They also have important 'natural' sea defence capabilities. Even if this capability is recognised they are often augmented by artificial structures, in the belief that this is essential for the protection of life, land and property.

Vegetated shingle beaches and structures are important habitats within the European Union 'Habitats' and 'Species' Directives. The values associated with this habitat and described in Chapters 01 and 02 have, not only been damaged and destroyed by human activities (Chapter 05) but have also come under pressure as a result of changing environmental conditions, driven by global warming and sea level rise.

Vegetated shingle is listed as a priority habitat under the UK Biodiversity Action Plan. The Vegetated Shingle Habitat Action Plan recognises two principle issues (2.1 and 2.2 below) relating to sea defence and the sustainability of shingle habitats:

"**2.1 Sediment supply**. *The health and ongoing development of a shingle feature depend on a continuing supply of shingle. This may occur sporadically as a response to storm events rather than continuously. It is frequently lacking owing to interruption of coastal processes by coast defence structures, by offshore aggregate extraction or by artificial redistribution of material within the site (e.g. Dungeness). Attempts have been made to rectify the situation by mechanical reprofiling, which is likely to fail in the long run because it does not address the lack of new material, or by beach recharge*."

Added to these considerations must be the fact that most shingle structures and many shingle beaches are derived from relict sources, i.e. relative to the quantities present today there is little or no new material (Chapter 02).

> **Comment**: *This study has clearly identified the importance of understanding the* ***relict nature*** *of many of the shingle deposits that are present today. The conclusions from Futurecoast summarised in the report on Slapton (Annex 02), highlight the continuing need for beach nourishment on the south coast and the deficit of material identified for Dungeness (Annex 05 and 05a) tend to confirm the view expressed in 2.1 above that in* ***many instances engineering solutions to shingle erosion are unsustainable in the medium to long term****.*

Erosion as a healing force in degraded areas

This leaves the consideration of approaches which ‘work with nature’ and accept the ‘naturally’ dynamic state of shingle beaches and many of the shingle structures as providing the potential for a more cost effective approach. This recognises the second key principle articulated in the vegetated shingle Habitat Action Plan, namely:

“**2.2 Natural mobility**. *Shingle features are rarely stable in the long term. Many structures exhibit continuous longshore drift and ridges lying parallel to the shoreline tend to be rolled over towards the land by wave action in storm events. This movement has a knock-on effect on low-lying habitats behind the shingle. Movement is likely to be accelerated by climate change resulting in sea level rise and increased storminess.*”

Taking these two principles into account a question arises as to the acceptability of allowing ‘nature to take its course’ when the re-creation of one habitat will be at the expense of another. Section 5.3.3 of the HAP expresses the dilemma as follows:

“*Allowing natural landward movement of shingle features* will, in some cases, affect other habitats such as saline lagoons, grazing marsh, fens and reedbeds, some of which will be designated sites. The implementation groups for the relevant HAPs should be advised on how to make appropriate provision for habitat creation. In some cases, breaches in shingle banks may lead to the development of saltmarsh habitats and this needs to be taken account of in the respective HAPs.*” [* Advocated in 5.1.1 of the HAP]

Letting nature take its course

The situation at Porlock (Annex 01) is perhaps the best illustration of the way things can develop under more or less natural conditions. Here a natural storm breach in effect pre-empted discussions about continuing to protect the shingle ridge through reprofiling and beach nourishment. Today the former tidal land converted to grazing marsh and arable land has now reverted to brackish and saltwater communities as the tide has reinvaded the land following a breach in the shingle ridge caused by a storm. The site was re-designated as a Site of Special Scientific Interest following the breach, with a new description reflecting the fact that saltmarsh and transitions to brackish water habitats had largely replaced the coastal grazing marsh. The site shows that coastal habitats can be re-created and that although they may be different from that which they replace, they may be no less important.

Other considerations are relevant at this site, not least the attitude of the local population, opposed to leaving things as they are i.e. NOT closing the breach and reinstating the sea defence structures. The site report (Annex 01) discusses this issue also.

> **Summary guidance - the example of Porlock (Annex 01)**
>
> This case clearly illustrates a possible way forward when existing protection measures are thought to be unsustainable. The lessons learned from here should be communicated and applied more widely. This is not only because of the nature conservation implications but also those associated with social attitudes to ‘abandoning’ the land to the sea.

The shingle squeeze

A further issue arises where ‘natural’ processes result in habitat loss, for example through ‘coastal squeeze’ described both for Slapton (Annex 02) and Cley (Annex 07). Where these form part of a candidate Special Areas of Conservation or Special Protection Areas is it appropriate to ‘let nature take its course’? With no interference it is conceivable that the Favourable Conservation Status of the selected habitats and species would be compromised and the overall biodiversity of the site diminished. This would not only compromise the overall value of the area but could also work against achieving biodiversity targets set for example within a ‘Natural Area’ as defined by English Nature.

In the UK the Conservation (Natural Habitats, & c.) Regulations 1994, as amended, implement the European Union ‘Habitats’ and ‘Birds’ Directives. In particular, “The Habitats Regulations” transpose into UK law the provisions of the European Union Habitats Directive and introduce stringent requirements for the conservation of Special Protection Areas and Special Areas of Conservation (including candidate SACs). [For more detail on the regulations see Annex 01.] Application of Regulations 48 and 49 of the regulations if strictly interpreted create a strong presumption that habitats be preserved in their present location. Only where “no alternatives” and “imperative reasons of over-riding public interest” are demonstrated is providing compensatory habitat an acceptable alternative.

At Cley the original realignment scheme (Annex 07) envisaged protecting some of the existing interest (mainly reedbeds for their bird interests) at the same time as allowing the ‘natural’ restoration of the shingle ridge following the cessation of beach reprofiling. The reconsideration of the scheme has led to the recognition that although leaving the system to reassert itself with minimal interference will lead to the loss of some habitats, others will develop. Overall it seems likely that the conservation value will be maintained and the site as a whole will remain in ‘favourable condition’. A similar question has arisen at Slapton Sands (Annex 02) where the continued roll-over of the shingle beach will ultimately encroach on a coastal freshwater lagoon reducing its area and changing its characteristics.

Summary guidance - ‘shingle squeeze’ and the ‘Habitats’ Directive

From these examples it seems entirely appropriate to consider that the loss of one habitat at the expense of another is entirely in keeping with the desire to promote more ‘natural’ and dynamic ecosystems. The dilemma as expressed in 5.3.3 of the coastal vegetated shingle Habitat Action Plan, quoted above, identifies the need to consider the re-creation of replacement habitats elsewhere. Where these are different from the vegetated shingle and include other coastal habitats reference should be made to the “Good Practice Guide for habitat restoration, re-creation and creation on the coast”.

Initiating erosion for conservation purposes

The reliance on a ‘static’ approach to conservation, which is so often associated with the identification of boundaries of sites on maps, may be counter productive for a habitat existing in such a dynamic environment. As expressed above the natural tendency for movement both alongshore and inland not only has implications for the management and restoration of beaches and areas of vegetated shingle, but also associated habitats such as lagoons and saltmarshes. Whilst natural movements of shingle in response to storms will be seen as being part of the “natural structure and function” of the system, interference to create instability may not!

These issues have particular poignancy in relation to Dungeness and Orfordness. Here the scale of damage to the surface shingle in some parts of the site covers such a large area that any of the approaches to restoration mentioned above would be likely to be ineffective. Initiating erosion or at least removing those static artificial features such as groynes and breakwaters and/or ceasing beach nourishment could help bring about major restoration of shingle beaches and ridges. This would, of course, require very careful consideration of the implications for the land and property formerly ‘protected’ from erosion and flooding by the coastal defence activities. In the case of Dungeness

(Annex 05), for example, this may be prevented because of the need to protect the nuclear power stations, but perhaps not at Orfordness (Chapter 06 and Annex 06)?

Summary guidance - creating instability

The past reliance on coastal protection measures to prevent shingle beaches and structures eroding has helped to create and sustain a much impoverished habitat. In some instances the area of damage is so large that even if the restoration techniques described above were to work and restore form and function to the shingle and with it vegetation and associated animal life, the resources needed would be considerable. Under these circumstances and on the larger sites, creating instability, or at least letting natural forces reassert themselves is probably the only option.

Comment: *Taking the above course of action will not be easy. As a general rule, however, wherever possible from a nature conservation perspective, **shingle structures should be left entirely alone**. In the majority of circumstances, geomorphological change promotes environmental diversity (Randall & Doody 1995). Given the historical reliance on engineering approaches to protection this approach **will require considerable persuasion**, not least amongst the local population. The situation at Porlock (Annex 01) and the potential examples of Cley (Annex 07) and Orfordness (Annex 06) may provide important pointers for this changing paradigm.*

The issues discussed in this section, which relate to allowing or promoting change for conservation purposes, especially where the loss of one habitat may be at the expense of another, are being examined in some detail in a current study "Options for maintaining features of European Importance in dynamic coastal situations" being undertaken as part of English Nature's Living with the Sea project (See: http://www.english-nature.org.uk/livingwiththesea/). For this guide the options are considered in more detail in relation to Orfordness (Annex 06) and the Cley-Salthouse realignment scheme (Annex 07).

References:

Ferry, B.W., 2001. Vegetation of Dungeness shingle: aspects of biodiversity. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 224-241.

Packham, J.R. & Spiers, T., 2001. Plants along the prom: an account of shingle vegetation associated with coastal defence works at Brighton, UK. In: *Ecology & Geomorphology of Coastal Shingle,* eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 174-190.

Randall, R.E., 1977. Shingle formations. In: *The Coastline*, ed., R.S.K. Barnes. John Wiley and Sons, London, 49-62.

Randall, R.E. & Doody, J.P., 1995. Habitat Inventories and the European Habitats Directive - the example of Shingle Beaches. In: *Directions in European Coastal Management*, eds., M.G. Healy & J.P. Doody, Samara Publishing, Cardigan, 19-37.

Walmsley, C.A. & Davy, A.J., 1997. The restoration of coastal shingle vegetation; effects of substrate composition on the establishment of seedlings. *Journal of Applied Ecology*, 34, 143-153.

Walmsley, C.A. & Davy, A.J., 2001. Habitat creation and restoration of damaged shingle communities. In: *Ecology & Geomorphology of Coastal Shingle* eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic and Scientific Publishing, 409-420.

Chapter 08 Monitoring

There are three key stages in any process which aims to monitor the status of any habitat as follows:

1. **survey** to establish the location, scale and value of a particular resource;
2. **surveillance** to identify unforeseen change and where appropriate ensure compliance with agreed legislative or other control mechanisms - simply 'watching to see what happens';
3. **monitoring** to help identify and assess the effect of management policy or action on a given set of parameters and give feedback on their effectiveness.

The purposes of survey and monitoring

Survey is used to assess the status of shingle and shingle vegetation. This is affected through habitat surveys and the like. Whilst strictly speaking it is not monitoring as such it is an essential prerequisite for any future attempts to assess change and the influence of policy and management action on this habitat. In particular surveys attempt to:

1. establish the location and extent of coastal vegetated shingle;
2. identify the condition of individual sites (included in this are Sites of Special Scientific Interest and candidate Special Areas of Conservation). Because nearly all shingle vegetation is included within Annex 1 habitats of the EU 'Habitats' Directive, base-line monitoring is required to confirm its status. This will add to the data already available and will be the precursor to monitoring for other purposes.

In its turn monitoring is necessary to:

1. assess current condition of Sites of Special Scientific Interest;
2. to record the success of habitat restoration or creation;
3. to examine the on-going effects of coastal management works on coastal vegetated shingle;
4. to measure the impact of flood management schemes on shingle habitats, particularly where creation/enhancement works have been carried out.

Survey techniques

Geomorphic survey and monitoring

At some sites it will be important to measure shore mobility. This is best carried out using a series of fixed transects orthogonal to the shoreline. These can be resurveyed at intervals using a dumpy level or theodolite. Ideally a useful body of data can be amassed by surveying monthly but even an annual monitoring of change is helpful for defining management objectives.

Neal *et al.* (2001) highlighted the value of ground-penetrating radar in the geomorphic study of coastal shingle structures. These techniques avoid the cost and damage of excavation and increase the historic knowledge of shingle structures, which is so significant in prediction.

Hydrology and soils

Monitoring the hydrology and soils of coastal shingle is complicated both by the large interstitial spaces between clasts and the difficulty of digging standard soil pits in such sediments. These problems are addressed by Burnham & Cook (2001) at Dungeness and for shingle soils more generally by Sneddon (1992). Burnham and Cook discuss the methods and values of borehole data and review the use of lysimeters in hydrological monitoring.

There is a lack of research on the edaphology of shingle substrates. Ferry et al. (1989) measured pH, sodium, potassium, calcium, magnesium and phosphorus with respect to vegetation type and along a transect from maritime to terrestrial shingle at Dungeness. The patterns offer evidence of significant leaching. Fine sediment, pH and nutrient ion concentration variation were important in explaining variation in vegetation.

Soil survey and monitoring is difficult on shingle because of the thin soil (commonly 0-10 cm but 30 cm maximum) which precludes standard collection methodologies within different horizons. This may be overcome by collecting material from the full depth of the limited profile. The inert nature of larger sediments makes analyses best conducted on interstitial material only (under 2 mm). Results must therefore be expressed not as a unit volume but with reference to percentage weight of fine fraction (Randall 1977).

The most significant factors to monitor in shingle substrates are silt/clay fraction as this gives an indication of soil-moisture retention; pH, which is a surrogate nutrient absorption; chlorides because of the proximity of the sea; macronutrient exchangeable cations, potassium, calcium and magnesium; and sodium which, due to salt spray, can be an important factor in shingle environments. Organic matter should also be monitored due to its wider implications for soil texture and its importance for cation exchange. Techniques of analysis are described by Brady (1974) and Courtney & Trudgill (1984). Shingle soils have been found to be highly variable and unique (Sneddon 1992).The shallow soils offer only a small reservoir of nutrients for plant growth and successful nutrient cycling is therefore vital. Management practises must take careful consideration of activities which may disturb the soil as there is a great potential for completely destroying thin soils of this nature.

Coastal vegetation and the National Vegetation Classification

Rodwell (2000) describes the most comprehensive coverage of the present knowledge of coastal vegetation in Britain. The techniques used and approach to data analyses are given in an "Introduction" to each volume of British Plant Communities. Stands of vegetation were chosen on the basis of their relative homogeneity in composition and structure. Data were recorded in quadrats of 2 x 2 m for short herbaceous vegetation, 4 x 4 m for taller or more open vegetation and 4 x 2 m for linear vegetation. Samples were recorded on standard sheets and subjected to standard analytical procedures. They are presented as phytosociological tables of community types on roughly the same scale as a 'Braun-Blanquet association'.

Sampling and analysis of shingle vegetation

The most relevant section of Rodwell (2000) for shingle is included within the section on 'shingle, strandline and sand-dune communities'. However, Rodwell admits that "*coverage of shingle features around the coast (is) less (than) adequate and ….we did not incorporate developing surveys of Dungeness by Dr Brian Ferry and of very many shingle beaches around the coasts of England and Wales by Pippa Sneddon working with Dr Roland Randall. Probably at least one further community could be added to our account from these surveys*."

Strandline and shingle communities

Rodwell (2000) recognises two assemblages, dominated by ephemeral, nitrophilous herbs which make a brief fragmentary appearance during the growing season on shingle where organic debris has been dumped along the strandline. On warmer, southern coasts the *Honckenya peploides-Cakile maritima* community (SD2) is present. Towards northern Britain the *Matricaria (Tripleurospermum) maritima-Galium aparine* community (SD3) replaces this. These vegetation types are regarded as pioneer communities that are overwhelmed by storm conditions and re-establish periodically as conditions become suitable. These are some of the 'annual vegetation of drift lines' legislated under Annex 1.

The only other assemblage included by Rodwell (2000) from coastal shingle is the *Rumex crispus-Glaucium flavum* community (SD1). This is essentially a southern British community. It is an example of the 'perennial vegetation of stony banks' also legislated for under Annex 1 of the EU 'Habitats' Directive.

In the UK the Annex I Annual vegetation of drift lines (1210) type is not always easy to classify using the National Vegetation Classification. It consists, as outlined above, of driftline vegetation on stony substrates and other coarse clastic sediments and can include the SD2 and SD3 NVC types. MC6 *Atriplex prostrata – Beta vulgaris* ssp. *maritima* sea-bird cliff community and other vegetation types not described in the NVC, e.g. monospecific stands of *Atriplex* spp. may also occur. Drift-lines on sandy shores are assessed as sand dune communities (see 2110 Embryonic shifting dunes), and are not included in this Annex I type. However, where drift line vegetation develops on other coarse clastic sediments, such as shell-banks (cheniers, Chapter 03), it can be considered as part of the Annual vegetation of drift lines.

JNCC's coastal survey programme

Although the NVC description of British Plant Communities is valuable at a national scale for all vegetation types, it was felt that a more detailed survey of British shingle was necessary to understand the variety of vegetation present. A survey of Dungeness was carried out by Ferry et al. (1990) and a survey of the other major shingle structures in Great Britain was completed by Sneddon & Randall (1993a, b, 1994a, b).

Methodology

Sneddon & Randall identified around sixty shingle structures and beaches supporting a permanent flora above the strandline. Each was identified using habitat maps; information supplied by English Nature Regional staff and published sources (Figure Chapter 08-01). Each site was surveyed using the framework of the National Vegetation Classification described above, and field techniques were based on those recommended for that survey.

Sites were firstly surveyed by eye to identify stands of homogenous vegetation to be used as mappable units. Within these stands, vegetation was sampled using a 4 x 2 m quadrat, found to be the most appropriate size for the vegetation types encountered and consistent with the quadrat size previously adopted by Ferry & Walters (1985) at Dungeness. Wherever possible a minimum of five quadrats was placed in each stand of vegetation. However, in some cases size constraints permitted only a smaller number.

All species of vascular plants, bryophytes and lichens (excluding saxicolous lichens) were recorded for each quadrat and each species was allocated a cover/abundance score using the Domin scale. In addition soil depth and pH were noted along with vegetation height and any evidence of grazing. Target notes were used to describe any smaller features of interest, either physical or biological, which may provide a useful supplement to the quadrat data.

Site data, such as land use and any forms of disturbance, were collected at each site, while additional site information such as % of SSSI cover and past land use were recorded, based on information collected prior to fieldwork.

The quadrat data were entered into a computer programme that organised them into classificatory units suitable for mapping. The programmes used were TWINSPAN and TWINTAB as specified by NVC. These packages combine quadrats of similar floristic composition into groups and these groupings were then compared with those already identified by NVC keys and tables. These units were then used for mapping. The original data analysis was conducted on a data set of 3250 quadrats. Two methods for mapping were employed in the field. Where vertical aerial photographs were available at a suitable scale they were used directly: elsewhere units were sketched onto enlarged 1:10000 maps of the sites on which the position of individual quadrats were located.

Results

Twinspan analysis is a particularly valuable technique for classificatory purposes because it uses reciprocal averaging to define clearly axes of dissimilarity within data sets (Causton 1988). The original analysis identified 170 quadrats that readily subdivided further but left 3080 quadrats somewhat difficult to subdivide. The 170 quadrats were therefore excluded as they were readily identified as similar to NVC saltmarsh or maritime cliff communities. Such communities are found on shingle where it is adjacent to marsh sediments or where the shingle contains relatively high levels of sea bird guano.

A second run of analysis on the 3080 quadrats gave a stable first division of 948 - 2132 quadrat separation. Indeed, this analysis continued to be robust with few classificatory end groups emerging before the sixth level of division and with most end groups containing less than 30 quadrats by the tenth level. Where over 50 quadrats still remained together further analyses were conducted to test the level of homogeneity and in some cases a further division of classificatory units was accepted.

The mapped information resulting from these analyses are published in Sneddon & Randall (1993b) for Wales and (1994a, b) for England and Scotland. The classificatory tables derived from the Twinspan analyses and their descriptions are published in Sneddon & Randall (1993a). There are 25 sections into which the communities are grouped based on 6 major categories (pioneer, secondary pioneer, mature grasslands, grasslands, heath and scrub). In all 124 separate communities (SH1 - SH124) are recognised. The closest match to an NVC category is also shown for each community; though in some cases there is no good match. [A summary of the main types is provided in Table 08-01 below. Details of each of these communities are given in the main report (Sneddon & Randall 1993a)].

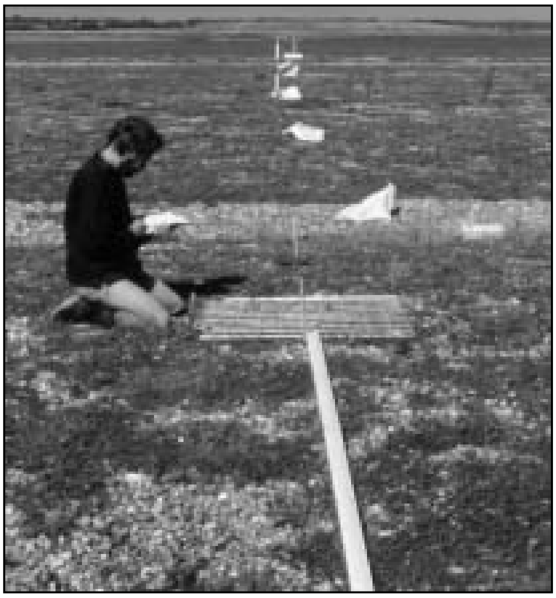
Table 08-01 Major divisions of the shingle vegetation classification. Divisions are listed in order broadly from the most landward to the most seaward vegetation types.

1. Scrub communities	la. *Prunus spinosa* communities lb. *Rubus fruticosus* communities lc. *Ulex europaeus* communities	
2. Heath communities	2a. Wet heaths 2b. Dry heaths	2b.i. *Pteridium aquilinum* 2b.ii. *Calluna vulgaris* communities 2b.iii Moss-rich communities
3. Grassland communities	3a. Saltmarsh-influenced grasslands 3b. *Agrostis stolonifera* grasslands 3c. *Arrhenatherum elatius* grasslands 3d. *Festuca rubra* grasslands 3e. Mixed grasslands 3f. Sandy grasslands	
4. Mature grassland communities	4a. Mature grasslands	4a.i. Mature grasslands - *Festuca rubra* 4a.ii. Mature grasslands - *Dicranum scoparium* 4a.iii. Mature grasslands - *Arrhenatherum elatius*
	4b. Less mature grasslands	4b.i. Less mature grasslands pure shingle 4b.ii. Less mature grassland saltmarsh influence
5. Secondary pioneer communities		
6. Pioneer communities	6a. *Honckenya peploides* dominated communities 6b. *Senecio viscosus* dominated communities 6c. *Beta vulgaris maritima* dominated communities 6d. *Raphanus maritimus* dominated communities 6e. Herb-dominated pioneer communities 6f. *Silene maritima* dominated pioneer communities	

Monitoring coastal vegetated shingle

The above techniques provide base-line surveys against which changes that may be occurring can be identified. Where change is identified or where management requires more specific monitoring to assess the effectiveness of treatment more detailed work may be required. Vegetated shingle is a designated habitat for HAP and several shingle species are recognised as Key Species in the National Species Action Plans. All sites should be recorded and monitored with these designations in mind. Some examples of specific monitoring techniques applied to coastal vegetated shingle are summarised below.

Permanent Transects and Quadrats



Where it is felt important to monitor change in a particular location within a site, permanent, relocatable quadrats may be set up. These can be placed randomly or systematically along a transect (Figure 08-01). Fuller & Randall (1988) assessing conflicts in coastal conservation used this latter method at Orfordness. In this study 10 relocatable vegetation transects were positioned to include all 5 shingle plant communities previously recorded and 45 10 x 10 m quadrats were recorded at the middle point of each vegetation zone. Presence/absence and species' percentage cover were recorded along with pebble size, litter type and disturbance. Ridges and lows were treated separately. Subsequently a continuous ribbon of 2 x2 m quadrats was run across the widest part of Orfordness spit to record the plant communities that were previously heavily disturbed within the old MOD fenceline.

Figure 08-01 Transect survey Orfordness using quadrats. The location of the transect (3.5) is shown in Figure 08-02 below.

This work helped to elucidate the essential conditions for plant growth on the 'inhospitable' shingle substratum. All these can be the basis of long-term monitoring programmes. Permanent sample plots must have their location marked on the ground or tied in to some permanent marker that can be relocated with accuracy. 'Permanent' may mean a season, a year or even a decade or more. Permanent quadrats may be constructed as 'exclosure quadrats' if grazing interference is to be avoided.

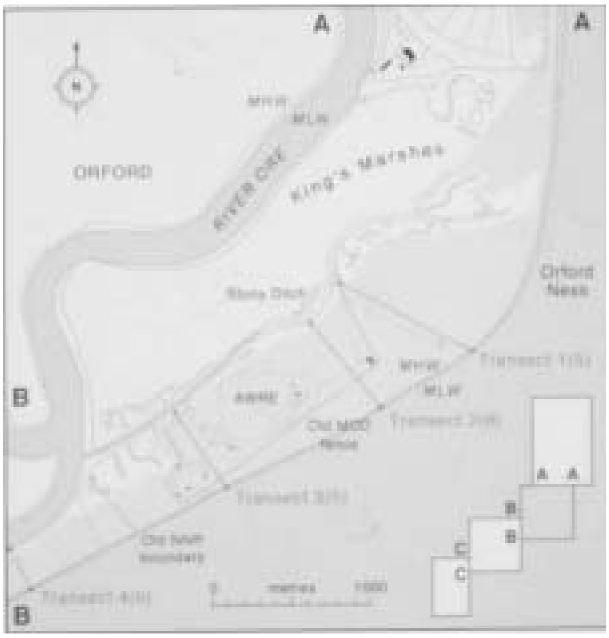


Figure 08-02 The location of transect 3.5 on Orfordness

Fixed point photography

A useful monitoring technique is to set up a series of locations from which to take repeatable photographs on a seasonal basis on approximately the same dates each year. These can be tied in with permanent quadrats or transects. The key to all these approaches lies in the consistency (location, lens focus, direction and height) of approach, the periodicity of photographs and the timescale over which these are taken. The real value of this approach lies in the timescale over which the photographs are taken - the longer the better. When combined with historical information and maps they can be invaluable.

Animal data

A variety of techniques are available to survey animals on shingle structures and beaches. Surveys of invertebrates and birds can be of value in helping to determine management.

Invertebrate surveys

To date, most effort to understand the ecology of shingle systems has been confined to botanical evaluation. Detailed recording is largely confined to Dungeness and Rye Harbour (Morris & Parsons 1991, 1992). However, ad hoc surveys and collecting activity by a variety of recorders provide wider indications of the faunas of some shingle systems (Shardlow [2001] provides an overview). There is considerable scope to expand our understanding of the invertebrate assemblages on particular sites.

The majority of invertebrate groups are represented on shingle structures, but some offer better opportunities for comparative studies and to put individual sites into context. These include the spiders, beetles and bees, wasps and ants, which are all readily taken in static traps. The lepidoptera (moths and butterflies) are also well represented, but are mostly taken at light traps or through active searching for larval stages.

Shingle is, however, extremely difficult to sample. The most effective quantitative sampling on shingle is trapping using pitfall and water traps, but a very large number of replicates are needed to yield statistically significant results. This has important logistic implications and means that detailed surveys will be comparatively expensive. Invertebrate surveys are highly specialised and require strong taxonomic and field craft skills. General netting and searching does not readily yield many specimens, but can be useful to augment the results from static traps. A specialist with knowledge of what to look for will greatly increase the level of understanding of taxa with more specialist habitat requirements or those of a more retiring nature.

There are strong possibilities that southern shingle systems in particular will yield a range of important records. This is because they lie at the extreme of the continental range of many species and are highly thermophilic, favouring those taxa that can cope effectively with extreme temperature fluctuations. The nature of the shingle matrix, including levels of finer sediment within the matrix, influence plant communities and vegetation structure, which in turn has a bearing on the invertebrate assemblage.

Whilst invertebrate surveys often lead to the removal of substantial numbers of individuals, this is an unfortunate necessity. Many species can only be determined with confidence following dissection. If substantial numbers of a rare species are taken, consideration should be given to moving traps. However, the levels of trapping that are likely to be afforded are unlikely to significantly affect populations.

Bird surveys

Surveying birds can be undertaken using less specialist recorders. However, it is important that pitfalls in methods and study design are avoided. Bibby, Burgess & Hill (1992) have produced a detailed description of bird census techniques and have good examples of census forms for ‘seabird colony registers’ and transect techniques for 'apparently occupied nest sites'. Special methodologies for gulls and terns are described. For most colonial species that nest on shingle, a single count of the site in June provides a good estimation of numbers. However, repeat counts of dense colonies on different days are a valuable way of checking results. For resident or passage migrant species, monthly or annual bird counts should be carried out using standard methodologies. The important questions to ask in bird survey are:

- what is the purpose of the study;

- what field methods are affordable;
- what are the likely sources of bias;
- will the information give enough detail for analysis to work?

Gibbons, Hill & Sutherland (1996) detail the most useful answers to these questions and should be consulted before survey is undertaken in order to avoid the collection of unusable data. What is important about all species monitoring is that it will enable management to be carried out in relation to groups/species that are rare or seen to be suffering change rather than those that are merely spectacular!

What is important about all species monitoring is that it will enable management to be carried out in relation to groups/species that are rare or seen to be suffering change rather than those that are merely spectacular!

The UK Common Standards Monitoring programme

The above discussion is not exhaustive and other more specific prescriptions for monitoring coastal vegetated shingle are not available. Approaches which provide guidance on monitoring geomorphological characteristics are also not well documented. However, the Habitat Restoration Monitoring Handbook (Mitchley et al. 2000) provides a general, systematic approach to recording change, which is largely concerned with terrestrial areas. The UK government conservation organisations (English Nature, Scottish Natural Heritage, Countryside Council for Wales and the Environment Heritage Service in Northern Ireland) have been working on producing a Common Standards Monitoring (CSM) guidance for designated sites, under the direction of JNCC (more details on CSM can be found on the JNCC website). A summary of the guidance so far produced is given next.

Attributes and targets

A series of broad habitat attributes have been defined that should normally be part of the conservation objectives or the management plan for all sites where vegetated shingle is an interest feature.

There should normally be at least one target specified for each of the attributes. The targets set out here are for guidance only. They should be interpreted in terms of local knowledge of the site, its history and its surroundings. When a target is not applicable to a particular site it should be ignored, but a record of why the decision was taken should be made.

For vegetated shingle the mandatory attributes are:

- habitat extent;
- geomorphological naturalness;
- zonation of vegetation;
- vegetation composition for each vegetation zone;
- negative indicators (negative indicator species and signs of disturbance).

The presence of rare species (vascular plants) is considered to be a discretionary attribute. It will not be appropriate to use these ‘quality indicators’ on every vegetated shingle site, but where they are part of the reason for notification of the feature they should form an integral part (mandatory) of the condition assessment.

Guidance is given in the following sections as to what needs to be considered for the above attributes and, where appropriate, some examples are provided of the sorts of targets that should be set.

Recommended visiting period and frequency of visits.

The suggested visiting period is April to August, although annuals, such as *Arenaria serpyllifolia* will flower earlier and perennials e.g. *Crambe maritima* later and where driftline annuals are more abundant this will need to be taken into account.

Monitoring methods

Preparation

Prior to going out in the field collate existing information on your site. Aerial photographs (and possibly satellite images, see below) are particularly useful. Some NVC information should be available for most sites. Sneddon and Randall carried out a comprehensive survey in 1993 (see above) but other information may exist for individual sites. The use of the oblique aerial photographs in the DEFRA Futurecoast CD-ROM also provide an important record to allow familiarisation with difficult to access sites and to help place the feature in the context of the coastal environment.

Guidance: Read the guidance prior to the field visit, to familiarise yourself with what is required. You will need to tailor the assessment forms to your site.

Habitat extent should be assessed using any previous information available, preferably aerial photographs. If none is available this first reporting round must form the baseline. The source of the baseline must be clearly identified - aerial photography should include source, date (at least month and year) and scale. Field trials have shown that failure to provide some of this information may mean change cannot be measured with respect to the first round.

The assessment of zonation by transect should be done after the structured walks to assess sward composition and negative indicators of each vegetated shingle habitat as at that stage you will be more familiar with the vegetation at the site (see below).

In the field

It is recommended that the vegetation composition, negative indicators etc. of the two principal vegetated shingle ‘zones’ (annual vegetation of driftlines and perennial vegetation of stony banks) be assessed using a **structured walk** (e.g. a W shaped walk) with at least 10 stops within each assessment unit (block, management unit etc.) to avoid excessively variable results. The number of stops should be enough to allow the assessor to have an overview of the site and judge the condition of the feature. To avoid subjectivity in selecting stops and to ensure that as wide an area as possible is covered general routes with stops should be pre-selected based on a map or aerial photograph before the field visit. This also allows the number of stops per unit area to be determined more consistently. The **exact** stopping locations will be recorded in the field using GPS if possible. If contractors are using the guidance then consultation with local staff on route selection and stopping points is **mandatory**.

At each stop, the appropriate attributes (e.g. percentage cover and/or presence of relevant species) should be assessed within approximate 4 m^2 sampling units. There is no need to measure cover values precisely – simple visual estimates will suffice. It should not take very long (no more than 5 minutes) to record all the relevant attributes at each ‘stop’.

The recommended methods of selecting the number and location of the stops are not intended to have statistical value, and the final condition of the interest feature is not simply the average of the condition of each stop. On the contrary, each stop should contribute to improve the assessor’s overview of the state of the site. The following is a quantitative definition of frequency, intended to assist with the assessment of several of the saltmarsh attributes. This is a version of the well known DAFOR scale, which has been adapted to the particular characteristics of vegetated shingle as follows:

- **Dominant:** the species appears at most (>60%) stops and it covers more than 50% of each sampling unit;
- **Abundant:** species occurs regularly throughout a stand, at most (>60%) stops and its cover is less than 50% of each sampling unit;
- **Frequent:** species recorded from 31-60% of stops;
- **Occasional:** species recorded from 11-30% of stops.
- **Rare:** species recorded from up to 10% of stops.

Having completed the rapid assessments for the quality of the main vegetated shingle ‘zones’ it should then be relatively straightforward to do the one or more **transects** required to assess the width of the saltmarsh zones. If there is no prior data on the width of these habitats for your site, this assessment can form a crude baseline.

The routes followed for the structured walk and the start and finish points for the transects, should be marked on a map for future comparative use. Ideally these should be traced over aerial photos of the site using GIS, to enable comparisons on future visits. Permanent markers could be used to aid orientation in this respect. Comparisons could be made using set bearings from a given permanent marker – the owner/occupier could be asked not to destroy or remove particular makers (pill boxes etc) that could be used (although loss due to erosion will have to be accepted). Some landmarks may already be used as permanent markers for surveys by local authorities, the Environment Agency or universities.

Photographs are essential to the condition assessment and should be taken as an accompanying record wherever possible. These should be archived with the assessment file. In some countries photography is a mandatory part of the condition assessment.

There are several technologies involving remote sensing, which are being trialled to aid the condition assessment process, such as CASI and LIDAR (see below). These may provide a very useful tool for assessing zonation as well as extent.

The reporting unit

The assessment should be applied to the reporting unit, which is at present an SSSI site unit. However, where there is erosion in one unit and, following the key for extent shown below, it was assessed as unfavourable, it could be judged favourable **provided** it is certain that there is at least equal accretion in other units on the same site.

Habitat extent

Extent of the vegetated shingle is a fundamental attribute to be assessed in determining condition of the vegetated shingle feature. The target is no decrease in extent from the established baseline with the caveat ‘subject to natural change’. There is a need to ensure that natural processes govern the system, and that the geomorphological ‘health’ of the feature is considered. However, the extent of the vegetation may be subject to periodic and seasonal variation, as natural processes re-distribute shingle sediments and change sediment composition. Extent of the driftline may be particularly difficult to assess as the community can vary enormously from year to year. The sparse nature of the vegetation and its seasonal appearance makes it difficult to detect on aerial photographs, but remote sensing images may be available. Driftlines on essentially sandy beaches are assessed within the sequence of sand dune communities. **The aim is to identify anthropogenic from natural processes which may be causing the feature to move away from favourable condition.**

Shingle deposits are dynamic and will adjust and respond to climatic changes (such as a rise in sea level) or local changes in wind and wave energy in an attempt to reach ‘geomorphological equilibrium’, which may include landward transgression. If this response is constrained by anthropogenic constructions such as fixed sea defences or infrastructures, natural habitat migration is prevented (‘coastal squeeze’). The ensuing loss of extent would fail the extent attribute, as the feature is prevented reaching a natural geomorphological equilibrium. However, if landward migration is prevented by a feature such as higher ground, this would be considered as favourable for the extent attribute (the shingle deposits are free to respond and reach a natural geomorphological equilibrium). The shingle structure might breach in response to ambient and storm effects, which would constitute ‘roll over’ - literally over landward habitat types including saltmarsh or sand dune.

The amount of offshore sediment available will also determine response of the system to such changes. There are other activities which may affect sediment supply, such as dredging see Chapter 03.

Zonation

The aim of this assessment is to detect negative trends arising from anthropogenic influences which are causing a long term decline in the habitat. One indicator involves assessing changes in the natural zonation of the habitats. Changes should be interpreted with great care given the dynamic nature of the vegetated shingle feature and in particular the driftline.

Vegetated shingle can usually be broken down into annual vegetation of driftlines and perennial vegetation of stony banks; however the NVC only describes part of the pioneer phase of perennial shingle vegetation, namely SD1 *Rumex crispus – Glaucium flavum* shingle community. Where a site has other communities, such as grassland, heathland or scrub these will need to be included in the overall assessment of zonation at the site.

Zonation of the vegetated shingle at some key points, using transects, will be assessed. The location of the transects is fixed by GPS, which means they can be easily relocated for future assessments. If a baseline is not available from an existing NVC survey, the condition assessment will form the new baseline. GPS information should be collected and marked on a map, and this should enable the width of the zones to be estimated.

Vegetation composition

After stability, the development of shingle vegetation is dependent on water availability, which is primarily controlled by the proportion and size of the fine fraction material of the matrix under 2mm in diameter. The matrix is usually composed of sand, silt or organic matter. The fine fraction is critical at germination and seedling stages, since without it enough moisture may not be present for growth to be initiated or to continue. The presence of finer particles of sand or detritus is essential for the development of the extensive absorptive roots most shingle plants need to thrive.

The greater expanse and stability on the largest and most stable structures results in a more complex development of vegetation over time. The sequence of vegetation may include long-lived perennials such as broom *Cytisus scoparius*, gorse *Ulex europeus*, and blackthorn *Prunus spinosa*. Heath vegetation with heather *Calluna vulgaris* and/or crowberry *Empetrum nigrum* can also occur, particularly in the north. The sequence of plant communities is influenced by natural cycles of degeneration and regeneration of the shrub vegetation that occurs on some of the oldest ridges. Sneddon and Randall (1991) gave a comprehensive description of stable shingle vegetation (see Table 02-01 above).

Vegetation composition - indicators of negative trends

There is a wide potential variation in the vegetation on more stable shingle banks, and invasion by many undesirable species is possible. Possible species occurring could be *Cirsium vulgare*, *Senecio jacobea* or *Pteridium aquilinum*; even gorse *Ulex europeus* can become a problem if the proportion becomes too high (e.g. over 10 % at Ballyquintin Point in County Down), although this would need to be done on a site-by site basis. *Lupinus arboreus* and *Tamarix gallica* are other introduced species on vegetated shingle.

Transitions to terrestrial habitats

A variety of terrestrial habitat types, such as heathland, grasslands etc. may be part of the vegetated shingle feature. However, transitions to other habitats such as saltmarsh, sand dune or M28 *Iris pseudacorus* mire may be present. Targets should be set according to conservation objectives or the management plan.

Other negative indicators:

In addition to observations on negative indicator species other negative indicators should be noted such as:

- signs of disturbance;
- vehicle damage or trampling at vulnerable locations (tracks, access points).

Indicators of local distinctiveness

Quality indicators are features of a shingle that make it 'special' but which are not covered by the attributes already described. They should be apparent from the SSSI citations or past surveys. This is a discretionary attribute in that it may not be applicable to every site; but where local distinctiveness has contributed to the selection of a site for shingle it should be mandatory. The target(s) should be tailored to each site. Quality indicators may include the following:

- notable species which are not notified features in their own right;
- structural attributes;
- associations between vegetated shingle and other habitats, e.g. mosaics of vegetation types, transitions to heath or freshwater reedbed.

Recording field forms

The countryside agencies will supply separate field recording forms that fit within the objectives detailed in this guidance.

It is advisable to record as much information as resources and time allow in a consistent manner during different visits and to keep all the records in a file. This will provide a track of the history of the condition of the site in relation to management. The route of the 'W' walk and transects should be marked on a map and photographs taken, especially of the more dynamic parts of the habitat.

The tables provided are for guidance only. Lists of species should be produced on a site-specific basis, and the assessment should be carried out based on the particular conservation objectives tables or management plans.

Use of satellites and other remote sensed images

Land based surveys are time consuming, especially where national data are being collected. A survey of saltmarsh vegetation in Great Britain (Burd 1989) took eight years to complete. Monitoring saltmarsh change in southeast England between 1972 and 1988 (Burd 1992) was expensive and time consuming. Neither study is likely to be repeated using traditional survey techniques. Other methods of large scale, more frequent survey would be more appropriate. In this context satellites may provide a possible alternative.

In the UK this approach has been initiated by English Nature and the Environment Agency National Centre for Environmental Data and Surveillance (NCEDS). The study has used combined LIDAR and CASI data collected by airborne instruments. These results need to be further investigated and extended.

CASI - **C**ompact **A**irborne **S**pectrographic **I**mager is a sensor which detects visible and near infrared electromagnetic energy reflected from the surface of the earth. The images provide information on ground-cover types to a high resolution. The imagery can also be located with a high degree of accuracy using a Global Positioning System (GPS).
LiDaR - **Li**ght **D**etection **a**nd **R**anging - is an airborne mapping technique using lasers to measure the distance from the aircraft to the ground. The results are presented in the form of a terrain map. It also provides information on coastal erosion and geomorphology.

The recent launch of ENVISAT should help provide an overview of the coast. There are several projects testing the value of this system and in time more use may be made, for example, in surveying and monitoring change at the coast. When combined with lower level airborne instruments a powerful tool could be developed. There is already calibration of remote sensed images for saltmarshes and it should easily be possible to use this approach for other coastal habitats. The issue needs to be addressed by a concerted effort, which brings together those who have knowledge of the coastal environment and those with technical expertise in remote sensing and GIS.

'Coastwatch'

The European Space Agency (European Space Research Institute) has recently let a service contract to a consortium led by the European Aeronautics Defence and Space Company (Systems and Defence Electronics) to provide an Environmental Monitoring Service for European coasts called 'Coastwatch'. The programme will focus on management and monitoring of the coastal zones of Europe. The area will include the land and the sea and provide information on specific coastal indicators, changes in land-cover, monitoring of erosion states, water condition monitoring and sea state dynamics. The policy sectors will include the Water Framework Directive, the Habitats and Species Directives and the Common Agricultural Policy. The approach taken will include the whole coastal zone, whilst at the same time responding to specific and multi-sectoral needs and providing information for user groups at all administrative levels. It is an ambitious project, starting in mid 2003.

References:

Baker, J.M., Hartley, J.P. & Dicks, B., 1987 Planning biological surveys. In: *Biological surveys of estuaries and coasts*, eds. Baker, J.M. & Wolff, W.J. University Press, Cambridge.

Bibby, C.J., Burgess, N.D. & Hill, D.A., 1992. *Bird Census Techniques*. Academic Press Ltd,. London

Brady, N.C., 1974 *The Nature and Properties of Soils.* Macmillan, New York

Burd, F., 1989. *The Saltmarsh Survey of Great Britain. An Inventory of British Saltmarshes*. Research & survey in nature conservation, **17**, Nature Conservancy Council, Peterborough.

Burd, F., 1992. *Erosion and Vegetation Change on the Saltmarshes of Essex and North Kent between 1973 and 1988*. Research & survey in nature conservation, **42**, Nature Conservancy Council, Peterborough.

Burnham, C.P & Cook, H.F., 2001. Hydrology and soils of coastal shingle with specific reference to Dungeness. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 107-131.

Causton, D.R., 1988. *Introduction to Vegetation Analysis*. Unwin Hyman Ltd., London.

Courtney, F.M. & Trudgill, S.T., 1984 *The Soil: an Introduction to Soil Study*. Edward Arnold, London

Digby, P.G.N. & Kempton, R.A., 1987 *Multivariate Analysis of Ecological Communities.* Chapman & Hall, London.

Dobson, F., 1992 *Lichens. An Illustrated Guide.* Richmond Publishing Co. Ltd., Richmond.

Ferry, B.W., Barlow, S.L. & Waters, S.J.P., 1989. The shingle ridge succession at Dungeness. In: *Dungeness - the Ecology of a Shingle Beach*, Eds. B.W. Ferry, S.J.P. Waters & S.L. Jury. *Botanical Journal of the Linnean Society*, **101**, 19-30.

Ferry, B. & Waters, S., 1985. *Dungeness ecology and conservation*. Focus on Nature Conservation, **No 12**: Nature Conservancy Council, Peterborough, 144 pp.

Ferry, B., Lodge, N. & Waters, S., 1990. *Dungeness: a Vegetation Survey of a Shingle Beach*. Research & survey in nature conservation, No. **26**. Nature Conservancy Council, Peterborough.

Fuller R.M. & Randall R.E., 1988. The Orford Shingles, Suffolk, UK – classic conflicts in coastline management. *Biological Conservation*, **46**: 95-114.

Gibbons, D.W., Hill, D. & Sutherland, W.J. (1996) Birds. In: Sutherland, W.J. ed. *Ecological Census Techniques: a Handbook*. University Press, Cambridge.
Kershaw, K.A. & Looney, J.H.H., 1985 *Quantitative and dynamic plant ecology, 3rd ed..* Arnold, London
Kirby, P., 1992. *Habitat Management for Invertebrates: a Practical Handbook*. Joint Nature Conservation Committee, Peterborough, RSPB, Sandy, Bedfordshire.
Mitchley, J., Burch, F., Buckley, P. & Watt, T.A., 2000. *Habitat Restoration Monitoring Handbook*. English Nature Research Reports No. 378, Peterborough, 26pp.
Morris, R.K.A., & Parsons, M.S., 1991. *An inventory of the invertebrate fauna of the shingle beaches at Dungeness (Kent), Rye Harbour (E. Sussex) and Orford Ness (Suffolk)*. Contract Survey No. **135**. The Nature Conservancy Council, Peterborough.
Morris, R.K.A., & Parsons, M.S., 1992. *A survey of invertebrate communities on the shingle of Dungeness, Rye Harbour and & Orford Ness*. NCC Report No. **77**. Joint Nature Conservation Committee, Peterborough.
Mueller-Dombois, D. & Ellenberg, H., 1974 *Aims and Methods of Vegetation Ecology*. John Wiley, New York.
Neal, A., Dackombe, R.V. & Roberts, C.L., 2001 Applications of ground-penetrating radar (GPR) to the study of coarse clastic (shingle) coastal structures. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 77-106.
Philp, E.G. & McLean, I.F.G., 1985. The invertebrate fauna of Dungeness. In: *Dungeness: ecology and conservation*, eds., B. Ferry & S. Waters, Focus on nature conservation, **12**, Nature Conservancy Council, Peterborough, 94-135.
Randall, R.E. & Fuller, R.M., 2001. The Orford shingles, Suffolk, UK: evolving solutions in coastline management. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, pp. 242-260.
Randall, R.E., 1977. Shingle formations. In: Barnes, R.S.K., ed. *The Coastline*. Wiley, London.
Rodwell, J., 2000. *British Plant Communities, Volume 5. Maritime Communities and Vegetation of Open Habitats*. Cambridge University Press, Cambridge.
Shardlow, M., 2001. A review of the conservation importance of shingle habitats for invertebrates in the United Kingdom. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, 355-376.
Sneddon, P., 1992. *Variations in shingle vegetation around the British Coastline*. PhD. Thesis, University of Cambridge.
Sneddon, P & Randall, R.E., 1993a. *Coastal vegetation shingle structures of Great Britain: Main Report*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P & Randall, R.E., 1993b. *Vegetated shingle structures survey of Great Britain: Appendix 1 - Wales*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P & Randall, R.E., 1994a. *Vegetated shingle structures survey of Great Britain: Appendix 2 - Scotland*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P & Randall, R.E., 1994b. *Vegetated shingle structures survey of Great Britain*: *Appendix 3 - England*. Joint Nature Conservation Committee, Peterborough.
Stace, C. 1997 *New Flora of the British Isles, 2nd edn.* University Press, Cambridge.
Sutherland, W.J. ed. 1996 *Ecological Census Techniques: a handbook*. University Press, Cambridge.
Watson, E.V., 1968 *British Mosses and Liverworts.* University Press, Cambridge.

Chapter 09 Conclusions and knowledge gaps

The first eight chapters of the report provide a summary of the existing knowledge of the coastal vegetated shingle habitat, giving guidance on habitat management and restoration. This is largely based on existing information, supplemented by the reviews of casework at the six sites (Annexes 01-06) visited by the contractors together with the additional sites (Annexes 07-09). This section of the report provides some general conclusions. It also attempts to assess the extent to which current practices have or will help meet the targets identified in the UK Vegetated Shingle Habitat Action Plan (**HAP**). Based on this assessment knowledge gaps are identified, including those involving monitoring the impact of flood management schemes and the effectiveness of habitat enhancement/creation works. It begins by looking at the wider information needs before considering the more specific requirements for individual sites and species.

Habitat loss versus 'coastal' change

Chapter 05 provides a broad indication of the losses, which have been suffered by vegetated shingle beaches and structures as a result of human action. It also highlights the important management issues that need to be addressed when attempting to conserve the habitat and its associated species. Habitat Action Plan Target 1 (opposite) is now much more likely to be achieved as the protective legislation, notably strengthening the SSSI designation and the 'Habitats' Directive is more strictly enforced. For some of the most important sites, e.g. Orfordness and Dungeness ownership and / or National Nature Reserve status should help ensure that further major losses do not occur.

> **HAP Target 1 -** *"Prevent further net loss of existing vegetated shingle structures totalling about 5800 ha. (However local gains and losses due to storm events occur sporadically and should be accepted provided that the national and regional resources are maintained overall.)*

The target also recognises the fact that natural events will cause changes to shingle features as erosion and deposition takes place. It would seem that a thorough review of this situation is needed to establish the 'context' in which the shingle features exist and potential long term declines in extent due entirely to natural changes. This may be particularly important in areas where sea level is known to be rising relative to the land.

The importance of understanding context

It is clear from the discussions so far, that the information obtained from the site studies when augmented by Futurecoast and the Executive Summaries for those CHaMPs overlapping with the study sites (Dungeness, Annex 05a, Orfordness, 06a and in relation to the Cley-Salthouse realignment Annex 07) that for many, if not most shingle beach and structure systems, sediment supply is limited. At some of the sites there may be no new sediment at all and the structures are relict features deriving from material deposited during the last Ice-Age. This certainly appears to be the case for two of the sites studied for this contract at Porlock (Annex 01) and in Start Bay Slapton (Annex 02). At the other sites on the south coast of England and at Orfordness although new material from cliff and shore platform erosion is available, the quantities appear to be insufficient to maintain the integrity of the systems. In several instances human intervention appears to have been instrumental in exacerbating erosional trends (e.g. Start Bay, Annex 02).

Coastal Cells

In recent years the concept of 'Coastal Cells' has developed in the UK. These represent a series of interlinked systems where sediment is moved around the coast by waves and currents (sediment transport cells). The cells and sub-cells that have been identified for England and Wales and Scotland comprise an arrangement of:

- sediment sources (e.g. eroding cliffs, river, sea bed);
- areas where sediment is moved by coastal processes;
- sediment stores or sinks (e.g. beaches, estuaries and offshore banks).

Together these have been used to define practical subdivisions of the coast (Figure 09-01) important for developing policy for Shoreline Management Plans. The Government has promoted the formation of voluntary coastal defence groups around these coastal cells made up of maritime district authorities and other bodies with coastal defence responsibilities. As part of this approach, DEFRA (2001) has issued guidance for maritime district authorities to help in the preparation of Shoreline Management Plans (SMPs) see http://www.defra.gov.uk/environ/fcd/policy/CoastalGroups.htm.

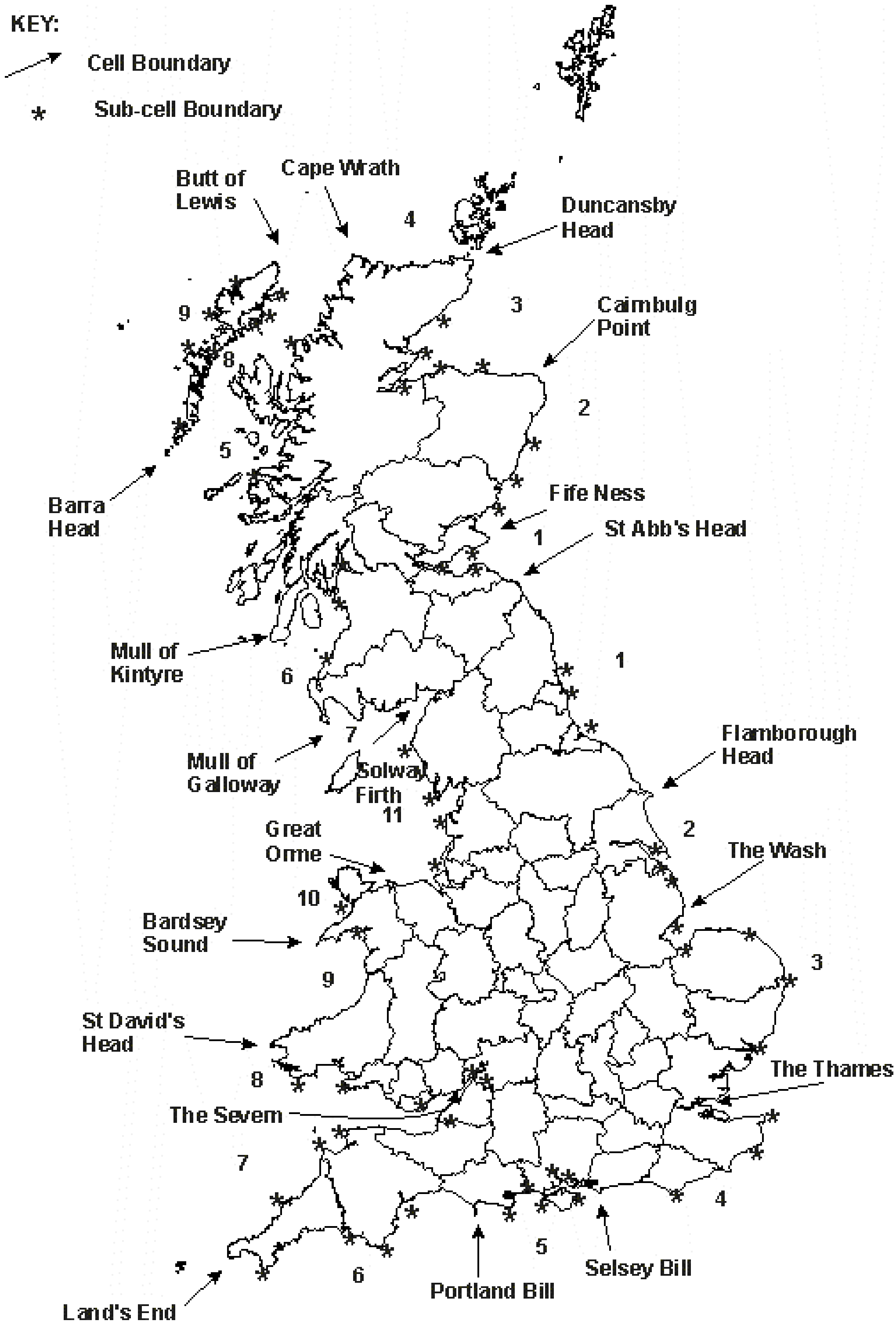


Figure 09-01 Coastal Cells and sub-cells in Great Britain.

Futurecoast

The Department of Environment, Food and Rural Affairs (DEFRA) and the National Assembly for Wales have recently collaborated on the promotion of a coastal process and geomorphological study of the coastline of England and Wales, called Futurecoast (see http://www.defra.gov.uk/environ/fcd/research/futurecoast.htm). The results of this project (Halcrow 2003) have recently been made available to selected organisations such as English Nature. Essentially it provides a linear view of the coastline of England and Wales at or around High Water. Included within it are assessments of the progression of the coastline based on maps of the location of the shoreline at different dates (derived from Ordnance Survey and Hydrographic Office data). These provide an indication of the way in which the coast is likely to react under different scenarios specifically in relation to the five generic policy options adopted by DEFRA as part of the development of Shoreline Management Plans.

Coastal Habitat Management Plans - CHaMPs

Of the 14 areas identified for the development of ChaMPs, 7 were chosen as pilot projects under a LIFE Nature funded project with English Nature, the Environment Agency and DEFRA.

The Executive Summary for each of these projects has recently been made available on the WEB (see EN ‘Living with the Seas’ project http://www.english-nature.org.uk/livingwiththesea/default.htm). These provide excellent overviews of the key factors determining the direction of the evolution of the coast and the likely consequences of adopting different shoreline management policies for each CHaMP. Those covering the study site reviewed for this contract are included as Annex 05a, 06a and 07a of this report.

Near-surface patterns of sea-water movement

The Ministry of Agriculture, Fisheries and Food (MAFF) (1981) produced a map of nearshore water movements (Figure 09-02) which goes some way towards explaining the five regional sectors that Sneddon (1992) discovered within the major community types of British shingle vegetation (Figure 09-03). More studies are needed on the importance of coastal currents in seed dispersal of shingle species, but enough is already known to highlight the importance of shingle vegetation management within the context of these regional sectors.

Figure 09-02 General near-surface pattern of water movement around the coast of the UK (after MAFF 1981).

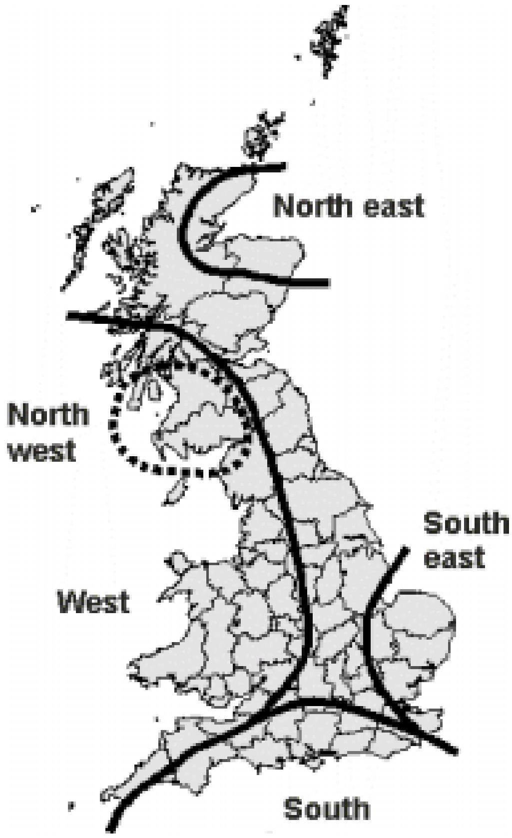


Figure 09-03 Regional sectors for vegetated shingle vegetation in Great Britain derived from the analysis of plant community data. Note there is no eastern section because of the absence of anything other than isolated, small shingle deposits along this stretch of coast.

The importance of context

It is clear from the above that here has been an increasing use of the knowledge derived from taking a wider view of the management of the coastal zone and for the understanding of shingle structures and their associated communities.

> Recommendation: These broad geographical zones should be used to provide sectors for the further assessment of change and the conservation needs of coastal vegetated shingle. The results of Futurecoast, the CHaMPs and the new generation of SMPs are valuable sources of information. In this context the recent comprehensive Regional Environmental Assessment of the cumulative impacts of planning applications to dredge offshore from the Sussex coast by the companies involved (Chapter 03 page 29) could prove to be an important initiative.

Armed with this **contextual** information decisions on future coast defence policy and planning issues such as siting of coastal development, will be better informed.

The reasoning behind this recommendation, from a biodiversity perspective at least, lies in the several ways in which such information can be used, namely:

1. helping to tease out human versus 'natural' evolution of the coastal shingle systems and with it the assessment of compliance with the HAP Target for the conservation of vegetated shingle habitat;
2. identifying and assessing potential areas where it would be appropriate for the development of new or restored habitat by allowing coastal processes of erosion and/or accretion to take place;
3. identifying areas where it would be inappropriate for 'nature to be allowed to take its course';

4. providing a link between the formation of the shingle structures and the development and management needs of the vegetation;
5. setting British shingle systems, and foreseeable changes to them, in a European and a World context.

This approach could be taken forward and included in the review of opportunities for biodiversity enhancement within ‘natural areas’ being undertaken by English Nature in the context of the development of the second generation Shoreline Management Plans. It also provides an essential component of all policy reviews for coastal areas and could be promoted through the EURosion Project (see http://www.eurosion.org/index.html), which is attempting to provide policy guidance for the European Union on coastal management of dynamic shores.

Sediment budgets

Determining sediment budgets is an important part of understanding the implications of a particular series of events or the likely outcome of human actions of coastal vegetated shingle. These studies have included work in both the coastal and nearshore environments as well as further offshore.

Coastal erosion studies

Some studies have attempted to provide sediment budgets for coastal systems as far dispersed as the Channel coast (the BERM project, southeast England has been described in Chapter 03) and Spey Bay in northeast Scotland (Annex 07). The former attempts to identify the contribution of contemporary material, derived from eroding cliffs to the integrity of the shingle beaches, whilst the latter takes a more wide-ranging view including sediment derived from the hinterland and the relationship between coastal processes and human coastal defence activities. The work of the BERM project is being continued and expanded upon to include work on biodiversity through the INTERREG III Beaches at Risk (BAR) Project.

Offshore sediment studies

The movement of sediment offshore has been studied by HR Wallingford in the “Southern North Sea Sediment Transport Study, Phase 2”. This work looked at the implications of offshore dredging for marine aggregates on the marine environment. However, although not part of the remit of the study it recognised the importance of considering in detail… “*the possible physical effects of offshore dredging with particular regard to how such operations might alter waves, tidal currents, sediment transport and morphological changes of the seabed and along the coast. The results from such an assessment can be used to determine the likely effect on beaches and coastal defences*.” (Information available from HR Wallingford web site where the results of the study can be downloaded @ http://www.sns2.org/project-outputs.html). At a regional scale (Brampton & Evans 1998) provide insights into the way sediment moves offshore.

It seems clear that managing coastal shingle deposits whether for sea defence or nature conservation, must take into account the contemporary contribution of material to the coast. Since this will be derived from or affected by the action of tides, winds and waves it is not only important to know how much is coming from erosion of the land, but also from the sea. The studies mentioned above provide some indication of the way in which the systems operate. However the link between the land-based and marine sources has not been made.

Recommendation: The implications of offshore dredging to the stability of the coast are implicit in the recommendations made for the revised Government View procedure and the production of an independent ‘Coastal Impact Study’ recognises this importance. Wide-ranging reviews of the sediment budget should be undertaken of the inter-relationships between offshore sediment movement and coastal change (erosion and accretion) in all areas where marine aggregate extraction is, or could take place. These should include offshore deposits and their relationship with onshore contemporary contributions to beach volume, for example derived from eroding cliffs.

The unpredictable

It is important to realise that understanding the inter-relationship between sediment budgets, the patterns of sediment movement and coastal change, is only part of the information need. Coastal process studies help to elucidate the nature and patterns of movement and the role they play in determining the geomorphic and ecologic patterns on coastal shingle. However, these processes can be severely disrupted by unpredictable and unforeseen events such as storms and storm surges. Having established the broad context for individual sectors of the coast it is suggested a vulnerability assessment could be made at progressively more detailed scales, including the coastal sub-cells.

Recommendation: Consideration should be given to providing a comprehensive and wide-ranging review based on existing sources of information (including Futurecoast and the detailed studies associated with SMPs and CHaMPs) of the vulnerability of shingle coasts to storms and other unpredictable events. This would contribute to the ongoing debate taking place at the European level through the EU funded EURosion project. [EURosion is attempting to identify at a European scale areas sensitive to erosion and/or flooding by virtue of their elevation, physical makeup, geomorphological characteristics and the rates of sea level change or incidence of storms. This information will in turn be used to identify appropriate policy responses, given the needs of the coast i.e. whether it is economically or environmentally significant.]

Control of visitors and other local activities

The site casework and general knowledge of the effect of localised recreational activities on shingle is well documented. In this study the situation at Rye and Pagham Harbours are particularly informative. Although there are many methods for controlling access and preventing other forms of damage it would appear that communication of the importance of shingle and the reasons for conserving the habitat, remains a key requirement for this habitat when considering meeting HAP Target 2, opposite.

HAP Target 2 - *“Prevent, where possible, further exploitation of, or damage to, existing vegetated shingle sites through human activities.*

Communications and publicity

It is extremely important to increase public awareness of the value and fragility of vegetated shingle through on-site interpretation. Although this has been carried out at some sites, to a limited extent, there is still much to be learned concerning the psychology of the use of public information notices what to say, how to say it, where to put car parks, interpretive boards etc. The reaction of British people is such that too terse information such as ‘keep off’ or ‘no entry’, which might be effective in Germany or Scandinavia, has little effect. Detailed information tends to put off the average visitor who only requires limited information, which is to the point. The examples of Nelson in New Zealand and Suffolk, England provide two contrasting examples which illustrate the point (Figures 09-04, 09-05 below).

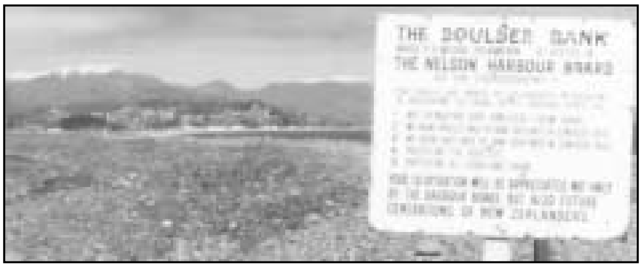


Figure 09-04 Nelson Harbour Board sign, New Zealand, contains little information, is difficult to read and ‘unsightly’. The sign also has a negative slant “NOT removing any boulders…”; “NOT taking vehicles onto the beach….”; “NOT taking dogs…”

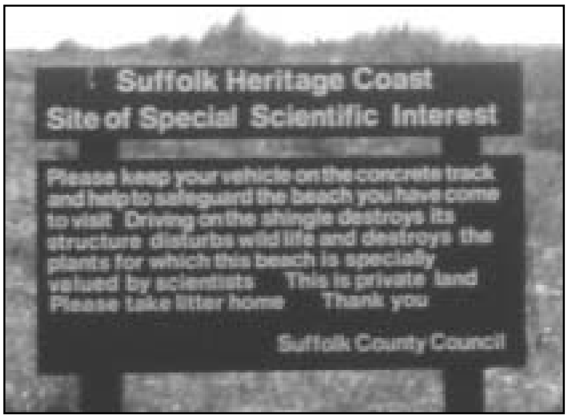


Figure 09-05 Heritage Coast sign at Shingle Street, Suffolk.

Awareness raising video

The Nature Coast Project and East Sussex Coastal Biodiversity Project have produced a short awareness raising/educational video on vegetated shingle, for use both on site in visitor or field study centres or in a wider area for example in schools, training events and public presentations. Both projects also put a considerable emphasis on raising awareness of vegetated shingle (and other coastal habitats) through events, guided walks, talks to local groups etc.

Recommendation: A more concerted national effort is required to raise the profile of shingle areas both among the general public and those with responsibility for the management of vegetated shingle sites. The initiatives taken by the West Sussex Vegetated Shingle project provide a possible model.

Comment: *In response to the production of the Sussex coastal vegetated shingle HAP, a partnership project was set up in 1999 to help achieve some of the action plan targets, in particular raising awareness of vegetated shingle in West Sussex. A project officer was employed for 3 years during which time a variety of methods were used to raise the public profile of vegetated shingle, including producing a leaflet, a mobile display, website, education pack, resources for coastal defence engineers, interpretation boards, a programme of presentations and enabling community participation. The project is acknowledged as having been successful in what it set out to achieve.*

Management

HAP Target 3 - *"Maintain the quality of existing plant and invertebrate communities which are currently in favourable condition.* ***Revised****"*

This study, particularly the site reviews, has highlighted the extent of management activity already being undertaken on many important sites in Great Britain. The ability to manage habitats and species, as well as people, within these areas is in many instances well tried and tested. For some sites (Pagham, Annex 03; Rye, Annex 04 and Orfordness, Annex 06) there are readily and easily accessible sources of information on the management techniques which have been adopted. However, this study has only been able to look at six sites (Annexes 01 - 06) due to time and cost constraints. Cley-Salthouse (Annex 07) has been included because it highlights many of the issues surrounding adopting a limited intervention approach to coastal defence. Culbin (Annex 09) and Spey Bay (Annex 08) were included to provide examples of a relatively untouched site and one where regeneration of disturbed / excavated shingle has taken place, respectively. The maps provided in Chapter 04 show there are many other vegetated shingle sites in Great Britain (there are also many more in Ireland) and a wealth of further information to be collected and collated on management strategies.

One of the primary aims of this contract was to provide management guidance for vegetated shingle commensurate with that available for the other primary coastal formations namely sand dunes, saltmarshes, sea cliffs, coastal wetlands and grazing marsh. However there remain many aspects of the management of coastal vegetated shingle that have only been covered in a relatively superficial way.

Recommendation: In order to fill in the gaps in knowledge both geographically and in more depth a further study should be carried out. This should look in more detail at specific issues such as grazing management, significance of vegetation control in relation to ground-nesting birds and control of recreational activities (see also below invertebrates).

Invertebrates

Invertebrates are one of the least well known groups of British shingle species, yet where studies have been carried out the habitat has been shown to hold considerable numbers of Red Data Book (RDB) and priority Biodiversity Action Plan species. A species of fly new to science was recently found living within the shingle at Rye suggesting there is much more to discover. Invertebrates are not only important in their own right as part of the biological diversity of shingle areas, but they are also important indicators of the health of the systems. Although there is detailed information for a few sites (notably Dungeness) it is clear that many other sites are under recorded. At the same time there is a paucity of knowledge on the importance of habitat type, the association with host plants and interactions between the two. Although some plants are known to be particularly important for some species, many more rely on a matrix of habitats including open and closed shingle vegetation. Invertebrates may also have a close relationship with and depend upon the physical structure of individual plants and/or plant communities. Thus the architecture of vegetation and the shingle matrix is very important. Not understanding this relationship runs the risk that management such as grazing, if advocated on largely stable vegetation, could lead to loss of invertebrate interest.

Recommendation: It is vitally important to extend the knowledge of the interactions between habitat, plant species and community structure to those sites that are currently understudied. These studies should be carried out across the range of shingle habitats, from bare shingle to closed grasslands, heathlands and scrub. The work should be designed to develop management plans that incorporate the protection of invertebrate taxa and their microhabitats. These studies should be linked to objectives associated more directly with vegetation management. There are strong possibilities that southern shingle systems, with their wealth of species lying at the edge of their geographical range, will yield a range of important records and could be tackled first.

Ecology of shingle drift lines (beaches).

At the time JNCC funded research on coastal vegetated shingle structures in Great Britain a decade ago, it was realised that no research had been carried out on the shingle foreshore habitats (strandlines) or on maritime islands. However, these are prime locations for the ‘Habitats’ Directive Annex1 Habitat: Annual Vegetation of Drift Lines. A study of shingle beaches was carried out for Dumfries and Galloway (Randall 2001) but this remains the only recent work of this kind.

Recommendation: It is vital that funding is found to carry out work on the ecology and conservation of this habitat, which is currently poorly understood.

Comment: *As has already been suggested the National Vegetation Classification only describes part of the pioneer phase of perennial shingle vegetation, namely SD1 Rumex crispus – Glaucium flavum shingle community, which at present is used to describe the 'Perennial vegetation of stony banks' Annex I habitat (1220) type.*

Patch dynamics and the establishment of vegetation

Work carried out at Kingston (Annex 08) has suggested that the abundance and diversity of lichens and particularly bryophytes indicate a mechanism of initial colonisation and primary succession on bare terrestrial shingle that has not been studied elsewhere. The resultant 'islands' of vegetation offer a model of succession on bare shingle with no maritime influence, a situation unusual in Britain but more common in Baltic Germany, Sweden and Norway.

Recommendation: Undertake successional studies of shingle island vegetation at Kingston, Scotland.

Restoration

There are several programmes which are attempting to restore vegetation to shingle areas on several of the sites reported in this study. The principle approaches involve the use of plant material. However, these are few in number, at a small scale and of limited duration. Regrading shingle in conjunction with the introduction of plant material has also been tried but again on a very limited scale. There are clearly opportunities for extending experimental work in both these areas.

HAP Target 4 - "*Achieve the restoration, where possible, of degraded or damaged habitats of shingle structures, including landward transitions, where such damage has been extensive and natural recovery is not likely to be initiated, by 2010.* ***Revised***"

Seeding and planting

A lack of experimental data on the ability of shingle beach species to prevent erosion or repair damaged shingle has meant that no large scale planting of native species has occurred. Walmsley and Davy's work (Walmsley & Davy 2001) at Sizewell has been reviewed in Chapter 07 and current experiments at Pagham and Dungeness are reported in Annex 03 & 05, respectively.

Recommendation: Undertake more experimental work on plant re-establishment using different substrate matrices, seeding combinations and different precipitation regimes.

Transplantation

Where loss of mature vegetated shingle is inevitable because of decisions to build on stable habitats, consideration might be given to transplanting existing vegetation. There are no examples reported so the effectiveness of treatment is not known. Evidence from the sites where seeding has been tried suggest that this would not be easy.

> **Recommendation**: Consider, **as a last resort**, experimental transplantation of mature shingle in areas where destruction is inevitable.

Regrading shingle in damaged areas

Little work has been carried out to date on geomorphic restoration of damaged shingle-ridge systems. The work at Orfordness (Annex 06) is extremely valuable if inconclusive. Recent work at Rye Harbour (Annex 04) has shown that buried systems can, with care, be excavated to display significant geomorphic sequences once more. More work should be carried out in this area to assess the value of more extensive restoration of the physical landscape.

> **Recommendation**: Consideration should be given to a large-scale re-grading experiment using an industrial plant in an existing extraction site. This could/should be accompanied by experiments to see how distance from the water table and the introduction of fine fractions influence the rate of colonisation and type of communities that are formed.

Plant autecological studies

Although several of the important plant species of shingle have been written up for the Biological Flora of the British Isles *e.g. Suaeda vera* (Chapman 1947), *Mertensia maritima* and *Glaucium flavum* (Scott 1963) and *Crambe maritima* (Scott & Randall 1976) - http://www.britishecologicalsociety.org/publications/journals/ecology/biologicalflora.php, there is still need for much greater understanding of the ecology of many other species. Some detail is available from the Ecological Flora of the British Isles database at York University - http://www.york.ac.uk/res/ecoflora/cfm/ecofl/index.cfm but it would be very useful to have more knowledge on the autecology of species such as the shingle ecotypes of *Cytisus scoparius*, *Galium aparine*, *Geranium robertianum*, *Prunus spinosa* and *Solanum dulcamara* or species like *Crithmum maritimum*, *Eryngium maritimum* or *Tripleurospermum maritimum.*

> **Recommendation**: Sponsor more autecological studies of rare plants and those potentially providing added stability to shingle beaches.

Letting nature take its course

Geomorphology

Over the years coastal defence works at Orfordness have been extremely damaging to the ecology of the area. A breach in the spit at Slaughden meant that 250,000 m^3 of shingle was transported from the Ness to fill the gap (Kinsey 1981). The King's Marshes were also bulldozed towards the shore to raise the sea defences. Both courses of action restricted the width of the beach, such that a minor breakthrough could quickly become much worse. Just below Aldeburgh, the river has cut into the landward side of the spit, while the sea erodes the outer shore because defence works further north starve the shoreline. Holding the line is only possible by beach feeding. It would be very helpful to carry out detailed modelling to ascertain the affect of ceasing beach feeding and leaving this site to nature. Would losses be that great? Is the present practice sustainable? Steers (1964) pointed out that the current situation at Orfordness is quite similar to that at Dungeness in the Middle Ages. Left to itself the Alde would eventually break through as the Rother once did. This might well be a cost-effective solution to a sea defence problem that would allow the coast to develop naturally without great loss or cost to man or the natural environment.

Recommendation: Undertake predictive modelling on the geomorphological implications of leaving certain sites to nature e.g. ceasing beach feeding at Slaughden (Orfordness, Annex 06).

Monitoring at Porlock

There are relatively few contemporary examples of situations in which natural processes have been allowed to re-create reprofiled shingle ridges and Porlock (Annex 01) is probably the prime example in the UK. It is increasingly being argued that in some cases allowing ‘nature to take its course’ may be a much more sustainable and cost-effective option to maintain coastal and flood defence than continuing to adopt the engineered solution.

Although detailed studies have taken place on the geomorphological change, monitoring the vegetation has been undertaken at a relatively small scale and by local staff. The opportunity exists (notably at Porlock, Annex 01 and possibly at Orfordness, Annex 06 and Cley-Salthouse, Annex 07) to undertake detailed monitoring both of the physical and ecological changes that ensue and the relationship with the socio-economic environment. Added to this is the possibility of seeking the views of the local population and assessing changing attitudes to taking this less interventionist approach. This case has already been used by the Field Studies Council as a case study for A-Level and GCSE Geographers (McTernan & Wilson 1999) and poses many of the questions relevant to this debate.

Recommendation: A detailed monitoring strategy should be set up for Porlock encompassing both the changes to the shingle ridge itself and the development of vegetation and animal usage of land now open to tidal inundation. This should be further developed to investigate attitudes to the socio-economic consequences of this less interventionist approach.

Letting people know things may not be as bad as they think.

Because there is a history of many centuries of winning land from the sea and creating strong sea defences, there is a natural aversion of people living in coastal areas to any reversal in this policy. There is a general feeling that any let-up in defences in the light of global warming, sea level rise and land subsidence in the south and east, will result in massive losses of coastal land (especially low land protected by shingle). With the evidence of current examples of managed realignment (dealt with in more detail in the “Good Practice Guide for habitat restoration, re-creation and creation on the coast”, it is important to highlight that 'letting nature take its course' may be a reasonable option where current defences are unsustainable in the long term. The case of Porlock also suggests that 'things may not be as bad as they seem' when 'natural' realignment of the coast takes place.

Recommendation: Take a more proactive approach to promoting the environmental and socio-economic benefits of taking a less interventionist (more realistic) approach to shingle barrier breakdown. This should include an explanation of how the coast will change in response to sea level rise/climate change.

Shingle-sand and shingle-saltmarsh ecotones

The implications of shingle restoration for habitats lying inland of the shingle beach/structure when 'roll-over' is contemplated, have already been discussed in relation to Porlock (Annex 01) and Cley (Annex 07). That there will be changes in the nature of the habitats is certain, with marginal habitats most likely to be replaced and a consequential overall loss of biodiversity.

Brightmore (1979) and Adam (1990) highlight the fact that there is a vegetation community comprising characteristic species such as *Frankenia laevis, Limonium bellidifolium, L. binervosum* and *Suaeda vera*, which occurs in a specialised habitat where saltmarsh, sand dune and shingle are in juxtaposition. This assemblage represents a Mediterranean element in the British flora and is best developed on the north Norfolk coast. However, a related, less diverse community is present in similar locations on the Sussex coast and in Anglesey. This ecotonal habitat is narrow, linear and susceptible to minor environmental changes and has declined markedly in recent times.

Recommendation: Augment the phytosociological understanding of these rare and valuable series of transitional community types with more detailed studies of their ecology. In this way it should be possible to be more certain of the likely consequences of taking a non-interventionist approach as one community is replaced by another. It will also help provide the basis for predicting the necessary environmental conditions, which might favour the re-creation of transitional habitats when managed realignment schemes are considered.

References

Adam, P., 1990. *Saltmarsh Ecology*. University Press, Cambridge.

Brampton, A. & Evans, C.D.R., 1998. *Regional Seabed Sediments Studies and Assessment of Marine Aggregate Dredging*. CIRIA Report **505**, Construction Industry Research and Information Association, London

Brightmore, D. & White, P.H.F., 1963. Biological Flora of the British Isles: *Lathyrus japonicus*. *Journal of Ecology*, **51**: 795-801.

Brightmore, D., 1979. Biological Flora of the British Isles: *Frankenya laevis* L. *Journal of Ecology*, **67**: 1097-1107.

Chapman, V.J., 1947. Biological Flora of the British Isles: *Suaeda fruticosa* (*vera*). *Journal of Ecology*, **35**: 303-310.

DEFRA 2001. *Shoreline Management Plans: a Guide for Coastal Defence Authorities*. Department for Environment, Food and Rural Affairs, London

Halcrow, 2003. *Futurecoast*. A 3 CD set comprising reports and interactive map browser and two CDs with oblique aerial photography of the shoreline of England and Wales, Department of Environment, Food and Rural Affairs.

Kinsey, G., 1981. *Orfordness: Secret Site*. Dalton, Lavenham.

MAFF, 1981. *Atlas of Seas Around the British Isles*. HMSO, London

McTernan, M., & Wilson, H., 1999. Coastal management in Porlock Bay: a case study and role play for A-Level and GCSE Geographers. *Field Studies*, **9**, 397-468.

Randall, R.E. & Fuller, R.M., 2001. The Orford shingles, Suffolk, UK: evolving solutions in coastline management. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, pp. 242-260.

Randall, R.E., 2001. *Solway Firth: Inventory of Shingle Vegetation*. Scottish Natural Heritage, Commissioned Report, CD-ROM.

Rodwell, J., 2000. *British Plant Communities, Volume 5. Maritime Communities and Vegetation of Open Habitats*. Cambridge University Press, Cambridge.

Scott, G.A.M. and Randall, R.E., 1976. Biological flora of the British Isles: *Crambe maritima* L. *Journal of Ecology*, **64**: 1077-1091.

Scott, G.A.M., 1963. Biological flora of the British Isles: *Mertensia maritima* (L.) S F Gray. *Journal of Ecology,* **51**: 733-742.

Sneddon, P., 1992. *Variations in shingle vegetation around the British Coastline*. PhD. Thesis, University of Cambridge.

Steers, J.A., 1964. *The Coastline of England and Wales*. Cambridge: Cambridge University Press.

Walmsley, C.A. & Davy, A.J., 2001. Habitat creation and restoration of damaged shingle communities. In: *Ecology & Geomorphology of Coastal Shingle* eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic and Scientific Publishing, 409-420.

Chapter 10 Funding sources and useful contacts

There are a number of different funding sources for management and restoration of vegetated shingle. Most of these are not specific to the habitat but the schemes most commonly used are identified below. These are presented from EU level downwards.

European Union

Several European Union sources of funding have been used for shingle related projects. LIFE, which is the Financial Instrument for the Environment, introduced in 1992, is one of the main means through which the European Union environmental policy is progressed. It co-finances projects in two areas relevant to shingle management and restoration:

1. **LIFE Nature -** involves actions aimed at conservation of natural habitats and the wild fauna and flora of European Union interest, according to the Birds and Habitats directives. They support implementation of the nature conservation policy and the Natura 2000 Network of the European Union;
2. **LIFE Environment -** involves actions which aim to implement the Community policy and legislation on the environment in the European Union and candidate countries. This approach enables demonstration and development of new methods for the protection and the enhancement of the environment;

Two other schemes potentially provide support for restoration and other work:

3. **Agri-environment** funding mechanism (agri-environment regulation, Council Regulation No (EEC) 2078/92) provides for programmes to encourage farmers to carry out environmentally beneficial activities on their land. The programmes are managed by regional or national authorities under a decentralised system of management, subject to approval by the Commission for each programme. The costs are part-financed from the EU budget - 75% in objective 1 areas and 50% elsewhere;
4. Interreg III follows up Interreg II (see below page 102). It is an initiative which aims to stimulate interregional cooperation in spatial planning in the European Union during the period 2000-06 and is financed under the European Regional Development Fund (ERDF). [Two projects relating specifically to shingle were carried out under INTERREG II, and a further shingle project is being undertaken under INTERREG III (Beaches at Risk).]

Each of these mechanisms is described further below where reference is made to the value of each for funding shingle related projects.

LIFE Nature

LIFE Nature is an appropriate mechanism for any shingle site which is included in the Natura 2000 series (candidate Special Areas of Conservation and Special Protection Areas). There are two projects with funding under this mechanism affecting vegetated shingle habitats. These are:

1. **The conservation of Orfordness** (LIFE94 NAT/UK/000850)

Having purchased the site in 1994, the National Trust looked towards the LIFE fund to help implement the actions needed to help restore the site. This work involved activities including re-establishing damaged or destroyed biotopes, re-introducing grazing regimes aimed at encouraging the return of Annex I species (‘Habitats’ Directive) and controlling many damaging activities like hunting and the use of four wheel drive vehicles. The project has provided the basis for the long term conservation of the site.

Duration: 1st January 1995 to 1st March 1998.

2. **Wild Ness : the conservation of Orfordness, Phase 2** (LIFE97 NAT/UK/004245)

This second project has built upon the successes and results of the first project in an attempt to restore the site to a favourable conservation state. In specific terms, the project identified the factors suppressing the breeding of Annex I ground nesting birds and the development of rare shingle flora. It has acted upon these findings to improve grazing on saltmarsh, coastal grazing marsh and along the river wall. New lagoons have been created for breeding and feeding waders. Restoring damaged shingle surfaces has also been attempted. The management plan has been updated and revised and provides a long term conservation/ restoration programme for the site.

Duration: 1st March 1997 to 1st April 2000

A summary of the results of these projects is given in the site report for Orfordness (Annex 06).

Living with the sea

This is also a LIFE Nature projects which aims:

To promote:

- understanding of long term (30-100 year) coastal change resulting from sea level rise;
- sustainable integrated coastal management policies;
- ownership of shared issues and common solutions.

To develop:

- mechanisms for delivering Habitats Directive compliant flood and coastal defence schemes e.g. CHaMPs;
- practical ways of demonstrating habitat creation at work e.g. North Norfolk Flood Defence schemes;
- working partnership between engineers, conservationists and landowners.

The project includes the Guide “Coastal Habitat Restoration, towards good practice”.

For **further information** on the LIFE programmes and projects see the **LIFE** home page at (http://europa.eu.int/comm/environment/life/home.htm) which provides information on:

- the programme in general terms and the three components (a third element is for Life - third countries);
- what’s happening within the programme, for example upcoming LIFE events, selection of new projects, other opportunities etc;
- practical steps when applying for funding - annual deadlines, application forms, who to contact etc;
- the results and lessons of the LIFE programme;
- past, present and future projects;
- all the operators involved in the day to day work on the programme;
- contacts at all levels, such as with European institutions, Member States, candidate countries, external teams, Mediterranean and Baltic Sea countries, etc.

Life Environment

There are no shingle related projects funded through this mechanism. However the LIFE Regulation defines five areas eligible for funding:

- land-use development and planning;
- water management;
- reduction of the environmental impact of economic activities;
- waste management;
- reduction of the environmental impact of products through an integrated product policy.

For more information see http://europa.eu.int/comm/environment/life/life/environment.htm.

Agri-environment Schemes

Examples of the type of land management activities carried out include:

- reversion of intensively used land, such as arable or grass for silage to biologically diverse, but unprofitable extensive grassland;
- reduction in use of nutrients (resulting in loss of yield);
- reduction or cessation of use of pesticides (e.g. organic farming);
- creation of nature zones taken out of production;
- continuation of traditional environmental land management in zones liable to neglect;
- maintenance of landscape features which are no longer agriculturally viable.

Information can be obtained via EC web page @
http://www.europa.eu.int/comm/agriculture/envir/index_en.htm

DEFRA operates two principle schemes: Countryside Stewardship and Environmentally Sensitive Areas (ESAs) under the European Union Agri-environment Scheme. Details of these are provided below:

Countryside Stewardship

Countryside Stewardship Schemes are governed by the Countryside Stewardship Regulations 1998, as amended, made under Section 98 of the Environment Act 1995. The scheme forms part of the England Rural Development Programme, part-funded by European Union funds, and is therefore subject to Council Regulation 1257/1999, Commission Regulation 1750/1999 and Commission Regulation 2075/2000. The scheme is administered by the Department of Environment Food and Rural Affairs (DEFRA) in consultation with the Office of the Deputy Prime Minister, Countryside Agency, English Heritage and English Nature. It offers payments to farmers and landowners to improve the natural beauty, habitats and wildlife of the countryside and to help people to enjoy them. The schemes are managed through a 10 year legally binding agreement, the maximum period “normally” permitted under Regulation 1257/1999. It operates outside Environmentally Sensitive Areas. Anyone who owns or manages suitable land may apply. The scheme is open to farmers and non-farming land owners and managers, including voluntary bodies, local authorities and community groups.

The Scheme is discretionary and the more work of different types entered the better. DEFRA gives priority to plans which amongst other things:

- include land in a county target area;
- are of landscape, wildlife and historical interest;
- are linked to land of special interest or contribute to a national target for a habitat or species listed in a Biodiversity Action Plan;
- offer a combination of different benefits;
- provide opportunities for people to enjoy the benefits;

- cover land in a village or urban fringe of high local amenity value.

Grants are also more likely if plans represent a positive change in management, are realistic and achievable, will produce the planned objectives, are well researched, are supported by environmental bodies and are good value for money. **NB**: Works associated with diversion of public rights of way are not eligible for Countryside Stewardship funding.

From January 2000, the Stewardship scheme has included an intertidal habitat creation option and payments for capital work where appropriate. The specific objectives for coastal areas relevant to coastal shingle are:

- re-create intertidal habitats on agricultural land;
- manage intertidal habitats including saltmarsh and **shingle ridges** where changes or active management are required.

Information on who can apply, how to submit an application and the levels of payment can be found on the DEFRA web site via the England Rural Development Home Page @ http://www.defra.gov.uk/erdp/erdphome.htm). [A review is currently underway to examine the future use of these payments, follow the link to the DEFRA Agri-environment Review.]

Environmentally Sensitive Areas (ESA)

Environmentally Sensitive Areas are specially designated areas where payments are made to enhance the conservation, landscape and historical value of the key environmental features of an area, and, where possible, improve public access to these areas. There are currently 22 ESAs in England. Each has a series of tiers identifying operations for which payments can be made to farmers. For example, Broads, Suffolk River Valleys, North Kent Marshes and Somerset Levels have tiers relating to raising water levels and maintaining wet grassland.

Comment: *None of these schemes currently have particular value for shingle habitats, though where roll-over or breaches to shingle structures are contemplated management of the hinterland could be enhanced if the land lies within an ESA.*

Wildlife Enhancement Scheme (WES)

English Nature operates the Wildlife Enhancement Scheme giving financial support to land managers in achieving positive management on SSSIs by means of short term agreements of up to five years. Standard payments may be made for achieving appropriate nature conservation management by means such as grazing, hay cutting, or water control over wet grassland. They may also be made for carrying out specific management works such as hedge laying, tree planting and scrub or bracken control or managing coastal wet grassland such as at Pevensey Levels. So far there are no examples on shingle areas, though this funding source could be relevant.

CCW's Berwyn Scheme

The Countryside Council for Wales administers a similar scheme - the Berwyn Standard Payment Scheme, which includes measures to ensure compatibility between farm management practices on hill grazings and the land's international, ornithological and habitat importance. Payments are made on a per hectare basis to farmers and land managers who agree to adopt agreed management programmes which regulate seasonal grazing and undertake rotational heather burning and pest control. Where appropriate, additional payments can be made to assist other management, such as bracken control and the planting of native tree species. There is no known use of this initiative for shingle habitats.

Interreg II

The Interreg Community Initiative, which was adopted in 1990, was intended to prepare border areas for a Community where internal national frontiers are of less significance. The aim of the Regen

Initiative launched in the same year was to help fill in some of the missing links in the trans-European networks for transport and energy distribution in the Objective 1 regions. It had three distinct strands, namely:

- Interreg II A (1994-1999): cross-border co-operation;
- Interreg II B (1994-1999): completion of energy networks;
- Interreg II C (1997-1999): co-operation in the area of regional planning, in particular management of water resources.

Two projects with interests relating to shingle were:

1. **BERM -** Beach Erosion in the Rives Manche

This set out to investigate the supply and depletion of shingle on Rives Manche beaches under present day management regimes, and to determine the sustainability of the beaches in a period of rising sea level. This project was an Interreg II project with matching funds coming from the relevant local authorities. [An Interreg II programme funded by the European Union (Priority E: Environmental Conservation and Enhancement. Measure 9: Information, Prevention and Awareness)]. The study was undertaken by the Coastal Research Group, University of Sussex and the Université de Rouen and Université de Caen. It will help determine the extent to which contemporary shingle beaches of Rives-Manche are depleting and assess the risks that this will pose for the region in the face of rising sea levels.

2. **Two Bays, One Environment Project** Interreg II East Sussex and France

The purpose of the project was to compare the wildlife and habitats of the TWO BAYS (Rye Bay East Sussex and Baie de Somme, northern France) with a view to improving management techniques for the rare species and habitats. The 50% match funding was provided by the East Sussex County Council.

The work included creating a joint database. Species records have been entered onto a biological database. This also involved the collection of new data and the exchange of surveyors and specialists. The project also provided an opportunity to undertake joint studies of wildlife management techniques with an exchange of experience between environmental workers. Habitat management advice was also given to farmers and landowners within the project areas.

Another important aspect to the project was to promote the understanding of the environmental importance of the area to decision makers, farmers, landowners and the general public. This took place through leaflets, displays, newsletters, guided walks, interpretation boards, workshops and a conference. Many of the publications were bilingual, and both areas displayed information about the project and its partner across the channel. The Communication and Interpretation Plan identifies the core and subsidiary messages presented to the public. The project includes Rye Harbour (Annex 04), which is one of the two sites included in the Interreg project - see also web site @ http://home.clara.net/yates/2bays.html).

Interreg III

Interreg III follows up Interreg II. It is an initiative which aims to stimulate interregional cooperation in the European Union between 2000-06 and is financed under the European Regional Development Fund (ERDF). This new phase of the Interreg initiative is designed to strengthen economic and social cohesion throughout the EU, by fostering the balanced development of the continent through cross-border, transnational and interregional cooperation. Special emphasis has been placed on integrating remote regions and those which share external borders with the candidate countries.

Again programme III is made up of 3 strands, with an emphasis on cooperation across regional and national boundaries:

Strand A: cross-border cooperation between adjacent regions aims to develop cross-border social and economic centres through common development strategies. (Only the southeast of England, Wales and eastern Ireland are eligible within the UK and Ireland.);

Strand B: transnational cooperation between national, regional and local authorities aims to promote better integration within the Union through the formation of large groups of European regions;

Strand C: interregional cooperation aims to improve the effectiveness of regional development policies and instruments through large-scale information exchange and sharing of experience (networks).

Supplementing the three strands, networks promoting the sharing of experiences and best practice will be funded. See http://europa.eu.int/comm/regional_policy/interreg3/index_en.htm for further information.

Interreg III is delivered through a series of programmes. These programmes set the regional priorities for funding. The opportunities for ‘shingle’ related projects depend on the provisions of the programming documents.

Interreg Programmes currently operating in the UK for the period 2000-2006 are:

- Interreg IIIA Franco- British Programming Area;
- Interreg IIIB North Sea Area Programme;
- Interreg IIIB Atlantic Area Programme;
- Interreg IIIB North West Europe Programme;
- Interreg IIIC West Zone Programme.

There may be particular opportunities for projects that relate to aspects of shingle protection and management from the North West Europe Programme and the North Sea Programme.

The North West Europe Programme may fund trans-national projects under the priorities:

- water resources and the prevention of flood damage;
- stronger ecological infrastructure.

The North Sea Programme may likewise fund trans-national projects under the priorities of:

- sustainable management of the Environment, natural Resources and Cultural Heritage, in the areas;
- creative rehabilitation, protection and development of cultural and natural landscapes and townscapes;
- integrated and concerted management and planning of coastal zones and the North Sea itself.

INTERREG III Project Beaches at Risk (BAR).

The two English Partners are the University of Sussex and East Sussex County Council. Aims to continue and expand upon the work carried out through BERM on beach sediment budgets, and the East Sussex Coastal Biodiversity Project carried out under Interreg II. Further information is available at http://www.geog.sussex.ac.uk/BAR/.

Countryside Agency grants

Funding is available from each of the countryside agencies:

English Nature Aggregate Levy

This fund includes opportunities for funding by English Nature through the Aggregates Levy Sustainability Fund, as is the case of shingle restoration at Rye Harbour. Grants are also available from the principle countryside agencies, namely:

Countryside Council for Wales (details from their web site http://www.ccw.gov.uk/);

Scottish Natural Heritage (details from their web site http://www.snh.org.uk/);

Northern Ireland Office (details from their web site http://www.nio.gov.uk/).

Flood and coastal management

Responsibility for funding sea defence schemes lies with the Department of Environment, Food and Rural Affairs. It gives financial support to the flood and coastal management operating authorities in England (these are the local authorities, the Environment Agency and Internal Drainage boards) for between 35% and 80% of the value of capital projects. Several of the schemes discussed here (Cley-Salthouse, Annex 07) and the majority of those on the south coast of England are funded in this way. In some instances DEFRA will fund such schemes which also enhance Natura 2000 sites damaged by human actions (see for example Freiston Shore in the Wash, Living with the Sea "Good Practice Guide for habitat restoration, re-creation and creation on the coast" and Cley-Salthouse Annex 07a).

Other sources

These include the National Heritage Lottery Fund, which supports the Nature Coast Project, which helped produce the video described above (page 92).

Chapter 11 Glossary of terms

Abiotic	without life; an absence of living organisms
Alien	not native, introduced to a region deliberately or accidentally by man and now ± naturalised
Allogenic	Succession where replacement of one community by another results mainly from environmental changes
Anastomosing	dividing up then joining again
Apposition Beach	beach that has grown in area as a result of successive deposition of ridges over time
Autecology	the study of individuals or species in response to environmental conditions
Autogenic	succession wherein replacement of one community with another results chiefly from changes induced by the plants themselves
Backwash	the movement of seawater downslope after a breaking wave has taken it to the highest point up the beach
Capillarity	the ability of a liquid to rise up narrow channels
Clast	rock material broken down to any sediment size
Climax	The plant community which, in a given area, was thought to perpetuate itself indefinitely
Closed-turf communities	species rich plant and animal communities that develop over a relatively long time, gradually building up a layer of soil and humus over the shingle, eventually completely covering it with vegetation, with no bare shingle visible.
Coastal defence	a combination of both Coast Protection (generally to prevent erosion – where the land is higher than sea level) and Sea Defence (to prevent flooding- where the land is lower than sea level).
Coastal squeeze	the shrinking of coastal habitats caught between rising sea level and fixed coastal defences.
Distal	the point furthest from origin
Dominant	the chief constituent of a particular plant community
Ecosystem	the biotic community and its non-living environment as an interacting system
Ecotone	a transition zone between two adjacent and differing communities
Edaphic	that which relates to the soil
Endemic	referring to a group of organisms native to a given region
Environment	all the conditions and influences surrounding and effecting an organism or community
Escape	a plant growing outside a garden derived from cultivated specimens
Flora	the total assemblage of plant species present in an area
Habitat	the specific kind of environment occupied by the individuals of a species
Halophyte	A plant that grows successfully in salty conditions
Holocene	The period of approximately the last 10000 years
Homeostasis	the maintenance of equilibria in an organism or system
Horizon	soil layer
Humus	dark brown or black organic matter in soils formed from the decomposition of dead plants and animals
Intermediate communities	plant and animal communities that are intermediate between pioneer and established, closed-turf communities.
Interpretation	means of displaying explanatory information for example in the form of a leaflet or notice board.
Introduced	not native, known to have been brought in by man within historic times
Leaching	the downward movement or removal of soluble chemicals from the soil
Matrix	the finer material present between shingle clasts
Nutrient enrichment	increase in nutrient content of shingle.
Oceanicity	the condition of being influenced by the physical attributes of the sea.
Phenology	study of periodicity in plants and animals
Pioneer communities	plant and animal communities that establish within a relatively short time and are usually the first to colonise a new area.
Quaternary	geological period of approximately the last two million years including the Pleistocene and the Holocene (the last 10000 years)

Ranker	a well-drained soil with an organic upper layer and little-altered, non-calcareous, unconsolidated material below
Relict	residual feature that has survived over a long period of time and is no longer geomorphologically active.
Ruderal	a plant characteristic of waste places
Sere	a group of plant communities that successively occupy the same site
Stochastic	statistically by chance
Succession	the changes in vegetation and animal life by which one population or community is replaced by another
Topography	characteristics of the ground surface in terms of physical features
Vegetated shingle	shingle supporting a community of flora and fauna.
Weed	any plant considered undesirable by man in a given location

Abbreviations

AONB	Area of Outstanding Natural Beauty
BAP	Biodiversity Action Plan
CCW	Countryside Council for Wales
CHaMP	Coastal Habitat Management Plan
COAST	Co-ordinated Action on Seaside Towns
cSAC	Candidate Special Area of Conservation
DEFRA	Department of the Environment, Food and Rural Affairs
EA	Environment Agency
EIA	Environmental Impact Assessment
EIA	Environmental Impact Assessment
EMP	Estuary Management Plan
EN	English Nature
ERDF	European Regional Development Fund
EU	European Union
EUCC	European Union for Coastal Conservation
GIS	Geographical Information Systems
GCR	Geological Conservation Review
HAP	Habitat Action Plan
ICZM	Integrated Coastal Zone Management
JNCC	Joint Nature Conservation Committee
LNR	Local Nature Reserve
NFU	National Farmers Union
Ramsar	Site designated as an International Wetland Site
RDB1	Red Data Book (endangered category)
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SCOPAC	Special Conference on Problems Associated with the Coastline
SMP	Shoreline Management Plan
SNH	Scottish Natural Heritage

SPA	Special Protection Area (for birds)
SSSI	Site of Special Scientific Interest

Shingle and shingle related bibliography

[NB Individual references are provided at the end of each Chapter and in the Annexes; the following is a consolidated reference list and bibliography]

Key texts

Carter, R.W.G., 1988. *Coastal Environments*. London: Academic Press.
Doody, J.P., 2001. *Coastal Conservation and Management: an Ecological Perspective*, Kluwer, Academic Publishers, Boston, USA, 308 pages.
Doody, J.P., 2001. Perspective: the importance of conserving coastal shingle in Europe. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 421-440.
Ferry, B.W., Waters, S.J.P. & Jury, S.L., eds. 1989. *Dungeness: the Ecology of a Shingle Beach*. Published as special issue of the *Botanical Journal of the Linnean Society*, **101**, by Academic Press, London.
Fuller, R.M. & Randall R E, 1988. The Orford Shingles, Suffolk, UK – classic conflicts in coastline management. *Biological Conservation*, **46**: 95-114.
Fuller, R.M., 1987. Vegetation establishment on shingle beaches. *Journal of Ecology*, **75**: 1077-1089.
Oliver, F.W., 1912. The shingle beach as a plant habitat. *New Phytologist*, **11**: 73-99,
Packham, J.R., Randall, R.E., Barnes R.S.K. & Neal A., 2001 *Ecology and Geomorphology of Coastal Shingle.* Westbury Academic & Scientific Publishing, Otley, West Yorkshire.
Pye, K., 2001. The nature of geomorphology of coastal shingle. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 2-22.
Randall, R.E. & Fuller, R.M., 2001 The Orford Shingles, Suffolk, UK: Evolving Solutions in Coastline Management; In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 242-260.
Randall, R.E. & Sneddon, P., 2001. Initiation, development and classification of vegetation on British shingle beaches: a model for conservation management. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 202-223.
Randall, R.E., 1989. Geographical variation in British shingle vegetation. *Botanical Journal of the Linnean Society*, **101**: 3-18
Scott, G.A.M., 1963. The ecology of shingle beach plants. *Journal of Ecology*, **51**: 517-527.
Scott, G.A.M., 1965. The shingle vegetation at Dungeness. *Journal of Ecology*, **53**: 21-31.
Shardlow, M., 2001. A review of the conservation importance of shingle habitats for invertebrates in the United Kingdom. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 355-376.
Sneddon, P. & Randall, R.E., 1993a. *Coastal vegetation shingle structures of Great Britain: Main Report*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P. & Randall, R.E., 1993b. *Vegetated shingle structures survey of Great Britain: Appendix 1 - Wales*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P. & Randall, R.E., 1994a. *Vegetated shingle structures survey of Great Britain: Appendix 2 - Scotland*. Joint Nature Conservation Committee, Peterborough.
Sneddon, P. & Randall, R.E., 1994b. *Vegetated shingle structures survey of Great Britain*: Appendix *3 - England*. Joint Nature Conservation Committee, Peterborough.

Shingle publications

Axell, H.E., 1956. Predation and protection at Dungeness bird reserve. *British Birds*, **49**: 193-212.
Barfoot, P.J. & Tucker, J.J., 1971. Geomorphological changes at Blakeney Point, Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society*, **25:** 49-59.
Barnes, R.S.K. & Heath, S.E., 1981 The shingle foreshore/lagoon system of Shingle Street, Suffolk: a preliminary survey. *Transactions of the Suffolk Naturalists' Society*, **18:** 168-181.
Bluck, B.J., 1967. Sedimentation of beach gravels: examples from South Wales. *Journal of Sedimentary Petrology*, **37**: 125-156.
Bluck, B.J., 1999. Clast assembling, bed-forms and structure in gravel beaches. *Transactions of the Royal Society of Edinburgh: Earth Sciences*, **89**: 291-323.
Bocher, T.W., 1969. Stenstrandens plantverdun. *Danmarks Naturforening*, **4***:* 84-97
Bradbury, A.P. & Powell, K.A., 1992. Short-term profile response of shingle spits to storm wave action. *23rd International Conference on Coastal Engineering.* American Society of Civil Engineers, 2694-2707.

Bray, M.J., 1997. Episodic shingle supply and the modified development of Chesil Beach, England. *Journal of Coastal Research*, **13**: 1035-1049.

Brightmore, D. & White, P.H.F., 1963. Biological Flora of the British Isles: *Lathyrus japonicus.* **51:** 795-801.

Brightmore, D., 1979. Biological Flora of the British Isles: *Frankenia laevis* L. *Journal of Ecology*, **67**: 1097-1107.

Brown, D.H. & Brown, R.M., 1967. Lichen Communities at Blakeney Point, Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society*, **21**: 235-250.

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

Burnham, C.P & Cook, H.F., 2001. Hydrology and soils of coastal shingle with specific reference to Dungeness. In: *Ecology & Geomorphology of Coastal Shingle*, eds., J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal. Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 107-131.

Butler, R.J., Greensmith, J.T. & Wright, L.W., 1981. Shingle Spits and Saltmarshes in the Colne Point area of Essex: a geomorphological study. *Occasional Papers in Geography*, **18,** London: Queen Mary College.

Carr, A.P. & Baker, R.E., 1968. Orford, Suffolk: evidence for the evolution of the area during the Quaternary. *Transactions of the Institute of British Geographers*, **45**: 107-123.

Carr, A.P. & Blackley, M.W.L., 1973. Investigations bearing on the age and development of Chesil Beach, Dorset and the associated area. *Transactions of the Institute of British Geographers*, **58**: 99-112.

Carr, A.P. & Blackley, M.W.L., 1974. Ideas on the origin and development of the Chesil Beach, Dorset. *Proceedings of the Dorset Natural History and Archaeology Society*, **95**: 9-17.

Carr, A.P., 1965. Shingle spit and river mouth: short term dynamics. *Transactions of the Institute of British Geographers*, **36**: 117-129.

Carr, A.P., 1969. The growth of Orford spit: cartographical and historical evidence from the sixteenth century. *Geographical Journal*, **135**: 28-39.

Carr, A.P., 1970. The evolution of Orford Ness, Suffolk before 1600 AD: geomorphological evidence. *Zeitschrift fur Geomorphologie*, **14**: 289-300.

Carr, A.P., 1972. Aspects of spit development and decay: the estuary of the River Ore, Suffolk. *Field Studies* **3**: 633-653.

Carter, R.W.G. & Orford, J.D., 1984. Coarse clastic barrier beaches: a discussion of the distinctive dynamic and morphosedimentary characteristics. *Marine Geology*, **60**: 377-389.

Carter, R.W.G. & Orford, J.D., 1993. The morphodynamics of coarse clastic beaches and barriers: a short and long term perspective. *Journal of Coastal Research*, Special Issue **15**: 158-179.

Chapman, V.J., 1947. Biological Flora of the British Isles: *Suaeda fruticosa* (*vera) Journal of Ecology*, **35***:* 303-310.

Chapman, V.J., 1947. Some vegetation changes on a shingle off-shore bar at Thornham. *Transactions of the Norfolk and Norwich Naturalists' Society*, **16**: 274-279.

Clymo, R.S., 1964. Movement of the main shingle bank at Blakeney Point, Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society*, **21**: 3-6.

Cobb, R.T., 1958. Shingle Street Suffolk: a brief geographical introduction. *Report of the Field Studies Council*, **3**: 31.

Coode, J., 1853. Description of the Chesil Bank with remarks upon its origin, the causes which have contributed to its formation, and upon the movement of shingle generally. *Minutes of the proceedings of the Institute of Civil Engineers*, **12**: 520-546.

Copping, A., 1982. Plant records from Landguard Common (1972-1982). *Transactions of the Suffolk Naturalists' Society*, **19**: 374-392.

DEFRA 2001. *Shoreline Management Plans: a Guide for Coastal Defence Authorities*. Department for Environment, Food and Rural Affairs, London

Doody, J.P., 1989 Dungeness - a national nature conservation perspective. *Botanical Journal of the Linnean Society* **101**: 163-171.

Eklund, O., 1931 *Crambe maritima* in Nordbaltischen Gebeit. *Memo. Soc. Fauna Flora fem.* **7**: 41-51.

Farrell, L. & Randall, R.E., 1992. The distribution of *Mertensia maritima* (L.) Gray, Oyster Plant, in Ireland. *Irish Naturalist's Journal*, **24**: 135-140.

Ferry, B. & Waters, S., 1985. *Dungeness ecology and conservation*. Focus on Nature Conservation, **No 12**: Nature Conservancy Council, Peterborough, 144 pp.

Ferry, B., Lodge, N. & Waters, S., 1989. *Dungeness: a vegetation survey of a shingle beach*. Research & survey in nature conservation, **No 26**: Nature Conservancy Council, Peterborough..

Ferry, B.W., 2001. Vegetation of Dungeness shingle: aspects of biodiversity. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 224-241.

Ferry, B.W., Barlow, S.L. & Waters, S.J.P., 1989. The shingle ridge succession at Dungeness. In: *Dungeness - the Ecology of a Shingle Beach*, Eds. B.W. Ferry, S.J.P. Waters & S.L. Jury. *Botanical Journal of the Linnean Society*, **101**, 19-30.

Fitzpatrick, J.M., 1981. Terrestrial plant communities of the Chesil beach and the shore of the Fleet. In: Ladle M, Ed. *The Fleet and Chesil Beach*. Dorset: Dorset County Council.

Forbes, D.L., Orford, J.D., Carter, R.W.G., Shaw, J. & Jennings, S.C., 1995. Morphodynamic evolution, self-organisation, and instability of coarse-clastic barriers on paraglacial coasts. *Marine Geology*, **126**: 63-85.
Forbes, D.L., Taylor, R.B., Orford, J.D., Carter, R.W.G. & Shaw, J., 1991. Gravel barrier migration and overstepping. *Marine Geology*, **97**: 51-86.
Fuller, R.M., 1975. The Culbin shingle bar and its vegetation. *Transactions of the Botanical Society of Edinburgh*, **42**: 293-305.
Fuller, R.M., 1985. An assessment of the damage to the shingle beaches and their vegetation. In: *Dungeness: ecology and conservation*. Eds. B. Ferry & S. Waters, Focus on nature conservation, No. **12**. Nature Conservancy Council, Peterborough, 25-42.
Géhu, J.M. & Géhu -Franck, J., 1979. Sur la vegétátion nord-Allantiques et baltiques à *Crambe maritima*. *Phytocoenologica*, **6**: 209-299.
Géhu, J.M., 1960. La vegetation des levees des galets du littoral francais de la Manche. *Bulletin Societe Botanique Nord France*, **13**: 141-152.
Géhu, J.M., 1960. Une site célèbre de la côte Nord bretonne: Le Sillon de Talbert (C-du-N). Observations phytosociologiques. *Bulletin Laboratoire maritime Dinard*, **46**: 93-115.
Hardy, J.R., 1964. The movement of beach material and wave action near Blakeney Point, Norfolk. *Transactions of the Institute of British Geographers*, **34**: 53-69.
Hart, B.S. & Plint, A.G., 1989. Gravelly shoreface deposits: a comparison of modern and ancient facies sequences. *Sedimentology*, **36**: 551-557.
Heath, S.E., 1980. A brief survey of the botany of Shingle Street, Suffolk. *Transactions of the Suffolk Naturalists' Society*, **18**: 249-253.
Hill, T.G. & Hanley, J.A., 1914. The structure and water content of shingle beaches. *Journal of Ecology*, **2**: 21-38.
Hoyle, J.W. & King, G.T., 1955. The lateral stability of shingle beaches. *Journal of the Institute of Municipal Engineers*, **81**: 356-366.
Hubbard, J.C.E., 1970. The shingle vegetation of southern England: a general survey of Dungeness, Kent and Sussex. *Journal of Ecology*, **58**: 713-722.
Isla, F.I. & Bujalesky, G.G., 1993. Saltation on gravel beaches, Tierra del Fuego, Argentine. *Marine Geology*, **115**: 263-70.
Isla, F.J., 1993. Overpassing and armouring phenomena on gravel beaches. *Marine Geology*, **110**: 369-376.
Jennings, S.C., Orford, J.D., Canti, M., Devoy, R.J.N. & Straker, V., 1998. The role of relative sea-level rise and changing sediment supply on Holocene gravel barrier development; the example of Porlock, Somerset, UK. The Holocene, **8**: 165-181.
Keating, T., 1984. Recharge into a shingle beach. *Journal of Hydrology*, **72**: 187-194.
Kidson, C., 1960. The shingle complexes of Bridgewater Bay. *Transactions of the Institute of British Geographers*, **28**: 78-87.
Kirk, R.M., 1980. Mixed sand and gravel beaches: morphology, processes and sediments. *Progress in Physical Geography*, **4**: 189-210.
Laundon, J., 1989. Lichens at Dungeness. *Botanical Journal of the Linnean Society*, **101**: 103-109.
Lewis, W.V., 1931. The effect of wave incidence on the configuration of a shingle beach. *Geographical Journal*, **78**: 129-148.
Lewis, W.V., 1932. The formation of Dungeness foreland. *Geographical Journal*, **80**: 309-324.
Long, A.J. & Hughes, P.D.M., 1995. Mid and Late Holocene evolution of Dungeness foreland, UK. *Marine Geology*, **124**: 253-271.
Marsh, A.S., 1915. Shingle banks at Holme, Norfolk. *Journal of Ecology*, **3**: 74-76
Massari, F. & Parea, G.C., 1988. Progradational gravel beach sequences in a moderate-high-energy, microtidal marine environment. *Sedimentology*, **35**: 881-913.
May, J., 1985. Geomorphology. In: *Dungeness Ecology and Conservation*, Ferry BW, Waters S Eds. Peterborough, Nature Conservancy Council and Royal Holloway College.
McKay, P & Terich, R A. 1992. Gravel barrier morphology, Olympic National Park, Washington State USA, *Journal of Coastal Research*, **8**: 813-29.
Mercer, I., 1982. Shingle beaches. In: Bellamy D, ed. *Discovering the Countryside: Coastal Walks.* London: Hamlyn, 86-99.
Mercer, I.D., 1966. The natural history of Slapton Ley Nature Reserve. I. Introduction and morphological description. *Field Studies*, **2**: 385-404.
Moore E J 1931 The ecology of the Ayreland of Bryde, Isle of Man. *Journal of Ecology*, **19,** 115-136
Morris, R.K.A., & Parsons, M.S., 1991. *An inventory of the invertebrate fauna of the shingle beaches at Dungeness (Kent), Rye Harbour (E. Sussex) and Orford Ness (Suffolk)*. Contract Survey No. **135**. The Nature Conservancy Council, Peterborough.
Morris, R.K.A., & Parsons, M.S., 1992 *A survey of invertebrate communities on the shingle of Dungeness, Rye Harbour and & Orford Ness*. NCC Report No. **77**. Joint Nature Conservation Committee, Peterborough.
Nakanishi, H. & Fukumoto, H., 1987. Zonation of Coastal vegetation and coastal topography in Southern Japan. *Japanese Journal of Ecology*, **37**: 197-207.

Nakanishi, H., & Fukumoto, H., 1987. Coastal vegetation and topography in northern Hokkaido, Japan. *Hikobia*, **10**: 1-12.

Nakanishi, H., 1982. Coastal vegetation on the shingle spits of southwestern Japan. *Phytocoenologica*, **10**: 57-71.

Nakanishi, H., 1984. Phytosociological studies on the shingle beach vegetation in central and southern Japan. *Hikobia*, **9**: 137-145.

Nielsen, L.H., Johnnessen, P.N. & Surlyk, F., 1988. A Late Pleistocene coarse-grained spit-platform sequence in Northern Jylland, Denmark. *Sedimentology*, **35**: 915-937.

Oliver, F.W. & Salisbury, E.J., 1913. The topography and vegetation of Blakeney Point, Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society*, **9**: 485-544.

Oliver, F.W. & Salisbury, E.J., 1913. Vegetation and mobile ground as illustrated by *Suaeda fruticosa* on shingle. *Journal of Ecology*, **1**: 249-272.

Olsson-Seffer, P., 1909. Hydrodynamic factors influencing plant-life on sandy shores. *New Phytologist*, **8**, 37-49.

Orford, J.D. & Carter, R.W.G., 1995. Examination of mesoscale forcing of a swash-aligned gravel barrier. *Marine Geology*, **126**: 201-211.

Orford, J.D., Carter, R.W.G. & Jennings, S.C., 1996. Control domains and morphological phases in gravel-dominated coastal barriers. *Journal of Coastal Research*, **12**: 589-605.

Orford, J.D., Carter, R.W.G., Jennings, S.C. & Hinton, A.C., 1995. Processes and timescales by which a coastal gravel-dominated barrier responds geomorphologically to sea-level rise: Story Head barrier, Nova Scotia. *Earth Surface Processes and Landforms*, **20**: 21-37.

Orford, J.D., Carter, R.W.G., McKenna, J. & Jennings, S.C., 1995. The relationship between the rate of mesoscale sea-level rise and the retreat rate of swash-aligned gravel-dominated coastal barriers. *Marine Geology*, **124**: 177-186.

Orford, J.D., Forbes, D.L. & Jennings, S.C., 2001. Origin, development and breakdown of gravel-dominated coastal barriers in Atlantic Canada: future scenarios for North western Europe. In: *Ecology & Geomorphology of Coastal Shingle*, eds. J.R. Packham, R.E. Randall, R.S.K. Barnes & A. Neal, Westbury Academic & Scientific Publishing, Otley, West Yorkshire, 23-55.

Peterken, G.F. & Hubbard, J.C.E., 1972. The shingle vegetation of southern England: the holly wood on Holmestone Beach, Dungeness. *Journal of Ecology*, **60**: 547-571.

Philp, E.G. & McLean, I.F.G., 1985. The invertebrate fauna of Dungeness. In: *Dungeness: ecology and conservation*, eds. B. Ferry & S. Waters, Focus on nature conservation, No. **12**, Nature Conservancy Council, Peterborough, 94-135.

Postma, G. & Nemec, W., 1990. Regressive and transgressive sequences in raised Holocene gravelly beach, southwestern Crete. *Sedimentology*, **37**: 907-920.

Randall, R.E. & Doody, J.P., 1995. Habitat Inventories and the European Habitats Directive **-** the example of Shingle Beaches. In: *Directions in European coastal management.* Eds. M.G. Healy & J.P. Doody, Samara Publishing, Cardigan, 19-36.

Randall, R.E., 1973. Shingle Street, Suffolk: an analysis of a geomorphic cycle. *Bulletin of the Geological Society of Norfolk*, **24**, 15-35.

Randall, R.E., 1977. Shingle foreshores. In Barnes, R.S.K., ed., *The Coastline*. Wiley, London, 49-61.

Randall, R.E., 1977. Shingle formations. In Barnes, R.S.K., ed., *The Coastline*. Wiley, London.199-213.

Randall, R.E., Sneddon, P. & Doody, J.P., 1990. *Coastal shingle in Great Britain: a preliminary review*. Contract surveys, **No. 85**, Nature Conservancy Council, Peterborough.

Randall, R.E., 1977. Shingle Street and the sea. *Geographical Magazine*, **49**: 569-573.

Randall, R.E., 1977. The past and present status and distribution of Sea Pea, *Lathyrus japonicus* Willd. in the British Isles. *Watsonia*, **11**: 247-251.

Randall, R.E., 1986. *The status of Mertensia maritima in Great Britain*. *An interim report*. Report, Nature Conservancy Council, Peterborough.

Randall, R.E., 1988. The vegetation of shingle street, Suffolk in relation to its environment. *Transactions of the Suffolk Naturalists' Society*, **24,** 41-58

Randall, R.E., 1992. The shingle vegetation of the coastline of New Zealand: Nelson Boulder Bank and Kaitorete Spit. *New Zealand Journal of Geography*, **93,** 11-19.

Randall, R.E., 1996. The shingle survey of Great Britain and its implications for conservation management. In: *Coastal Management and Habitat Conservation, vol. 2.* eds. A.H.M.P. Salman, M.J. Langeveld & M. Bonazountas. EUCC, Leiden, 369-376,

Reynolds, D.H.B., 1986. Dungeness foreland: its shingle ridges and what lies under them. *Geographical Journal*, 152: 81-87.

Riley, H. & Ferry, B.W., 1986. Fighting for the beaches of Dungeness. *New Scientist*, June, 46-52.

Scott, G.A.M. & Randall, R.E., 1976. Biological flora of the British Isles: *Crambe maritima* L. *Journal of Ecology*, **64**: 1077-1091.

Scott, G.A.M., 1963. Biological flora of the British Isles: *Mertensia maritima* (L.) S F Gray. *Journal of Ecology*, **51**: 733-742.

Sherman, D.J., 1991. Gravel beaches. *Natural Geographic Research Exploration*, **7**: 442-452.
Shulmeister, J. & Kirk, R.M., 1993. Evolution of a mixed sand and gravel barrier system in North Canterbury, New Zealand, during Holocene sea-level rise and still-stand. *Sedimentary Geology*, **8**: 215-235.
Sneddon, P. & Randall, R.E., 1989. *Vegetated Shingle Structures Survey of Great Britain. Bibliography*. Report, Research & Survey in nature conservation series. No. **20**, Nature Conservancy Council, Peterborough.
Steers, J.A., 1926. Orfordness: A study in coastal physiography. *Proceedings of the Geology Association*, **37**: 306-325.
Walmsley, C.A. & Davy, A.J., 1997a. Germination characteristics of shingle beach species, effects of seed ageing and their implications for vegetation restoration. *Journal of Applied Ecology*, **34**: 131-142.
Walmsley, C.A. & Davy, A.J., 1997b. The restoration of coastal vegetation: effects of substrate composition on the establishment of seedlings. *Journal of Applied Ecology*, **34**: 143-153.
Waters, S. & Ferry, B., 1985. Vegetation of natural wetlands. *In: Dungeness ecology and conservation*, Eds. Brian Ferry & Stephen Waters. Focus on Nature Conservation. No. **12**. Nature Conservancy Council, Peterborough, 52-63.
Waters, S.J.P. & Ferry, B.W., 1989. Shingle-based wetlands at Dungeness. In: *Dungeness - the ecology of a shingle beach*, Eds. B.W. Ferry, S.J.P. Waters and S.L. Jury. *Botanical Journal of the Linnean Society*, **101:** 59-67.
White, D.A., 1961. Some observations on the vegetation of Blakeney Point following the disappearance of rabbits in 1954. *Journal of Ecology*, **49**: 113-118.
White, D.A., 1967. Brown hares (*Lepus europaeus*) on Orford Beach 1964-66. *Transactions of the Suffolk Naturalists' Society*, **14**: 49-57.
White, D.J.B., 1967. *An Annotated List of the Flowering Plants and Ferns on Blakeney Point, Norfolk*. National Trust, 2nd Edition
Wilkin, P.J., 1989. The medicinal leech, *Hirudo medicinalis* (L.) (Hirudinea: Gnathobdellae), at Dungeness, Kent. In: *Dungeness - the ecology of a shingle beach*, eds. B.W. Ferry, S.J.P. Waters and S.L. Jury, *Botanical Journal of the Linnean Society*, **101**: 45-57.
Williams, A.T. & Caldwell, N.E., 1988. Particle size and shape in pebble beach sedimentation. *Marine Geology*, **82,** 199-215.
Williams, P.H., 1989. Why are there so many bumble bees at Dungeness? In: *Dungeness - the ecology of a shingle beach*, Eds. B.W. Ferry, S.J.P. Waters & S.L. Jury, *Botanical Journal of the Linnean Society*, **101**: 31-44.
Williams, R.B., 1973. The significance of saline lagoons as refuges for rare species. *Transactions of the Norfolk and Norwich Naturalists' Society*, **22**: 352-387.
Zonfrillo, B., 1983. *Mertensia maritima* (L.) Gray in Ayreshire. *Glasgow Naturalist*, **20**: 260-261.

Shingle related publications

Adam, P. Birks, H.J.B., & Huntley, B., 1977. Plant communities of the island of Arran, Scotland. *New Phytologist*, **79**, 689-712.
Anon, 1980. *A study of South Walney*. Barrow-in-Furness: Barrow-in-Furness Borough Council.
Anon, Ed., 1966. *Orfordness: a selection of maps mainly by John Norden presented to James Alfred Steers*. Cambridge: Heffers.
Barne, J.H., Robson, C.F., Kaznowska, S.S. & Doody, J.P., 1998. *Coasts and seas of the United Kingdom. Region 7, South-east England: Lowestoft to Dungeness*. Peterborough, Joint Nature Conservation Committee.
Barnes, R.S.K, ed., 1977. *The Coastline*. London: Wiley.
Boorman, L.A., 1991 Coastal Habitats. In: *The Greenhouse Effect and Terrestrial Ecosystems of the UK*. Research Publication no. 4. Institute of Terrestrial Ecology. Cannell M G R, Hooper M D, Eds., London, HMSO, 51-53.
Causton D.R., 1988. *Introduction to vegetation analysis*. Unwin Hyman Ltd., London.
Cavers, P.B. & Harper, J.L., 1967. The comparative biology of closely related species living in the same area. IV. *Rumex*. The nature of adaptation to a seashore habitat. *Journal of Ecology*, **55**: 73-82.
Chapman, V.J., 1960. The plant ecology of Scolt Head Island. In: Steers J A, ed. *Scolt Head Island*. Cambridge: Heffer, 85-163.
Chapman, V.J., 1976. *Coastal Vegetation*. Pergamon Press, Oxford.
Conyers, L.B. & Goodman D., 1997. *Ground-Penetrating Radar: An Introduction for Archaeologists*. London: Altamira Press.
Corre, T.J., 1993. Dry coastal ecosystems of Southern France. In: *Dry Coastal Ecosystems, **2A** Polar Regions and Europe*. Ed. E. van der Maarel, Elsevier, Amsterdam, 309-375.
Davis, J.L., 1972. *Geographical Variation in Coastal Development*. Edinburgh: Oliver and Boyd.
Dobbs, C.G., 1939. The vegetation of Cape Napier, Spitzbergen. *Journal of Ecology*, **27**: 126-148.
Doody, J.P., 1992. Sea defence and nature conservation: threat or opportunity. *Journal of Aquatic Conservation*, **2**, 275-283

Doody, J.P., Pamplin C, Gilbert C & Bridge L, 1998. *European Union Demonstration Programme on Integrated Coastal Zone Management - Theme F, INFORMATION*. Report to the European Environment Agency, 60 pp.

Doody, J.P., Salman A H P M, Heslenfeld, P. & Valentijn, L., 1998a. *European Coastal & Marine Ecological Network (ECMEN) Phase II Report*. EUCC, Leiden, The Netherlands.

Evans, A.L., 1971. Maritime Cumbria: some landforms and associated ecology. In: Evans, A.L., ed. *The Naturalist's Lake District*. Clapham, Yorkshire: Dalesman, 17-34

Field, J.E. & Randall, R.E., 1986. The lagoons of Shingle Street, Suffolk: a pilot study of their water characteristics. *Bulletin of the Geological Society of Norfolk*, **36**: 97-107.

Fjelland, E. et al., 1983. *Botanical conservation values on seashores in Troms, Northern Norway*. Institute of Biology and Geology, University of Tromso, 290 pp.

Flinn, D., 1974. The coastline of Shetland. In: Goodier, R., Ed. *The Natural Vegetation of Shetland*. Edinburgh: Nature Conservancy Council.

Géhu, J.M. & Géhu-Franck, J., 1993. Dry coastal ecosystems of Belgium and the Atlantic coasts of France. In: *Dry Coastal Ecosystems. **2A**. Polar Regions and Europe*. Ed E. Van der Maarel, Elsevier, Amsterdam, 307-327.

Géhu, J.M., 1991. Vegetations et paysages littoraux de type Cantabro-atlantique. *Berichte der Reinhold-Tuxen Gesellschatf* **3**: 59-128

Giddings, J.L., 1967. *Ancient Men of the Arctic*. Alfred A. Knoff.

Gubbay, S., 1986. Nature conservation in the coastal zone of Great Britain. *Journal of Shoreline Management* **2**: 241-257

Halcrow, 2003. *Futurecoast*. A 3 CD set comprising reports and interactive map browser and two CDs with oblique aerial photography of the shoreline of England and Wales, Department of Environment, Food and Rural Affairs.

Harrison, J.M., 1953. *The Birds of Kent*. 2 Volumes, H.F. & G. Witherby.

Hepburn, I., 1952. *Flowers of the Coast*. London: Collins New Naturalist Press.

Howarth, W.O., 1920. Notes on the habitats and ecological characters of three sub-varieties of *Festuca rubra*. *Journal of Ecology*, **8**: 216-231.

Hubbard, J.C.E. & Grime B.H., 1972. The analysis of coastal vegetation through the medium of aerial photography. *Medical and Biological Illustrations*, **22**: 182-190.

Jermy, A.C. & Crabbe, J.A., 1978. *The Island of Mull, a Survey of its Flora and Environment.* London: British Museum.

Johnson, D.W., 1919. *Shore Processes and Shoreline Development*. New York: J Wiley and Sons.

Jol, H.M., Smith, D.G. & Meyers, R.A., 1996. Digital ground penetrating radar (GPR): a new geophysical tool for coastal barrier research (examples from the Atlantic, Gulf and Pacific coasts, USA). *Journal of Coastal Research*, **12**: 960-968.

Kidson, C., 1959. The uses and limitations of vegetation in shore stabilisation. *Geography*, **44**: 241-250

Kidson, C., 1963. The growth of sand and shingle spits across estuaries. *Zeitschrift fur Geomorphologie*, **7**: 1-22

King, C.A.M., 1972. *Beaches and Coasts*. London, Arnold.

Kinsey, G., 1981. *Orfordness: Secret site; a history of the establishment 1915-1980*, Dalton: Lavenham.

Kirby, P., 1992. *Habitat Management for Invertebrates: a Practical Handbook*. Joint Nature Conservation Committee, Peterborough, RSPB, Sandy, Bedfordshire.

Kjerfve, B., ed., 1994. *Coastal Lagoon Processes*. Elsevier: Amsterdam.

Lovric, A.Z., 1993. Dry coastal ecosystems of Croatia and Yugoslavia. In: *Dry Coastal Ecosystems. **2A**. Polar Regions and Europe*. Ed. E. Van der Maarel, Elsevier, Amsterdam, 391-420.

Lundberg, A. (& Losvik, M.H.), 1993. Dry coastal ecosystems of central and southern Norway. In: *Dry Coastal Ecosystems. **2A**. Polar Regions and Europe*. Ed. E. Van der Maarel, Elsevier, Amsterdam, 119-127.

Lundqvist, A., 1983. Olandska havstrandaspekter. *Sven. Bot. Tidskr.*, **77**: 105-116.

McManus, J., 1988. Grain size determination and interpretation. In: Tucker M, ed. *Techniques in Sedimentology*. Oxford, UK: Blackwell Scientific Publications, 63-85.

Nordhagen, R., 1940. Studien uber die maritime vegetatin Norwgens I. Die pflanzengeselleschaften der tangwalle. *Bergens Museum Aarbheit*, 1939-1940: 1-123.

Ogilvie, A.G., 1923. The physiography of the Moray Firth coast. *Transactions of the Royal. Society of Edinburgh*, **53**: 377-379.

Packham, J.R. & Willis, A.J., 1997. *Ecology of Dunes, Salt Marsh and Shingle*. London: Chapman and Hall.

Polunin, O. & Walters, M., 1985. *A guide to the vegetation of Britain and Europe*. Oxford University Press.

Prater, A.J., 1976. Breeding population of the ringed plover in Britain. *Bird Study* **23**: 155-161.

Prince, S.D. & Hare, A.D.R., 1981. *Lactuca saligna* and *Pulicaris vulgaris* in Britain in: *The biological aspects of rare plant conservation*, Synge, H. ed. London, Wiley, 379-388.

Pye, K., 1994. Properties of sediment particles. In: Pye K, ed. *Sediment Transport and Depositional Processes*. Oxford, UK: Blackwell Scientific Publications, 1-24.

Randall, R.E. & Scott G.A.M., 1997 Communities of sand and shingle beaches. In: *Ecosystems of the world, 2c, Dry Coastal Ecosystems, General Aspects.* Ed. E. van der Maarel, Elsevier Science, Amsterdam, 263-274.

Ratcliffe, D.A., 1974. Ecological effects of mineral exploitation in the United Kingdom and their significance to nature conservation. *Proceedings of the Royal Society of London, Series A*, **339**: 355-372.
Rebassoo, H.E., 1975. S*ea-shore plant communities of the Estonian islands*. Academy of Sciences of the Estonian SSR, Tartu, 17pp.
Reynolds, J.M., 1997. *An Introduction to Applied and Environmental Geophysics*. Chichester: Wiley.
Rodwell, J., 2000. *British Plant Communities, Volume 5. Maritime Communities and Vegetation of Open Habitats*. Cambridge University Press, Cambridge.
Salisbury, E.J., 1952. *Downs and Dunes*. London: Bell.
Simpson, H.J.A., 1976. Vegetation. In: Collyer, E., ed. *History and Natural History of the Boulder Bank, Nelson Haven, Nelson, New Zealand.* Nelson: Cawthorn Institute, 20-25.
Sorenson, J., Gable, F. & Bandarin, F., eds. 1993. *The Management of Coastal Lagoons and Enclosed Bays.* New York: American Society of Civil Engineers.
Sparks, B., 1972. *Geomorphology*. Longman, London.
Steers, J.A., 1964. *The Coastline of England and Wales*. Cambridge: Cambridge University Press.
Steers, J.A., 1973. *The Coastline of Scotland*. Cambridge: Cambridge University Press.
Sutton, P., 1999. The Scaly Cricket in Britain. A complete history from discovery to citizenship. *British Wildlife*, **10**: 145-151.
Tansley, A.G., 1939. *The British Islands and their Vegetation*. University Press, Cambridge.
Thomas, G.J., Partridge, J., Wolstenholme, R.S., Richards, P., Everett, M.J. & Cadbury, C.J., 1982. The increase and feeding habits of herring and lesser black-backed gulls at Orfordness, Suffolk. *Transactions of the Suffolk Naturalists' Society*, **18**: 277-285.
van der Maarel, E. ed., 1993. *Dry Coastal Ecosystems, **2A** Polar Regions and Europe*. Elsevier Science, Amsterdam.
van der Maarel, E. ed., 1993. *Ecosystems of the world, 2c, Dry Coastal Ecosystems, General Aspects*, Elsevier Science, Amsterdam,
van Heteren, S., Fitzgerald, D.M., McKinlay, P.A. & Buynevich, I.V., 1998. Radar facies of paraglacial *barrier* systems: coastal New England, USA. *Sedimentology*, **45**: 181-200.
Williams, W.W., 1956. An east coast survey: some recent changes in the coast of East Anglia. *Geographical Journal,* **122**: 317-334.

APPENDIX 01 A SUMMARY OF LEGISLATION

[Produced by David Tyldesley MIEEM, FRTPI, FRSA for English Nature]

This Annex provides an overview of the various regulatory controls that may affect proposals to manage or restore shingle habitats. These fall into two principal categories:

- Controls that would relate to all such proposals, irrespective of site designations – general regulatory controls; and
- Controls that are specific to and apply in relation to particular designations – specific regulatory controls.

This chapter also looks at the key policy frameworks that may influence the decisions taken under these procedures and provides maps showing the location and extent in Great Britain of sites designated for their biological or geomorphological shingle interest features. These designations are principally Sites of Special Scientific Interest (SSSI), National and Local Nature Reserves, candidate Special Areas of Conservation (cSAC) and Ramsar Sites.

GENERAL REGULATORY CONTROLS

Development requiring planning permission

Development is defined by section 55 of the Town and Country Planning Act 1990 and section 26 of the Town and Country Planning Act (Scotland) 1997 as "*the carrying out of building, engineering, mining or other operations in, on, over or under land, or the making of any material change in the use of any buildings or other land*". Generally, planning permission is required to undertake any works that fall within the definition of development that are not exempt by the 1990 / 1997 Act. In the case of physical works to vegetated shingle habitats, involving the movement of shingle or construction of structures such as groynes, it is likely that planning permission will be required. Permission may also be required if a material change of land use would be involved, but such cases are likely to be infrequent. Planning permission is not required for ongoing management of habitats that do not involve engineering or mining operations.

Extraction of shingle for use as a mineral would be a mining operation and will always require planning permission. All but minor movements of shingle, even where there is no intention to use it as a mineral, are likely to be an engineering operation in the meaning of the Act and will also require planning permission.

Planning permission for engineering and mineral operations on shingle would normally be obtained following the submission and consideration of a planning application by the relevant planning authority. If the local planning authority refuses permission it may be granted, on appeal, in England and Wales by a Planning Inspector (acting under delegation from the first Secretary of State / Welsh Assembly Government) or in Scotland by a Reporter (acting under delegation from the Scottish Ministers).

Certain works, for example by the Environment Agency or Scottish Environment Protection Agency (SEPA) or a local authority, may be granted planning permission generally by the Secretary of State / Welsh Assembly Government, through the provisions of Article 3 and Schedule 2 of the Town and Country Planning (General Permitted Development) Order 1995 or by the Scottish Ministers through the provisions of Article 3 and Schedule 2 of the Town and Country Planning (General Permitted Development) (Scotland) Order 1992. These general grants of planning permission are referred to as "permitted development". An express planning application does not have to be made for permitted development because permission has already been granted. However, these permitted developments are subject to conditions, two of which are explained further below in respect of the Habitats Regulations and the EIA regulations.

Most new or replacement local authority coast protection schemes will require planning permission on an application. However, because the local authority is also the planning authority, such applications are dealt with under special procedures in the Town and Country Planning (General) Regulations 1992 or Town and Country Planning (Development by Planning Authorities) (Scotland) Regulations 1981.

Sections 54A and 70 of the Town and Country Planning Act 1990 / S.25 and 37(2) Town and Country Planning (Scotland) Act 1997 require planning authorities (and the Secretary of State / Welsh Assembly Government and Inspectors and, in Scotland, Scottish Ministers / Reporters) to determine planning applications in accordance with the development plan unless material considerations indicate otherwise[2]. It means that the development plan is a particularly important consideration in deciding planning applications. The development plan consists of the Structure Plan and the Local Plan (including any Mineral and Waste Local Plans) or the Unitary Development Plan[3]. Other material considerations may include national planning guidance that comprises, in England, the series of Planning Policy Guidance Notes (PPGs) and the fifteen Mineral Planning Guidance Notes (MPGs) issued since 1992. PPG7 *The Countryside: Environmental Quality and Economic and Social Development* 1997; PPG9 *Nature Conservation* 1994; PPG20 *Coastal Planning* 1992 and PPG25 *Development and Flood Risk* 2001 are particularly relevant here. The series of PPGs and MPGs is currently under review and will be replaced by new government planning policy statements (PPSs).

Similar guidance is found in relation to Scotland in Scottish Planning Policy (SPP) 1, *The Planning System* 2002; National Planning Policy Guidelines (NPPG)7 *Planning and Flooding*, 1995, NPPG13 *Coastal Planning* 1997 and NPPG14 *Natural Heritage* 1999; and, in relation to Wales, in *Planning Policy Wales* 2002 and Technical Advice Notes (TAN) 5 *Nature Conservation and Planning* 1996, TAN14 *Coastal Planning* 1998 and TAN15 *Development and Flood Risk* 1998. In Scotland the series of NPPGs is being replaced by Scottish Planning Policies, SPPs.

The jurisdiction of planning control is normally down to MLWM (MLWMOST in Scotland).

Works below MHWM

Works or deposit of materials below MHWM (eg movement of shingle on the intertidal areas or construction of groynes) will require the consent of the Crown Estate Commissioners (or other landowner). A licence under the Food and Environment Protection Act (FEPA) 1985 may also be required from D*efra* and in some circumstances, where works below MLWS may affect navigation, consent from the Department for Transport (Ports Division), Welsh Assembly Government or Scottish Executive will be required under the Coast Protection Act 1949.

Works on or affecting flood or coastal defence structures

Any works to structures that form part of coastal protection schemes or flood defences, whether natural or artificial, will require the agreement of the Coast Protection Authority (usually the local authority) or the Environment Agency respectively. Policy and strategic planning for flood defence and coastal protection is embodied in D*efra*, 2001, *Shoreline Management Plans – A Guide for Coastal Defence Authorities* and the national series of Shoreline Management and Estuary Management Plans. Other D*efra* publications are accessible via www.defra.gov.uk/environ/fcd/pubs

Land drainage works

In this context land drainage has a wide definition. Works that may affect a Land Drainage Improvement Scheme authorised under the Land Drainage Act 1991 or Land Drainage (Scotland) Act 1958 or Flood Prevention and Land Drainage (Scotland) Act 1997 will need to be agreed with the appropriate land drainage body, likely to be the Environment Agency, Internal Drainage Board (IDB) or Scottish Environment Protection Agency (SEPA).

---

[2] This requirement is more fully explained in paras 39 – 56 of Planning Policy Guidance Note (PPG) 1 *General Policy and Principles*, 1997 (England), and paras 46 – 49 Scottish Planning Policy (SPP) 1, *The Planning System*, 2002.

[3] See PPG 12 *Development Plans* 1999; paras 3.1.1 – 3.1.6 *Planning Policy Wales*, 2002 and *Unitary Development Plans Wales* National Assembly for Wales 2001; and paras 25 – 40 SPP1, *The Planning System*, 2002).

Rivers and other watercourses

If the water level in a main river is likely to be affected by any works to the shingle, or if it is proposed to discharge into a watercourse, consent is required from the Environment Agency or SEPA. Consent from the local IDB will also be required for proposals likely to affect the water level of main drains or other watercourses on land in another ownership.

Environmental impact assessment

It is unlikely that most habitat restoration or management schemes for vegetated coastal shingle will be subject to the Environmental Impact Assessment (EIA) process. However, where undertaken in connection with flood defence or coast protection schemes, or other types of project listed in Schedules 1 or 2 of the Town and Country Planning (Environmental Impact Assessment) (England and Wales) Regulations 1999 or the Environmental Impact Assessment (Scotland) Regulations 1999 the whole project may be subject to EIA procedures. Works that may otherwise be permitted development (see above) cannot proceed without an application for express planning permission being made if they would constitute EIA development[4].

SPECIFIC REGULATORY CONTROLS

Works on or affecting a SSSI

Under the provisions of S.28 of the Wildlife and Countryside Act 1981, as amended, English Nature, CCW and SNH have a duty to notify Sites of Special Scientific Interest (SSSI) where they are of the opinion that the land is of special interest by reason of its flora, fauna, geological or physiographical (including its geomorphological) interest. The reasons for notification are known as the site's interest features. It should be noted that the provisions of the section in relation to England and Wales were modified and extended by section 75 and Schedule 9 of the Countryside and Rights of Way (CRoW) Act 2000 and differ substantially from the provisions in Scotland.

In England and Wales any operations likely to damage the interest features of a SSSI are subject to one of three types of control, under section 28E, 28H or 28I, depending on who would be carrying out the works, where, and whether they need the consent of a public body. The provisions are set out below in outline only and reference must be made to the relevant sections of the Act that prescribe the procedures to be followed and how offences may arise for non-compliance.

Section 28E

The operations likely to damage a SSSI are listed in the citation accompanying the notification of the site; examples relevant to shingle habitat conservation are given in the box below.

[4] Detailed guidance is provided on EIA procedures in DETR Circular 2/99 *Environmental Impact Assessment*;Welsh Assembly Government Circular 11/99 *Environmental Impact Assessment;* Scottish Executive Circular 15/1999 *The Environmental Impact Assessment (Scotland) Regulations 1999* and Scottish Executive Planning Advice Note (PAN)58 *Environmental Impact Assessment* 1999.

Some operations likely to damage shingle interest features of SSSI

- Grazing
- Reclamation
- Gravel extraction
- Use of vehicles or craft.
- Draining or water abstraction.
- Sea defences or coast protection works
- Reprofiling.
- Roads, tracks, walls, fences, hardstands, banks, ditches or other earthworks.
- Erection of permanent or temporary structures.

Before any operations that are likely to damage the interest features of the SSSI may be carried out, within a SSSI, by an owner or occupier, or by someone on their behalf, or with their permission, the owner or occupier must first give notice to EN / CCW and may not proceed with the works unless:

a) they have received the written consent of EN / CCW; or
b) the operations are carried out in accordance with a management agreement under previous legislation, or a management scheme (under S.28J) or a management notice (under S.28K); or
c) the works were an emergency operation and particulars of them (including details of the emergency) are submitted to EN / CCW as soon as practicable after the commencement of the operation; or
d) the operations have been authorised by a planning permission granted on an application (this excludes permitted development, see above) or in accordance with a consent granted by another public body (called a Section 28G Authority see below) that has followed the consultation requirements of S.28I (also described below).

Conditions can be imposed on any consent granted under S.28E. Further guidance on the requirements and implications of S.28E can be obtained from the EN website at www.english-nature.org.uk

Section 28G

Section 28G defines all public bodies and persons holding any public office as a “Section 28G Authority” and imposes a general duty on them to take reasonable steps, consistent with the proper exercise of their functions, to further the conservation and enhancement of the interest features of all SSSI.

Section 28H

Under S.28H, a Section 28G Authority must give notice to EN / CCW before carrying out any operations likely to damage any of the interest features of a SSSI, whether or not the operations would take place in the SSSI. If EN / CCW do not assent to the operations the S.28G Authority may only carry them out in accordance with procedures set out in S.28H and, in any event, shall carry out the operations in such a way as to give rise to as little damage to the interest features as is reasonably practicable in all the circumstances, taking account of any advice from EN / CCW. The authority must also restore the site to its former condition so far as is reasonably practicable.

Section 28I

S.28I provides for cases where a Section 28G Authority is responsible for giving any kind of consent or authorisation to operations likely to damage any of the interest features of a SSSI, whether or not the operations would take place in the SSSI. Before giving any permission in these cases, the S.28G Authority must give 28 days notice of the proposed operations to EN / CCW and must take account of any advice received. If the Authority proposes to grant permission to the operations against the advice of EN / CCW (or not including conditions recommended by EN / CCW) they must give EN / CCW notice of the terms of the permission, how they have taken account of the advice and ensure that the operations cannot commence until after the expiry of 21 days notice to EN / CCW.

Further guidance on the requirements and implications of S.28G - I can be found in DETR Circular 04/2001 *The Countryside and Rights of Way Act 2000.*

Sections 28E and G – I, as described above were introduced by the Countryside and Rights of Way Act 2000 and do not apply in Scotland. SNH does not have the power to refuse to permit operations likely to damage the interest features of SSSI and public bodies do not have the duties in relation to carrying out or permitting operations. However, new legislation is expected to be proposed in the Scottish Parliament. Emerging Scottish legislation can be monitored on www.scotland.gov.uk/legislation

Works on or affecting National and Local Nature Reserves

National and Local Nature Reserve (NNR and LNR) designations are a recognition of a site's particular national or local importance. The designation is a material consideration in decisions but these designations do not have associated legislation that imposes specific duties on decision makers, or others wishing to carry out operations or projects that may affect them. However, all NNRs and many LNRs will be SSSI so the above provisions will apply and, in any event, works in NNRs and LNRs should be consistent with the terms of any nature reserve agreement or other legal / management agreements in force. NNRs are particularly important for their potential contribution to research and education and are owned or otherwise managed by EN / CCW / SNH or managed by other owners / occupiers under specific NNR agreements with nature conservation as the priority. LNRs can only be designated by local authorities, in consultation with EN / CCW / SNH, under the provisions of S.21 National Parks and Access to the Countryside Act 1949.

Works on or affecting a European Site

In addition to the controls relating to SSSI, there are further controls imposed by Regulations 48 – 53 of the Conservation (Natural Habitats &c) Regulations 1994. Regulation 3 imposes a general duty on all competent authorities (widely defined in Reg.6 to include any public body or person holding a public office), in the exercise of any of their functions, to have regard to the requirements of the Habitats Directive so far as they may be affected by the exercise of those functions.

Specifically, Regulation 48 requires that, before deciding to undertake or to give any kind of consent, licence, permission or other authorisation, for a plan or project (widely defined to include any kind of new works), a competent authority must consider whether the proposal would be likely to have a significant effect on a European Site in Great Britain, either alone or in combination with any other plans or projects. If it is likely to have such an effect, it must be subject to an appropriate assessment. This is an assessment of the implications of the project in view of the conservation objectives for the site. Plans and projects directly connected with and necessary to the management of the site for nature conservation are exempt from the requirements for an assessment.

In England European Sites are all classified SPAs and cSAC, and in due course, Sites of Community Importance (SCI) and fully designated SACs. In Scotland and Wales they are at present only classified SPAs, but see below in respect of proposed European Sites and Ramsar Sites.

The competent authority must consult EN / CCW / SNH, and have regard to their representations, and may consult the general public. It must consider the way in which the project is proposed to be carried out and any restrictions such as conditions that may be imposed. The competent authority cannot grant permission or undertake the project unless:

a) It can ascertain that the project would not adversely affect the integrity of the site; or
b) If the project would adversely affect the integrity of the site or there is uncertainty over the possible effects,
    i. there are no alternative solutions; and
    ii. there are imperative reasons of overriding public interest (which are more restricted in scope if a habitat or species listed as a priority in the Habitats Directive would be affected).

If a competent authority is minded to grant a permission or undertake a project in the circumstances of (b) above, it must first give notice to the Secretary of State / Welsh Assembly Government / Scottish Ministers and comply with any directions they may issue. If permission is to be granted the government must ensure that any necessary compensatory measures are taken to ensure the overall coherence of Natura 2000 is protected[5].

Regulation 60 of the Habitats Regulations imposes a condition on all forms of permitted development (see above) that would be likely to have a significant effect on a European Site in Great Britain, either alone or in combination with other plans or projects. Such permitted development shall not be carried out or continued without the prior written approval of the planning authority. This does not in itself withdraw permitted development rights but subjects permitted development likely to affect a European Site to a prior approval procedure (under Regulation 62) in which the planning authority will undertake an appropriate assessment and consult EN / CCW / SNH. Permitted development directly connected with and necessary to the management of the European Site for nature conservation is exempt from the requirements for prior approval. If the planning authority can ascertain that the permitted development would not adversely affect the integrity of the European Site, it should approve the development which may then proceed as permitted development in accordance with the General Permitted Development Order. If the planning authority cannot ascertain that the permitted development would not adversely affect the integrity of the European Site, it is prohibited from granting prior approval and a full planning application would need to be made which would be subject to the requirements of Regulations 48 – 53 described above.

Works on or affecting a proposed European Site or Ramsar Site

In England candidate SACs are already European Sites as a matter of law. In Scotland and Wales cSACs are not European Sites as a matter of law but it is government policy to treat them and (as in England) proposed SPAs and classified Ramsar Sites as if they are fully designated European Sites for the purposes of considering development proposals that may affect them[6].

Works affecting a Scheduled (Ancient) Monument

If any proposed works would be undertaken on or adjacent to (i.e. affecting the setting of) a Scheduled (Ancient) Monument it would be necessary to obtain, in England a Scheduled Monument Consent from English Heritage; in Wales a similar consent from Cadw; and in Scotland a Scheduled Monument Consent from the Scottish Ministers (Historic Scotland) under the provisions of The Ancient Monuments and Archaeological Areas Act 1979[7].

---

[5] Further guidance on the application of these regulations can be found in Annex C of DoE PPG9, 1994; Ministerial Statement House of Commons, published by DETR, 12 May 1998, *Guidance on Application of Articles 6(3) and (4) of the Habitats Directive*; paras 39 – 45 of Scottish Office Development Department NPPG14 *Natural Heritage* 1999; Scottish Executive (SERAD) Circular of June 2000, *Nature Conservation: Implementation in Scotland of EC Directives on the Conservation of Natural Habitats and Wild Flora and Fauna and the Conservation of Wild Birds (the Habitats and Birds Directives)* and paras 6 – 20 Welsh Office, TAN5 *Nature Conservation and Planning* 1996; European Commission DG Environment, *Managing Natura 2000 Sites The provisions of Article 6 of the Habitats Directive 92/43/EEC*, April 2000 and European Commission DG Environment, *Assessment of Plans and Projects Significantly Affecting Natura 2000 Sites – Methodological guidance on the provisions of Article 6(3) and 6(4) of the Habitats Directive 92/43/EEC*, November 2001

[6] Further guidance on this policy may be found in paras 13 and C7 DoE PPG9, 1994; DETR, *Ramsar Sites in England A Policy Statement*, 2000; the footnote page 1 of Welsh Office TAN 5 *Nature Conservation and Planning* 1996; and para 39 Scottish Executive Development Department NPPG14 *Natural Heritage* 1999.

[7] Guidance on taking archaeological interests into consideration in developments is set out in DoE PPG16 *Archaeology and Planning*, 1990; Welsh Office Circular 60/96 *Planning and the Historic Environment: Archaeology*, 1996; and Scottish Office Environment Department NPPG5 *Archaeology and Planning*, 1994.

Works affecting a Listed Building or Conservation Area

It is possible that shingle areas may contain (or may lie in the curtilage of) buildings or other structures that are Listed Buildings of Special Architectural or Historic Interest on registers of Listed Buildings compiled by English Heritage, Cadw and the Scottish Ministers (Historic Scotland). Any works that may affect such buildings or structures will require Listed Building Consent in addition to any planning permission or other consents required, under the provisions of the Planning (Listed Buildings and Conservation Areas) Act 1990 or the Planning (Listed Buildings and Conservation Areas) (Scotland) Act 1997. In considering any such application, Ss. 16 and 66 of the 1990 Act require any planning authority, Inspector, the Secretary of State or the Welsh Assembly Government to have special regard to certain matters, including the desirability of preserving the setting of the building and any features of special architectural or historic interest it possesses as well as the building itself. A similar requirement is imposed on planning authorities, Reporters and the Scottish Ministers in Ss.14 and 59 of the 1997 Act[8].

Works impeding a public right of way

If works would obstruct a public right of way or impede passage along such a route it would be necessary to obtain a temporary (or permanent) diversion order via the local Highway Authority (England and Wales) or Roads Authority (Scotland).

Other Considerations

Other, general, legal considerations that could apply to such works are not covered in the above discussion but may include such matters as health and safety, employment law, human rights, compliance with any legal agreements (including tenancy, financial and management agreements) and / or restrictive covenants on land and obtaining the consent of private landowners.

[8] Guidance on Listed Building Consents and development control in Conservation Areas is provided in DoE PPG15 *Planning and the Historic Environment*, 1994; Welsh Office Circular Circular 61/96 *Planning and the Historic Environment: Historic Buildings and Conservation Areas*, 1996; Scottish Office Development Department NPPG18 *Planning and the Historic Environment*, 1999 and Scottish Office *Memorandum of Guidance on Listed Buildings and Conservation Areas* 1998.

Appendix 02 Descriptions of the shingle element within the candidate Special Areas of Conservation, derived from the Joint Nature Conservation Committee web site

Chesil Beach

1210 Annual vegetation of drift lines

Chesil Beach is a large (28km-long), relatively undisturbed shingle bar, and is one of two representatives of **Annual vegetation of drift lines** on the south coast of England. The inner shore of the beach supports extensive drift-line vegetation dominated by sea beet *Beta vulgaris* ssp. *maritima* and orache *Atriplex* spp. This community exists in a dynamic equilibrium with the perennial shrubby sea-blite *Suaeda vera* community typical of **1420 Mediterranean and thermo-Atlantic halophilous scrubs** (***Sarcocornetea fruticosi***), for which this site has also been selected.

1220 Perennial vegetation of stony banks

The 28km-long shingle bar of Chesil Beach, with the contiguous Portland Harbour shore, is an extensive representative of **Perennial vegetation of stony banks** on the south coast of England, and most of it is relatively undisturbed by human activities. Much of the shingle bar is subject to wash-over and percolation in storm conditions and is therefore sparsely vegetated. It supports the most extensive occurrences of the rare sea-kale *Crambe maritima* and sea pea *Lathyrus japonicus* in the UK, together with other grassland and lichen-rich shingle plant communities typical of more stable conditions, especially towards the eastern end of the site.

Dungeness

1210 Annual vegetation of drift lines

The Dungeness foreland has a very extensive and well-developed shoreline, although with sparse vegetation and in places some human disturbance. It is one of two representatives of **Annual vegetation of drift lines** on the south coast of England. The strandline community on this site comprises Babington's orache *Atriplex glabriuscula*, which occurs mostly on the accreting eastern shoreline, although it is also present on the eroding southern shoreline.

1220 Perennial vegetation of stony banks

Dungeness is the UK's largest shingle structure and represents the habitat type on the south-east coast of England. The total area of exposed shingle covers some 1,600ha, though the extent of the buried shingle ridges is much greater. Despite considerable disturbance and destruction of the surface shingle, the site retains very large areas of intact parallel ridges with characteristic zonation of vegetation. It still has the most diverse and most extensive examples of stable vegetated shingle in Europe, including the best representation of scrub on shingle, notably prostrate forms of broom *Cytisus scoparius* and blackthorn *Prunus spinosa*. A feature of the site, thought to be unique in the UK, is the small depressions formed within the shingle structure, which support fen and open-water communities.

Blakeney Point

1220 Perennial vegetation of stony banks

Perennial vegetation of stony banks occurs at Blakeney Point, a shingle spit on the east coast of England with a series of recurves partly covered by sand dunes. This extensive site has a typical sequence of shingle vegetation, which includes open communities of pioneer species on the exposed ridge and more continuous grassland communities on the more sheltered shingle recurves. It also includes some of the best examples of transitions between shingle and saltmarsh, with characteristic but rare species more typical of the Mediterranean. These include one of the best examples of the transition from sand and shingle to vegetation dominated by shrubby sea-blite *Suaeda vera* (**1420 Mediterranean and thermo-Atlantic halophilous scrubs**). Blakeney Point is part of a multiple-interest site. The shingle structure forms a highly significant component of the geomorphological structure of the North Norfolk Coast and helps to maintain a series of interrelated habitats.

Minsmere to Walberswick

1210 Annual vegetation of drift lines

This site is one of two representatives of **Annual vegetation of drift lines** on the east coast of England. It occurs on a well-developed beach strandline of mixed sand and shingle and is the best and most extensive example of this restricted geographical type. Species include those typical of sandy shores, such as sea sandwort *Honckenya peploides* and shingle plants such as sea beet *Beta vulgaris* ssp. *maritima*.

Orfordness

1210 Annual vegetation of drift lines

Orfordness is an extensive shingle spit some 15km in length and is one of two sites representing **Annual vegetation of drift lines** on the east coast of England. In contrast to Minsmere to Walberswick Heaths and Marshes, drift-line vegetation occurs on the sheltered, western side of the spit, at the transition from shingle to saltmarsh, as well as on the exposed eastern coast. The drift-line community is widespread on the site and comprises sea beet *Beta vulgaris* ssp. *maritima* and orache *Atriplex* spp. in a strip 2-5m wide.

1220 Perennial vegetation of stony banks

Orfordness is an extensive shingle structure on the east coast of England and consists of a foreland, a 15km-long spit and a series of recurves running from north to south on the Suffolk coast. This spit has been selected as it supports some of the largest and most natural sequences in the UK of shingle vegetation affected by salt spray. The southern end of the spit has a particularly fine series of undisturbed ridges, with zonation of communities determined by the ridge pattern. Pioneer communities with sea pea *Lathyrus japonicus* and false oat-grass *Arrhenatherum elatius* grassland occur. Locally these are nutrient-enriched by the presence of a gull colony; elsewhere they support rich lichen communities. The northern part of Orfordness has suffered considerable damage from defence-related activities but a restoration programme for the shingle vegetation is underway.

Culbin Shingle Bar

1220 Perennial vegetation of stony banks

Historically, Culbin Bar in north-east Scotland formed part of the same shingle aggregation as Lower River Spey – Spey Bay to the east. Although sea-level rise has separated the sites, they are still linked, being maintained by the same coastal processes. Culbin Bar and the Lower River Spey – Spey Bay are, individually, the two largest shingle sites in Scotland and together form a shingle complex unique in Scotland. They represent **Perennial vegetation of stony banks** in the northern part of its range in UK. Culbin Bar is 7 km long. It has a series of shingle ridges running parallel to the coast that support the best and richest examples of northern heath on shingle. Dominant species are heather *Calluna vulgaris*, crowberry *Empetrum nigrum* and juniper *Juniperus communis*. The natural westward movement of the bar deposits new ridges for colonisation. Being virtually unaffected by damaging human activities, Culbin Bar is an example of a system with natural structure and function.

Spey Bay

1220 Perennial vegetation of stony banks

Historically, Lower River Spey – Spey Bay in north-east Scotland formed part of the same shingle aggregation as Culbin Bar to the west. Although sea-level rise has separated the sites, they are still linked, being maintained by the same coastal processes. Lower River Spey – Spey Bay and Culbin Bar are, individually, the two largest shingle sites in Scotland and together form a shingle complex unique in Scotland. They represent this habitat type in the northern part of its range in the UK. Lower River Spey – Spey Bay contains significant areas of both bare and naturally vegetated parallel shingle ridges, although some of these have been planted with trees. The most significant feature of the site is the complex of wet and dry vegetation types, depending on the physical relief of the shingle ridges and hollows. Species-rich dry heath and grassland occurs on the ridges, while in the wetter hollows there is species-rich wet heath and transitions to a vegetation type comparable to that of dune slacks. Large areas of scrub, mainly of gorse *Ulex europaeus*, also occur.

Appendix 03 - Shingle Invertebrate lists

This appendix provides a more detailed description of those invertebrates most likely to be associated with shingle habitats in Great Britain. They are grouped under their habitat preferences. RDB - Red Data Book species. Tables 1 and 2 below give an indication of the species represented within the different groups. Information supplied by Roger Morris, English Nature, Peterborough.

Species likely to be associated with shingle or drier habitats on shingle

pRDBK & Endemic *Aphrodes duffieldi* Hemiptera Cicadellidae
A leafhopper, 3.7 - 5mm. long, the male brown with variably developed transverse white bands, the female mottled brownish. Found on grasses, and currently recorded only from Dungeness, Kent. Apparently endemic.

RDB1 *Apostenus fuscus* Araneae Liocranidae
A 3mm long spider known in Britain so far only from coastal shingle at Dungeness, despite the fact it is a woodland spider on the continent.

RDB1 *Pellenes tripunctatus* Araneae Salticidae
A jumping spider found on sparsely vegetated shingle. Only recent records are from Dungeness, East Kent.

RDB1 *Dibolia cynoglossi* Coleoptera Chrysomelidae
A small (2-3mm) flea beetle associated with various species of labiate, including Galeopsis, Mentha, Salvia, Stachys, Ballota and also Cynoglossum. Very rare; scattered old records in southern Britain.

RDB1 *Paroxyna lhommei* Diptera Tephritidae
A picture winged fly which was added to the British list relatively recently (1970s). Originally recorded from Sugarloaf Hill, Folkestone, Kent, it has subsequently been found in the Dover district, at Dungeness and at Sandwich. The host plant is not yet known, although large numbers of adults have been seen on *Senecio* spp., particularly *S.erucifolius* and this may well be the true host. So far the total distribution of this species seems to be confined to the channel coast.

RDB1 *Thalera fimbrialis* Lepidoptera Geometridae Sussex Emerald Moth
Known from shingle beaches in Kent and East Sussex, probably extinct at the latter site. The larva feeds on wild carrot, common ragwort and hoary ragwort, possibly also on yarrow.

pRDB1 *Polyodaspis sulcicollis* Diptera Chloropidae

A small fly whose biology is currently imprecisely known. Members of the family feed on a variety of grasses as stem borers.

pRDB1 *Coleophora galbulipennella* Lepidoptera Coleophoridae
A case bearing micro-moth associated with Nottingham catchfly. In Great Britain this species is only known from Dungeness and Hythe Ranges, East Kent.

pRDB1 *Tinagma balteolella* Lepidoptera Douglasiidae
A micro-moth associated with viper's bugloss. Only known from Kent and East Sussex where it is found in a very few coastal localities.

RDB2 *Trichoncus affinis* Araneae Linyphiidae
A small money spider found among the roots of sparse vegetation on shingle. Recorded from Hants, Sussex, Kent and Suffolk.

RDB2 *Hadena albimacula* Lepidoptera Noctuidae White Spot Moth
A moth found on shingle beaches and chalk or limestone cliffs. Larva on Nottingham catchfly. Very local on the southern coast, Kent, Hampshire and South Devon.

pRDB2 *Xyletinus longitarsis* Coleoptera Anobiidae a wood boring beetle
A small (2.5-4mm long) black wood boring beetle recorded mainly from old oaks but also recorded from dead broom. Formerly widespread in the southern half of England, recent records only from Herefordshire.

pRDB2 *Ethmia bipunctella* Lepidoptera Ethmiidae
Black and white micro-moth. The larva feeds on the flowers and leaves of viper's bugloss, *Symphytum* or other Boraginaceae, pupating in a dead stem or rotten wood. Very local, resident in Kent and East Sussex, occasionally occurs elsewhere on southern and eastern coasts.

pRDB2 *Ethmia terminella* Lepidoptera Ethmiidae
Small black and white moth. The larvae feed on the flowers and unripe seeds of viper's bugloss. Only reliably recorded from Kent and Sussex, on areas of coastal shingle.

pRDB2 *Pediasia fascelinella* Lepidoptera Pyralidae
Frequents sand hills. The larva feeds on various grasses. On the coast of Lincolnshire, Norfolk, Suffolk, Essex and south Devon.

RDB3 *Euophrys browningi* Araneae Salticidae
A jumping spider. Found in tide litter and in empty whelk shells on shingle banks. Recorded from Norfolk, Suffolk, Essex and Kent.

RDB3 *Lathys stigmatisata* Araneae Dictynidae
A small spider so far recorded from only Kent, East Sussex, Cornwall and Lundy Island. Found on coastal heath and shingle.

RDB3 *Phlegra fasciata* Araneae Salticidae
A jumping spider found mainly on sand dunes and sometimes shingle along the south coast of England.

RDB3 *Smicronyx coecus* Coleoptera Curculionidae
A small weevil that feeds on Dodder .

RDB3 *Hylaeus euryscapus* Hymenoptera Colletidae
A yellow-faced bee. Habitats used are soft rock cliffs, landslips, open expanses of sand or shingle and coastal dunes, where a female has been seen entering a burrow in loose sand. Pollen sources are unknown, although visits to a number of flowers have been noted. A rare species recorded from southern coastal counties, with about a dozen post-1970 localities.

RDB3 *Leptothorax tubero-interruptus* Hymenoptera Formicidae
A small ant of warm, sandy or stony areas such as dry heathland or coastal localities. It has been found nesting in (dry?) peat and in moss. Confined to the extreme south of England: reasonably frequent in the New Forest, S. Hants., local on the Dorset heaths; Rye Harbour, E. Sussex and Dungeness, E. Kent.

RDB3 *Myrmica specioides* Hymenoptera Formicidae
A red ant nesting in dry sand in coastal positions. Added to the British list in 1962 from colonies discovered on the sandhills at deal in Kent and has since been found at a small number of other coastal sites, all in Kent. Is probably a native species rather than a recent introduction, as it is easily confused with *M. scabrinodis*.

RDB3 *Calophasia lunula* Lepidoptera Noctuidae Toadflax Brocade Moth
A moth of shingle beaches, waste land and gardens. Larva on yellow toadflax and occasionally other Linaria spp. Resident in Kent and Sussex, also a suspected immigrant.

RDB3 *Eilema pygmaeola* Lepidoptera Arctiidae Pygmy Footman Moth
A moth with two subspecies in Britain. Subsp. pygmaeola; found on coastal sandhills in Kent and Norfolk, immigrant elsewhere. Subsp. *pallifrons*; found on shingle at Dungeness, Kent. The larva is said to feed on unspecified lichens.

RDB3 *Heliothis viriplaca* Lepidoptera Noctuidae Marbled Clover Moth
Breckland, waste places, shingle and sandy beaches and chalk downland, the larva feeding mainly on the flowers of wasteland plants, e.g. *Silene, Ononis* etc.

pRDB3 *Apion rubiginosum* Coleoptera Apionidae
A seed weevil of southern distribution, associated with sheep's sorrel (*Rumex acetosella*), apparently with a preference for coastal habitats.

pRDB3 *Cantharis fusca* Coleoptera Cantharidae
A large soldier beetle of wet places. Larvae predators on soil surface. Adults usually on flowers, especially umbellifers. Declining. Now apparently restricted to small part of S Britain where it still can be found in

abundance.

pRDB3 *Ceutorhynchus verrucatus* Coleoptera Curculionidae
A small weevil that appears to be exclusively associated with *Glaucium flavum* in Britain. Adults and larvae occur inside a cavity in the main tap-root. Found on coastal shingle and recorded from Sussex, Essex, Hants, and Devon.

pRDB3 *Dromius vectensis* Coleoptera Carabidae
A small reddish brown ground beetle with conspicuous markings. Lives among vegetation on sandy ground, most often on the coast. Widespread but rare along southern coastal counties.

pRDB3 *Dryophilus anobioides* Coleoptera Anobiidae a wood boring beetle
A small brown beetle, larvae develop in the dead stems of broom, and the adults are usually found by beating dead broom. Occurs in woodlands scrub and roadside verges. Very few modern records.

pRDB3 *Geomyza hendeli*_Diptera Opomyzidae
A small fly with a darkened wing tip. The larvae of this family develop in the stems and middle shoots of grasses, though exact host plants of this species are uncertain. The status of this species in Britain is somewhat uncertain. Specimens under this name in the BM(NH) have proved to be *G. apicalis*, but female specimens from Wicken Fen, Cambs and Dungeness, Kent are possibly true *G. hendeli* - males are required for confirmation.

pRDB3 *Acleris permutana* Lepidoptera Tortricidae
Apparently confined to sandhills and other coastal habitats where the larval foodplant *Rosa pimpinellifolia* occurs. Local and scarce, a discontinuous distribution from Kent, Sussex, Cornwall, Derbyshire, Cheshire and parts of Wales.

pRDB3 *Cynaeda dentalis* Lepidoptera Pyralidae
An extremely local micro-moth frequenting coastal localities. The larva feeds in the stem and on the leaf bases of viper's bugloss. Recorded from southern and south-eastern England, from Suffolk to Devon.

pRDB3 *Melissoblaptes zelleri* Lepidoptera Pyralidae
Flies from June to August, larvae feed on *Brachythecium albicans*. A rare species occurring on the coasts of Norfolk,Suffolk and Kent. Also recorded from the Isle of Wight and Glos.

pRDB3 *Platytes alpinella* Lepidoptera Pyralidae
Frequents sandy coasts, the larva feeding on Tortula spp. and other mosses. Very local and rather uncommon, distributed along the south coast from Devon to Kent, also East Anglia, Lincolnshire and Yorkshire.

pRDBK *Astenus procerus* Coleoptera Staphylinidae
Small ground dwelling predatory rove beetle

pRDBK *Hister quadrimaculatus* Coleoptera Histeridae
A carrion beetle

pRDBK *Neofriseria singula* Lepidoptera Gelechiidae a micro-moth
A micro-moth, the larva of which lives in a silken tube on sheep's sorrel *Rumex acetosella*. This species has been much confused with *N. peliella*.

Table 1: Invertebrates listed as Red Data Book species in the Invertebrate Site Register that have relatively strong affinities to shingle habitats

Hemiptera	Aranaea	Coleoptera	Diptera	Lepidoptera	Hymenoptera
Aphrodes duffieldi	*Apostenus fuscus*	*Dibolia cynoglossi*	*Paroxyna lhommei*	*Thalera fimbrialis*	*Hylaeus euryscapus*
	Pellenes tripunctatus	*Xyletinus longitarsis*	*Polyodaspis sulcicollis*	*Coleophora galbulipennella*	*Leptothorax tubero-interruptus*
	Trichoncus affinis	*Smicronyx coecus*	*Geomyza hendeli*	*Tinagma balteolella*	*Myrmica specioides*
	Euophrys browningi	*Apion rubiginosum*		*Hadena albimacula*	
	Lathys stigmatisata	*Cantharis fusca*		*Ethmia bipunctella*	
	Phlegra fasciata	*Ceutorhynchus verrucatus*		*Ethmia terminella*	
		Dromius vectensis		*Pediasia fascelinella*	
		Dryophilus anobioides		*Calophasia lunula*	
		Astenus procerus		*Eilema pygmaeola*	
		Hister quadrimaculatus		*Heliothis viriplaca*	
				Acleris permutana	
				Cynaeda dentalis	
				Melissoblaptes zelleri	
				Platytes alpinella	
				Neofriseria singula	

Green shade = probable dry grassland species.

Species likely to be associated with wetland or damp habitats on shingle structures

RDB1 *Clostera anachoreta* Lepidoptera Notodontidae Scarce hocolate-tip Moth
This species is a relatively recent arrival that has a tenuous foothold at Dungeness, the larva feed on *Salix* and *Populus*.

pRDB2 *Anagnota collini* Diptera Anthomyzidae
An Anthomyzid fly whose larvae develop in the galls of the Chloropid fly *Lipara* formed on *Phragmites*, also recorded from the galls of the mite *Stenotarsonemus*.

pRDB2 *Gelechia muscosella* Lepidoptera Gelechiidae
A micro-moth recorded from fenland and amoungst sallow scrub on coastal shingle. The larva feeds in a catkins of *Poplus* and *Salix* spp.

RDB3 *Hydrophilus piceus* Coleoptera Hydrophilidae Great Silver Water Beetle
Britains largest insect. A large, shiny black water beetle living in weed choked dykes in grazing levels. The adult is phytophagous and detritivorous, but the larvae are predatory on aquatic molluscs. Adults fly readily and are attracted to light at night. Very scarce, confined to the Thames Marshes and other grazing levels in Kent and Sussex, with other populations in South Hampshire and the Somerset and Gwent levels and with a few records in East Anglia. Included in the published Red Data Book as RDB3, but more realistically graded at Notable category A. Distribution map available in Foster (1987).

RDB3 *Minettia flaviventris* Diptera Lauxaniidae a fly

A small fly recorded from herb rich meadows and unimproved pasture, woodland edge and marshes. Larval biology unknown, but other members of the genus have been reared from decomposing vegetable matter such as leaf litter, dead wood and rotting pine cones. Few, widely scattered records throughout Britain.

RDB3 *Hirudo medicinalis* Gnathobdelli Hirudinidae Medicinal Leech
Large leech, formerly widespread and used in phlebotomy. Lives in warm shallow lakes, usually where the temperature exceeds 19oC for much of the summer, including some upland shallow tarns. Feeds on mammals, birds and amphibians, the main host species varying from site to site. Now very rare, still found in a few areas including Cumbria, SE Scotland, Anglesey, East Anglia and the New Forest.
Declined due to over-collecting, changes in land use surrounding suitable lakes and drainage of ponds and lakes. Deepening of ponds for trout fishing, thereby altering their temperature regime, is also a threat. On Appendix II of CITES and schedule 5 of the Wildlife & Countryside Act.

RDB3 *Monosynamma bohemani* Hemiptera Miridae
A rare plantbug. Members of the genus *Monosynamma* are difficult to identify, and records must be treated with care. *M. bohemanni* has so far been certainly identified only from a sandpit in Surrey, where it was associated with creeping willow *Salix repens*. Old records are likely to refer to *M. sabulicola*.

RDB3 *Archanara algae* Lepidoptera Noctuidae Rush Wainscot Moth
Inhabits broadland, freshwater ponds and old water-filled gravel workings. Larva in the stems of *Scirpus lacustris, Typha latifolia* and *Iris pseudacorus*. Locally in the Norfolk Broads, also in a few ponds in mid Sussex, noted in a few localities elsewhere in southern England.

RDB3 *Photedes brevilinea* Lepidoptera Noctuidae Fenn's Wainscot
Inhabits fenland and reedy ditches. Larva lives in the stems *Phragmites australis*. Adults fly from mid July to mid August. A very local and rare species confined to Norfolk and Suffolk, it is also rare on the continent.

pRDB3 *Telmatophilus brevicollis* Coleoptera Cryptophagidae
A small brown beetle of southern distribution, found on reedmace and other waterside vegetation.

pRDB3 *Poecilobothrus ducalis* Diptera Dolichopodidae

A small dancefly, larvae probably semi-aquatic carnivore in mud beside saline pools and ditches. Adults recorded from July to September. All modern records are from the North Kent Marshes, though there are also old records from Hants and Somerset.

pRDBK *Ocyusa nigrata* Coleoptera Staphylinidae
Small shiny black rove beetle living among litter in marshes. Scattered localities, mainly in S England. Very rare.

Table 2: Invertebrates listed as RDB in the Invertebrate Site Register that occur in wetlands within shingle structures (not shingle associates)

Leaches	Hemiptera	Coleoptera	Diptera	Lepidoptera
Hirudo medicinalis	*Monosynamma bohemani*	*Hydrophilus piceus*	*Anagnota collini*	*Clostera anachoreta*
		Telmatophilus brevicollis	*Minettia flaviventris*	*Gelechia muscosella*
		Ocyusa nigrata	*Poecilobothrus ducalis*	*Archanara algae*
				Photedes brevilinea

Anthropogenic habitats

RDB1 *Omophron limbatum* Coleoptera Carabidae
Patterned yellowish and bronze green globular ground beetle, living in burrows in bare sandy soil at the margin of water. Very rare, recorded only from Rye Harbour in Sussex and Dungeness in Kent.

RDB1 *Pilophorus confusus* Hemiptera Miridae
There are only two records for this plant bug in Britain, from a Surrey sandpit and from Dungeness. In both cases creeping willow, *Salix repens* was present. The British examples were found largely on the ground, but the species may also occur on trees. The ecology and habitat requirements in Britain are not clearly established.

RDB1 *Nomada ferruginea* Hymenoptera Anthophoridae
A cuckoo bee or cleptoparasite of the mining bee *Andrena praecox*. It has been recorded from a number of counties, mostly in the south-east of England, from Hampshire to Leicestershire and Norfolk. Found breeding on spoil heaps in the Long Pits area of Dungeness.

RDB1 *Hydraecia osseola hucherardi* Lepidoptera Noctuidae Marsh Mallow Moth
The larva feeds on the roots of *Althaea officinalis*. Local, occurring in south-east Kent, East Sussex and also in north Kent. Formerly bred on the Romney Marshes and not a shingle species *per-se*.

pRDB2 *Dyschirius obscurus* Coleoptera Carabidae
Small (3.5-4.5mm) dull black fossorial ground beetle, occurring on bare sand in damp places. Specific predator on rove beetles of the genus *Bledius*, especially *B. arenarius*. Modern records from Kent, Norfolk and Sussex. Very rare but localised colonies can be large.

RDB3 *Heterocerus hispidulus* Coleoptera Heteroceridae
A small black and orange beetle, 3.5mm long. Burrows in soft sand beside gravel pits etc, living in colonies. Only two localities known in Britain, one in Sussex and one in Suffolk.

Vagrants and migrants

RDB2 *Catocala sponsa* Lepidoptera Noctuidae Dark Crimson Underwing
Oak woodlands, the larva on *Quercus*. Now known form the New Forest, Hampshire, formerly known in Wiltshire, Sussex and Kent.

RDB2 *Coscinia cribraria* Lepidoptera Arctiidae Speckled Footman
Very local, restricted to a few heathland areas in Hampshire and Dorset. Larva possibly on low growing herbaceous plants. Subsp.*arenaria* is a rare migrant to Britain.

RDB2 *Scopula nigropunctata* Lepidoptera Geometridae Sub-angled Wave
A small moth.

Extinct: *Nola aerugula* Lepidoptera Nolidae Scarce Black Arches
Formerly restricted on sandhills at Deal, Kent, but since the turn of the century it has been regarded as a migrant in Britain. Continental authors state that the larva feeds on *Lotus* spp.