5 INTERTIDAL SAND AND MUDFLATS

5.1 Habitat definition

Intertidal sand and mudflats are defined here as areas of generally bare sediment between mean high water mark and mean low water mark, as indicated on O.S. 1:10,000 maps (or 6" to 1 mile series where metric equivalents are not yet published). Areas of algal growth are included within this category.

5.2 Data sources and reliability

Figures for total intertidal sandflat and mudflat area are available from the *Coastwatch* database. Aggregate figures for 'sandflats' and 'mudflats' were derived from the original categories used in the database as follows:

(a) Intertidal sands		(b) Intertidal muds	
includes	sandy shore	includes	muddy shore
	sandy /shingle shore		muddy/sandy shore
	sand/ shingle/ boulder		mud/ sand/ shingle
	sand/ shingle/ rock		muddy / shingle shore
	sand/ boulders / rock		muddy / boulder shore
			mud / shingle / mussel beds

The *Estuaries Review* database also provided figures for undifferentiated total intertidal area based on measurements from O.S. maps. Due to its emphasis on estuaries, most of the more open parts of the coast are omitted. Despite this fact, the national total intertidal area derived from the *Estuaries Review* is almost 50% higher than that derived from the *Coastwatch* database. The main reason for the disparity can be attributed to the fact that the *Coastwatch* survey did not always include information down to low water mark.

The limitations of the information derived from O.S. maps should be clearly recognized. Even recent editions often show the position of the low and high water rmark determined from air photographs taken in the early 1970's, 1960's or even late 1950's. More recent surveys have generally been undertaken only in areas of extensive residential or industrial development, or where other special factors apply. In addition, some published sheets do not show the position of low water mark owing to the very great width of the intertidal zone. As a consequence, even the *Estuaries Review* data significantly underestimate the extent of the intertidal zone in some areas. However, the information given presents a valid indication of inter-regional variations.

5.3 Resource extent

5.3.1 National area:

233361 ha (minimum, refers principally to estuarine areas and adjoining coasts; *Estuaries Review* 1992 update)

5.3.2 Regional distribution and habitat importance

Intertidal sand flats occur all around the coastline of England but they are most entensively developed in areas with a gently sloping nearshore profile and large tidal range. Such areas include the Irish Sea coasts in northwest England, the Humber estuary, the Wash, north Norfolk, the Outer Thames estuary the Medway estuary and the Severn estuary. Intertidal flats tend to be narrower along the coasts of southern, southwest and northeast England, with a few local exceptions.

The areal extent of intertidal sand and mudflats within different administrative units and the major process cells is shown in Table 5.1. The largest areas of mudlfats are found in Essex, Kent,

Table 5.1: Estimated area of intertidal sand and mud flats along the English coast (ha).

County	Coastwatch Database			Davidson *et.al.* (1991)*
	Mud Flat	Sand Flat	Total	Mud & Sand
Cumbria	327.62	29691.54	30019.16	{
Lancashire	657.46	16659.31	17316.77	78668.0
Merseyside	262.48	12117.91	12380.39	7019.0
Cheshire	95.32	3039.60	3134.92	12981.0
Gloucestershire	2846.73	86.60	2933.33	{
Avon	1708.22	121.87	1830.09	16890.0
Somerset	4200.50	1021.86	5222.36	5497.0
Devon	2327.23	1719.19	4046.42	6459.0
Cornwall	1713.43	1863.84	3577.27	2137.0
Dorset	1110.24	285.60	1395.84	2450.0
Hampshire	3899.46	810.32	4709.78	4859.0
Isle of Wight	-.-	-.-	-.-	1090.0
Sussex	1133.60	1748.96	2882.56	3001.0
Kent	7717.21	1679.69	9396.90	9852.0
Greater London	238.14	0.94	239.08	-.-
Essex	11050.17	10398.51	21448.68	24606.0
Suffolk	2304.20	250.86	2555.06	4267.0
Norfolk	4393.99	8850.50	13244.49	6673.0
Cambridgeshire	46.56	0.00	46.56	-.-
Lincolnshire	4089.05	14977.64	19066.69	29770.0
Nottinghamshire	28.08	15.72	43.80	-.-
Humberside	5768.76	3492.66	9261.42	13521.0
Yorkshire	69.08	314.54	383.62	9.0
Cleveland	129.50	669.92	799.42	471.0
Durham	0.20	35.50	35.70	-.-
Tyne & Wear	58.44	111.86	170.30	89.0
Northumberland	809.16	2698.13	3507.29	3052.0
Total	**57506.21**	**114249.42**	**171755.63**	**233361.0**

* Figures revised August 1992

Process Cell	Intertidal Area (Davidson *et.al.* 1991)
1	3141.0
2	14001.0
3	65416.0
4	10411.0
5	10741.0
6	5562.0
7	25421.0
10	98668.0
Total	**233361.0**

Humberside, Norfolk, Lincolnshire, Hampshire and Gloucestershire, reflecting the generally muddy character of the upper intertidal flats in the estuaries of eastern and southern England. The Severn estuary and Bristol Channel are also mud-dominated. By contrast the intertidal flats of northwest and northeast England are predominantly sandy, with mud generallly restricted to the highest intertidal zone and the inner parts of estuaries. Extensive sand flats also occur in the lower intertidal zones of most east coast estuaries including the Humber, Wash, Outer Thames estuary and on the barrier coastline of north Norfolk. The total area of mudflat is almost twice that of saltmarsh while the sandflats are approximately twice as extensive as mudflats.

Intertidal flats, particularly mudflats, support high densities of invertebrates and consequently are highly important as feeding grounds for birds (Prater, 1981). The higher intertidal banks also act as important breeding grounds and resting areas for marine mammals.

Intertidal flats also serve an important coastal defence function by dissipating wave energy before it reaches the shoreline. The wider and higher the intertidal flats, the greater is the potential for wave energy dissipation.

5.4 Threats to intertidal flats

The principal natural threat to intertidal sand and mudflats is presented by erosion, while the main causes of human-induced loss are landclaim for industrial and port development. Capital dredging programmes can involve direct removal of intertidal sediment but more commonly lead to indirect losses by modifying the pattern of flow and sediment transport within estuaries. Tidal barrage developments also pose a long-term threat to intertidal flats by artificially raising the level of low water mark and reducing the exposed intertidal area.

Disturbance to mudflats and sandflats can be caused by bait digging, cockle fishing and recreation activities, but in general the habitat is not totally destroyed. Serious medium to long-term damage to the intertidal flat ecology may also be caused by pollution in highly populated and industrialized areas.

5.5 Recent habitat loss

5.5.1 Erosion loss

Few investigations of changes in intertidal area within specific areas have been undertaken and no clear national picture is at present available. Comparison of maps prepared at different dates, undertaken as part of the Anglian Sea Defence Management Study (Anglian Water 1988a,b) suggested that up to 78% of the open coastline between Flamborough Head and Dengie Flats has experienced steepening of the intertidal profile in recent years as the position of mean low water mark has moved landwards. This trend was observed both in areas where the mean high water mark has moved landwards and seawards. Average rates of landward movement of low water mark in excess of 2 m/yr were recorded near Walton on-the-Naze and the mouth of the River Blackwater, but elsewhere 0.5 - 1.0 m/yr is more typical.

In other parts of southeast England, such as the Medway estuary, the position of mean low water mark appears to have remained more or less constant but the level of the flats has changed substantially (Kirby, 1990, 1992). The precise causes of these changes are the subject of current research, but tidal changes related to sea level rise appear to play a central role (Pye & French, in prep.).

On the coast of north Norfolk and in the Wash, the average position of low water mark appears not to have shifted significantly in the past century, although there have clearly been local changes due to the movement of banks and channels (Kestner, 1962; Pye 1992a, 1992b). However, there has been a slight reduction in exposed intertidal flat area due to lateral accretion of saltmarsh. Similar losses of intertidal flat have occurred in many of the estuaries in northwest England where expansion of saltmarsh has taken place (e.g. Dee, Ribble, Solway), although the precise magnitude of the changes has not been quantified. Training wall construction and dredging have had a significant impact on many estuaries which is difficult to separate from natural changes. However, the general pattern of recent change in northwest England appears to be one of a narrowing of the intertidal zone on exposed open coast shores (due to a landward movement of low water mark) and a widening due to sediment accretion and channel infilling within the major estuaries.

5.5.2 Loss due to human activities

Some estuaries (e.g. the Tyne and the Tees) have experienced almost total loss of intertidal habitat due to development during the last 100 years, while there have been significant reductions in others (Rothwell & Housden, 1990; Davidson *et al.*, 1991). Some ongoing projects which involve intertidal loss are listed in Table 5.2.

5.6 Projected habitat loss

5.6.1 Erosion loss

If sea level continues to rise at its present rate, or a more rapid one, it may be expected that the position of mean low water mark will continue to move landward, leading to profile steepening. Where the high water mark is fixed by hard defences, no equilibrium adjustment in accordance with the Bruun Rule (Bruun, 1962, 1988) will be possible, and there will be an increase in high tide water depth and mean wave height across the intertidal zone. Reflection of such waves off hard defences is likely to cause scour which will lead to further lowering of beach levels in the intertidal zone. The 'squeeze' on the intertidal zone is therefore likely to be exacerbated, and in addition there will be an increase in substrate instability. The magnitiude of losses in area are difficult to quantify precisely because of variations between adjacent sections of coast and between regions, reflecting differences in sediment budget and rate of sea level rise. However, a best estimate of the landward movement of low water mark, averaged around the entire coast of England, suggests it may be of the order of 10 m over 20 years, leading to a loss of 8-10,000 ha. In practice, losses are likely to occur mainly in southern and southeastern England where sea level is forecast to rise most rapidly, and where there is relatively lower potential for landward wave reworking of intertidal sediment by wave action.

5.6.2 Human activities

Current proposals for development which threaten further intertidal loss, recorded by the *Estuaries Review* team, provide a guide to the likely magnitude of the future problem (Table 5.3). At present, there are proposals for developments which would lead to a further intertidal loss of 1126 ha. In addition to the figures presented in Table 5.3, many more proposals for marinas and barrages exist for which areal estimates are presently unavailable. A summary of the numbers of such proposals by county is presented in Table 5.4.

5.7 Targets for habitat recreation

An accurate estimate of the total losses of intertidal flat in the next 20 years is difficult to make, particularly since the present extent is not accurately quantified. However, a minimum loss of 10000 ha is likely. Losses are likely to be greatest in areas where sediment supply from coastal cliffs and other sources is very restricted, where sea level is rising most quickly and where the high water mark cannot move landwards, thereby preventing release of eroded sediment to the intertidal zone. This includes much of southeast England and parts of the south coast.

Although it will be possible to create some locally important areas of new intertidal mudflat by managed retreat schemes, the very large extent of the predicted losses on a national scale means that it will also be necessary to adopt a variety of measures which aim to preserve, or limit losses to, the existing intertidal flat areas. Such measures could include (1) foreshore recharge, using material dredged from navigation channels or deep water areas offshore, (2) enhancement of sediment supply to the foreshore by allowing sacrificial erosion of selected soft cliff sections, and (3) construction of wave dissipation structures such as offshore breakwaters and rock groynes.

Table 5.2: Sites of ongoing intertidal loss, recorded in the Estuaries Review Database (updated to 1992).

County	Area (ha)
Cornwall	4.0
Kent	70.0
Essex	45.0
Lincolnshire	10.0
Humberside	400.0
Northumberland	21.0
Total	550.0 (0.4% of the national resource)

Table 5.3: Projected intertidal loss based on current proposals for development recorded in the Estuaries Review Database (updated to 1992).

County	Area (ha)
Lancashire	216.0
Cornwall	24.0
Devon	130.0
Hampshire	280.0
Isle of Wight	304.4
Kent	60.0
London	10.0
Essex	10.0
Cleveland/Tyne & Wear	87.0
Northumberland	5.0
Total	1126.4 (0.7% of the total resource)

Table 5.4: Proposed developments resulting in habitat loss around the English Coast.

	Nd	TW	Cd	Hs	Li	Nk	Sk	Ex	Kt	Sx	Ha	IW	Do	Dn	Cl	St	Me	La	Cu	Total
Coastal defence									2	1	1	1		1	1	3			1	11
Management barrage								3				1					1		1	6
Leisure barrage			1					1			4	1			4	2	1		2	16
Tidal power barrage				1	1							1			1	3	1		3	11
Other power stations				2				1	1				2						2	8
Dock developments				5				1	1	2		1		3	2	2				17
Industrial developments		1	1		1										2					5
Gas/Oil industry		1		1				1	2								4	1	1	11
Waste discharge/disposal	2							4	3		1	1				2	1	2	2	18
Tipping					1			2								2				5
Capital dredging			1	1			2	3	2	1	1	3		3	2	2			1	22
Maintenance dredging						1									1					2
Aggregate extraction	1			1		1			2	2					1					8
Transport network			1	3			2	12	3	4	1	1	3		2	11	3		3	49
Housing & car parks							1	2	1	1	3	2		4	1	2			2	19
Marinas	1	1	1		2	1	2	6	9	3	13	3	3	4		5		3	2	59
Other moorings	1			17							2			1						21
Dune grazing																		1		1
Land claim				1												1			1	3
County total	5	3	5	32	5	3	7	36	26	14	26	15	8	16	17	35	11	7	21	292

KEY

Nd - Northumberland
TW - Tyne & Wear
Cd - Cleveland
Hs - Humberside
Li - Lincolnshire
Nk - Norfolk

Sk - Suffolk
Ex - Essex
Kt - Kent
Sx - Sussex
Ha - Hampshire
Iw - Isle of Wight
Do - Dorset

Dn - Devon
Cl - Cornwall
St - Somerset
Me - Merseyside (Inc. Cheshire)
La - Lancashire
Cu - Cumbria

6 SHINGLE STRUCTURES

6.1 Habitat definition

These features are defined as accumulations of sediment whose mean grain size falls within the size range 2 - 200 mm. The majority are composed of relatively well-sorted pebbles (size range 2 - 64 mm), but some contain a significant admixture of sand or cobbles. They represent a number of morphological types, including both active and relict fringing beaches, barrier beaches, spits, tombolos and forelands.

6.2 Data sources and reliability

The *Shingle Survey of Great Britain* (Randall *et al.*, 1990; Sneddon & Randall, 1991) contains information regarding the location and area of the major shingle accumulations, although many smaller features including shingle beaches are not included. Vegetation types were mapped onto 1:10,000 O.S. base maps, but no information is given regarding the method by which the limits of the shingle structures were defined. It is clear that in some instances the figures cited relate to the area covered by SSSIs, rather than shingle *per se*. In a few cases conflicting figures for the areal extent of a site are given in the two reports.

The *Coastwatch* database also contains information about shingle extent. The original survey included the following headings which have been grouped together to provide a single figure for 'shingle' which is cited in this report:

shingle shore
shingle/ boulder shore
shingle/ boulder/ clay
shinge/ rocky shore
shingle / clay shore
shingle / saltmarsh
terrestrial shingle
terrestrial shingle / boulders

Perhaps not surprisingly, the figure for areal extent of 'shingle' derived from *Coastwatch* database is almost twice that reported in the *Shingle Survey*. The actual extent of true shingle deposits, as opposed to boulder / rock / sand / shingle mixtures, almost certainly lies somewhere between the two figures, but is probably closer to the figure obtained by summation of Sneddon & Doody's data .

Further information about geomorphological change and shingle habitat loss has been obtained from the *Macro Review of the Coastline of England and Wales*, and from numerous papers and reports dealing with specific shingle formations and associated sections of coast (e.g. Fuller & Randall, 1988; Ferry & Waters, 1985).

6.3 Resource extent

6.3.1 National area

(i) major shingle features only: 5023 ha (Randall *et al.*, 1990, with modifications)

(ii) shingle and mixed shingle / sand accumulations, including beaches:12375 ha (*Coastwatch* database)

6.3.2 Regional distribution and habitat importance

The distribution of shingle structures shows a high degree of concentration on the coasts of southeast and southern England (Figure 6.1). A list of the major sites is presented in Table 6.1. In

SHINGLE STRUCTURES

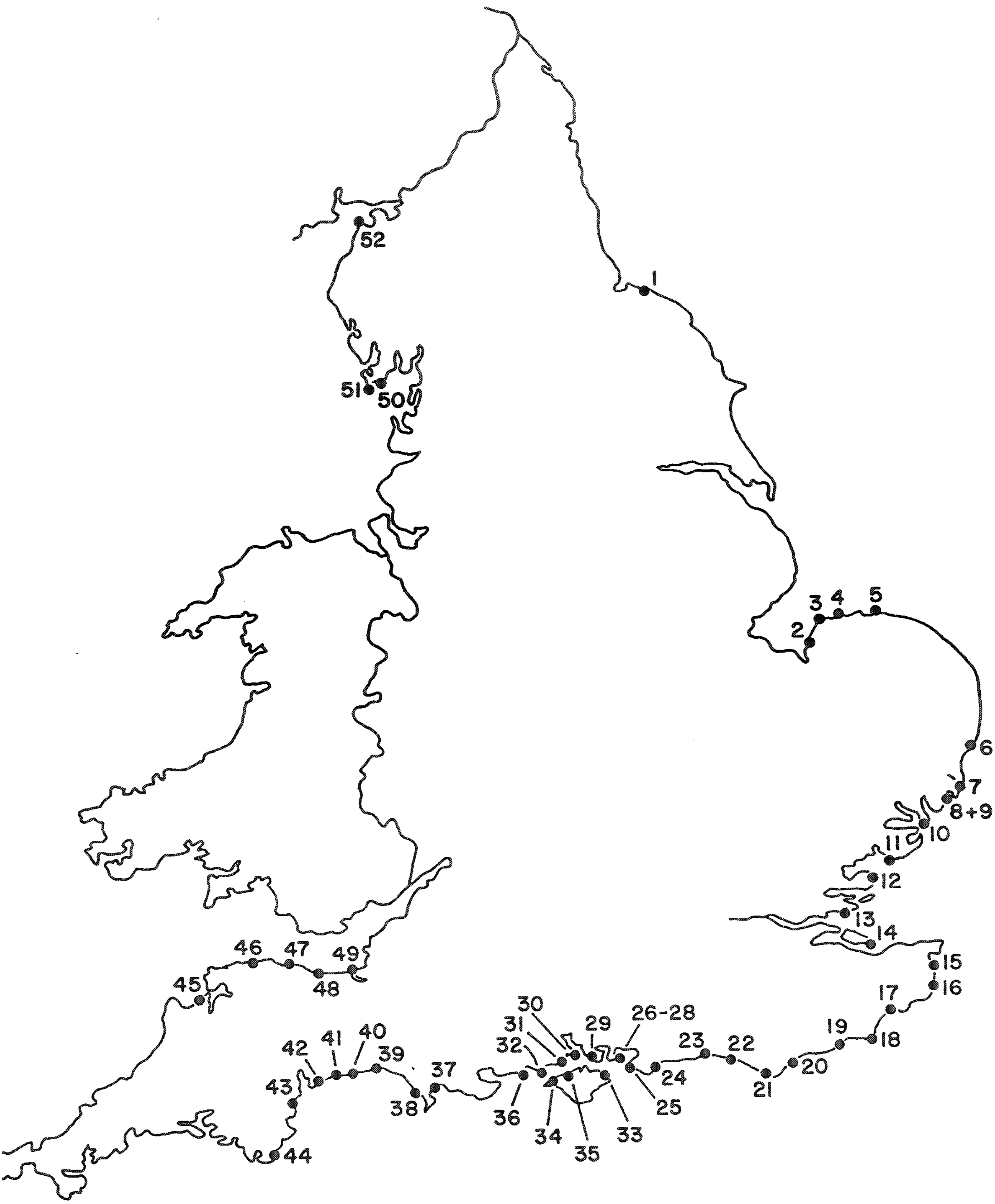

Figure 6.1. Location of major shingle features in England.

Table 6.1: Location of major shingle features in England

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
01	Skinning Grove	NZ 71 20	-.-		Cleveland	2
02	Snettisham	TF 64 33 - TF 64 30	23.80	SSSI, RS	Norfolk	3
03	Thornham	TF 71 45 - TF 73 45	10.00	SSSI, R, A, S, HC, B	Norfolk	3
04	Scolt Head	TF 78 46 - TF 84 46	50.00	NNR, SSSI, R, A, S, HC B, NT	Norfolk	3
05	Blakeney Point	TG 09 44 - TF 98 45	160.00	SSSI, R, A, S, HC, B, NT	Norfolk	3
06	Kessingland	TM 53 83 - TM 53 85	33.90		Suffolk	3
07	Walberswick - Sizewell	TM 48 71 - TM 50 74	43.80	NNR, NT, LNR	Suffolk	3
08	Orford Ness	TM 37 43 - TM 47 66	504.00	NNR, SSSI, R, A, (S), HC	Suffolk	3
09	Shingle Street	TM 35 40 - TM 37 43	30.00	SSSI	Suffolk	3
10	Languard Common	TM 28 31 - TM 29 32	31.40	SSSI, (R), (S), HC, LNR CNT	Suffolk	3
11	Colne Point	TM 13 12 - TM 10 12	50.00	NNR, SSSI, (R), (S), CNT	Essex	3
12	Bradwell Shell Bank	TM 03 08	8.00	SSSI, (R), (S), CNT	Essex	3
13	Shoebury Common & Foulness	TQ 93 84	40 .00	SSSI, (R), (S), LNR, CNT	Essex	3
14	Shellness	TR 05 67 - TR 04 67	10.20	NNR, R, S, CNT	Kent	4
15	Sandwich Bay	TR 37 54 - TR 35 62	10.00	NNR, SSSI, NT, RS, CNT	Kent	4
16	Walmer	TR 37 48 - TR 37 51	49.00		Kent	4
17	Hythe Ranges	TR 13 32 - TR 15 33	-.-		Kent	4
18	Dungeness	TQ 99 17 - TR 08 23	2714.00*	SSSI, R, S	Kent/Sussex	4
19	Rye Harbour	TQ 89 13 - TQ 94 17	721.20*	SSSI, (R), (S), LNR	Sussex	4
20	The Crumbles	TQ 63 00 - TQ 70 06	-.-		Sussex	4
21	Cuckmere Haven	TV 51 97	10.00	SSSI, A, HC	Sussex	4
22	Ouse Mouth	TQ 45 00	-.-	SSSI, HC	Sussex	4
23	Shoreham Beach	TQ 20 04 - TQ 27 04	-.-	(SSSI)	Sussex	4
24	Pagham Harbour	SZ 87 94 - SZ 88 96	42.40	SSSI, R, LNR	Sussex	4
25	East Head	SZ 76 98	14.10	R, A, S, NT, (LNR)	Sussex	5
26	Eastoke Point	SZ 74 98	-.-	R, A, S	Hampshire	5
27	Sinah Common	SZ 69 99	-.-		Hampshire	5
28	Fort Cumberland	SZ 68 99	-.-		Hampshire	5
29	Browndown	SZ 57 99 - SZ 58 98	64.30	SSSI	Hampshire	5
30	Calshot Spit	SU 48 01 - SU 48 02	-.-		Hampshire	5
31	Needs Ore Point	SZ 40 96 - SZ 42 97	-.-	NNR, SSSI	Hampshire	5
32	Hurst Spit	SZ 29 90 - SZ 31 89	-.-	SSSI, CNT	Hampshire	5
33	The Duver, St. Helens	SZ 63 89	19.10	SSSI, A, NT	Isle of Wight	5
34	Yarmouth	SZ 34 89	-.-	A	Isle of Wight	5
35	Newtown Harbour	SZ 40 93 - SZ 42 93	-.-	SSSI, A, (S), HC	Isle of Wight	5
36	Hengistbury Head	SZ 18 91 - SZ 17 90	-.-	SSSI	Dorset	5
37	Lodmoor	SY 68 80 - SY 69 81	-.-		Dorset	5
38	Chesil Beach	SY 49 88 - SY 68 73	250.10	SSSI, R, A, S, HC, NT LNR	Dorset	6
39	Charmouth	SY 36 92	-.-		Dorset	6
40	Seaton	SY 25 89	-.-		Devon	6
41	Sidmouth	SY 12 87	-.-		Devon	6
42	Otter Mouth	SY 07 81	-.-	A	Devon	6
43	Teignmouth Bar	SX 94 72	-.-		Devon	6
44	Slapton Ley	SX 82 42 - SX 83 46	34.00	SSSI, A, LNR	Devon	6
45	Westward Ho!	SS 43 29 - SS 44 31	-.-		Devon	7
46	Lynmouth Harbour	SS 72 49	-.-		Devon	7
47	Porlock Bay	SS 86 47 - SS 89 49	28.00	NT	Somerset	7
48	Minehead	SS 98 46 - SS 99 45	-.-	SSSI	Somerset	7
49	Bridgwater Bay	ST 23 45 - ST 25 45	25.30	NNR, SSSI, R, (S)	Somerset	7
50	Foulney Island	SD 23 65 - SD 24 63	21.60	SSSI, (R), (S)	Cumbria	10
51	South Walney	SD 20 62 - SD 23 62	11.38	NNR, SSSI, (R), (S)	Cumbria	10
52	Grune Point	NY 10 54 - NY 14 56	23.10	SSSI	Cumbria	10

* Area value refers to SSSI area. No independent area estimates are available

For Key, see figure 4.1

{SOURCE: Randall, Sneddon & Doody (1990) and Sneddon & Randall (1991), with modifications from other sources.}

large part this distribution pattern reflects the availability of coarse grained sediment, much of which owes its origin to cold weathering processes and fluvioglacial sorting beyond the margins of the late Pleistocene ice sheets. This material was deposited by braided rivers on the continental shelf at times of glacially-lowerd sea level and was subsequently partially reworked landward during interglacial transgressions (Carr, 1983; Carter & Orford, 1984).

The largest single shingle formation in England is the Dungeness foreland complex in Kent (Ferry & Waters, 1985). Other large features of note are Orford Ness (a spit and ness complex) in Suffolk (Steers, 1925), Blakeney Point spit in north Norfolk, the Rye Harbour spit complex in Sussex (Wallace, 1990) and the Chesil Beach tombolo in Dorset (Carr & Blackley, 1973, 1974).

The total national area covered by shingle and mixed shingle sand accumulations, including beaches, is approximately the same as that covered by sand dunes. However, the extent of pure shingle banks, spits and forelands is much smaller (less than half the dune-covered area). An estimated 60% of the shingle resource occurs in the two counties of Kent and Sussex. Only Dorset, Suffolk and Norfolk amongst the other counties contain large areas of shingle (Table 6.2), although there are significant features in Somerset (Porlock, Bridgwater Bay) and Devon (Westward Ho, Slapton).

Shingle formations support a varied range of vegetation communities, including populations of generally rare annuals and lichens. They are also significant as breeding sites for a diversity of insects and birds, some of which, like the Little Tern, are relatively rare.

In addition to their ecological significance, shingle beaches and banks are highly important as natural sea defences. Shingle is extremely effective in dissipating wave energy on acccount of its high permeability and the relatively deep envelope of sediment within which frictional energy dissipation takes place.

6.3.3 Vegetation communities

A summary of information about the vegetation communities present on the major shingle structures is presented in Sneddon & Randall (1991).

In general, the nature of the vegetation present is governed by variations in substrate mobility, substrate composition and moisture availability (Randall, 1977; Fuller, 1987). All active shingle beaches and some inland areas are unvegetated or have an extremely sparse cover. Old, long-stabilized ridges, on the other hand, may support dense grass or shrub vegetation.

6.4 Threats to shingle formations

The response of shingle beaches to sea level rise depends on the balance between the rate of rise and the effectiveness of sediment transport processes which tend to move the shingle landwards (Carter, 1988; Orford *et al.*, 1991). As indicated above, landward movement of shingle during the Flandrian marine transgression is thought to have played a crucial role in the formation of several shingle features in the British Isles. Quite a number have probably existed in more or less their present position for several thousand years, during which period the supply of sediment from the shelf has virtually dried up (Carr, 1983; Bray *et al.*, 1992). The beaches have therefore become relict or increasingly dependent on material supplied by erosion of coastal cliffs and littoral drift. Redistribution of material by littoral processes has led to the localised formation of new shingle complexes in the last few hundred years, as on the Sussex coast (Wallace, 1990).

During periods of long-period swell or moderate storm wave activity, pebbles are tossed by waves to the top of the ridge, which grows in height while the beach profile becomes steeper. However, during major storms and surges the beach is 'combed' down and the crest of shingle spits and barrier beaches may be overtopped or breached, allowing the development of shingle aprons which spread out over the backbarrier area. Provided that sufficient matrial is available to be moved onshore by constructive waves during fair weather, the ridge is normally rebuilt within a few years. However, where the supply of new sediment is restricted, a pattern of repeated breaching and washover may become the norm, and landward movement or 'rollover' takes place (Carter, 1988).

Under conditions of exceptionally rapid sea level rise and generally low storminess, a shingle barrier may be partially or wholly drowned *in situ*, a process referred to as 'overstepping' (Orford *et al.*, 1991). A number of possible drowned early to mid-Flandrian-age shingle barrier beaches have been identified off the coast of Sussex and Hampshire (Eddison, 1983a,b; Wallace, 1990). However, the bulk of evidence available from studies in Britain, Ireland and Canada suggests that the 'rollover' model of response to sea level rise is more appropriate for most shingle barriers than either the 'Bruun' model or the 'overstepping' model (Carter, 1988; Forbes *et al.*, 1989; Orford *et al.*, 1991)

The rate of landward migration is dependent partly on the rate of sea level rise, partly on the frequency and magnitude of storms and partly on the supply of sediment. Low rates of sea level rise, moderate storm activity and high availability of sediment tend to encourage slow landward movement of a high, coherent ridge. More rapid rates of sea level rise, the occurrence of very severe storm surges, which raise water levels by up to 2 metres above predicted high tide levels, together with shortage of sediment, tend to favour more rapid landward movement through washover and breaching. The rate and mode of landward retreat is also influenced by the nature of topography landward of the beach. Where shingle accumulations rest against steep cliffs, then clearly no retreat is possible and the feature will either be submerged or dissipated through offshore transport of material. At the other extreme, a very flat, low-lying hinterland will tend to favour very rapid lateral movement and dissipation of the shingle as a series of broad, low ridges and washover aprons. Maintenance of a high, coherent ridge is most favoured where the ridge is backed by land of moderate slope.

Changes in wind and wave conditions could have a serious effect on shingle features if the balance of littoral drift is changed. A change in mean wave approach angle, for example, might lead to enhanced shore erosion and retreat or even breaching at one end of a structure with enhanced progradation at the other, leading to a change in orientation and plan morphology of the structure. A future increase in the magnitude or frequency of storms (especially from a southwesterly direction) in British coastal waters may therefore be expected to accelerate both the rate of landward retreat and the likelihood of breaching and washover.

In recent decades, the natural processes of littoral drift have been disrupted in many places by construction of groynes and harbour breakwaters. Protection of coastal cliff sections has also reduced the supply of coarse sediment. This has led to starvation of some shingle beaches which lie down-drift of such structures. Consequently the net sediment budget of such coastal sections has become increasingly negative, leading to falling beach levels and increased erosion risk at the high water mark. This problem is likely to persist in the future.

Other anthropogenic threats to shingle formations include aggregate extraction and loss of area due to development for housing, recreational activity or industry. Damage to the vegetation and details of the surface morphology on older shingle ridges can be caused by grazing, trampling, offroad vehicles, and military activity, although such activities normally do not result in total habitat destruction.

6.5 Recent habitat loss

6.5.1 Erosion loss

No national survey of shingle beach morphodynamics has been undertaken, and there is no accurate quanatitative information about changes in shingle area over time. Some features (e.g. Chesil Bank) have apparently maintained a more or less constant position for several thousand years, while others (e.g. Orford, Blakeney) have shown marked lateral growth, with complex changes in position and morphology, during historical to recent times. Erosion has affected the up-drift ends of many shingle beaches in recent decades, and, landward movement of sediment during major storms has been documented in a number of places (e.g. Hurst Castle Spit, Chesil Bank; Carr & Seaward, 1990;

Table 6.2: Estimated area of major shingle features along the English coast (ha).

County	Coastwatch Database	Randall, Sneddon & Doody (1990) Sneddon & Randall (1991)
Cumbria	2117.00	56.08
Lancashire	358.72	0.00
Merseyside	120.44	0.00
Cheshire	0.00	0.00
Gloucestershire	9.40	0.00
Avon	242.24	0.00
Somerset	588.52	53.30
Devon	824.56	34.00
Cornwall	592.30	0.00
Dorset	474.90	250.10
Hampshire	867.00	64.30
Isle of Wight	-.-	19.10
Sussex	1422.07	787.70
Kent	2205.41	2783.20
Greater London	162.58	0.00
Essex	680.66	98.00
Suffolk	800.97	643.10
Norfolk	419.58	243.80
Cambridgeshire	0.00	0.00
Lincolnshire	12.12	0.00
Nottinghamshire	0.08	0.00
Humberside	141.74	0.00
Yorkshire	12.88	0.00
Cleveland	73.84	-.-
Durham	127.96	0.00
Tyne & Wear	48.76	0.00
Northumberland	72.11	0.00
Total	**12375.84**	**5032.68**

Process Cell	Area (ha.) Randall Sneddon & Doody (1990) Sneddon & Randall (1991)
1	0.0
2	0.0
3	984.9
4	3556.8
5	97.5
6	284.1
7	53.3
10	56.1
Total	**5032.7**

Nicholls & Webber, 1987). However, there is no conclusive evidence that any net loss of total area has occurred.

6.5.2 Loss due to human activities

Shingle has been extracted for use as aggregate over many centures, and this practice continues in some areas (e.g. Dungeness, Shingle Street, Walberswick). The principal technique used is suction dredging, which results in the formation of freshwater (or brackish) lagoons when extraction is completed. Dungeness contributes about 25% of all sand and gravel production in Kent and east Sussex. Peak production in 1973 amounted to 1.5 million tonnes, but since then has fallen back to below 1 million tonnes per annum. The area of open water increased from 61 ha in 1961 to 141 ha in 1981, and has subsequently increased further (Findon, 1985).

Construction of fishermen's huts, caravan parks and holiday chalets, followed by construction of more permament houses, has occurred close to the high water mark on many shingle coastal frontages (e.g. Snettisham, Shingle Street, Colne Point, Crumbles, Dungeness, Slapton). This has resulted not only in a direct loss of area, but also to requests for the construction of sea defences to protect the properties. In a few areas, large areas have been lost to construction of power stations and other major industrial developments. For example, the nuclear power station built at Dungeness in the 1960's resulted in the loss of an initial area of 108 ha (Findon, 1985).

The construction of sea defences and breakwaters has had a major effect on shingle beaches. Three major aspects are worthy of note: (1) rates of sediment supply from soft cliffs have been reduced by construction of revetments and sea walls; (2) rates of littoral drift have been reduced by groyne and breakwater construction; and (3) the effect of building walls at the top of some shingle beaches has increased wave reflection and led to greater scouring of the beaches in front, resulting in net offshore or alongshore movement of material. The consequences of reduced littoral drift have been well documented in a number of instances, including Hurst Castle Spit, where there was a progressive reduction in shingle volume, a lowering of mean crest level and increasing frequency of washover during the 1970's and 1980's (Nicholls & Webber, 1987).

6.6 Projected habitat loss

6.6.1 Erosion loss

In the absence of further human interference, a sea level rise of 20 - 60 mm in the next 20 years will contribute to the likelihood of further erosion losses to shingle formations. The natural response to a sea level rise of this magnitude is for landward movement of sediment. However, particularly if there is an increase in storminess, there may be significant net offshore movement of sediment and the risk of overtopping and breaching is likely to increase. There could be an increase in the total area of shingle as washover aprons are formed, but the integrity of some banks and spits would be lost, and there would be serious implications for back-barrier marsh and lagoon habitats.

Beaches at the up-drift end of coastal sediment cells, particularly where rates of sediment supply have been reduced in recent years by coastal protection works, are likely to experience a further loss of volume and height, leading to increased risk of overwash and breaching, regardless of future sea-level behaviour. Where sediment is able to accumulate at the down-drift end of coastal cells, progradation in either a longshore or offshore direction will continue even if sea level rise accelerates. Exceptions to this pattern will occur where the volume of littoral-drifted sediment is small or sediment is lost into ebb-dominated tidal inlets and subsequently moved offshore.

6.6.2. Human activities

Statutory protection of shingle features is not as extensive as that covering other habitats, partly reflecting the degree to which this habitat has already been destroyed or severely damaged. Of the 52 sites identified in Table 5.1, 8 lie within NNR's, 11 within Ramsar sites (a further 7 proposed), and 8 are within SPA's (a further 10 proposed). This designation includes most of the larger and better known sites. The only localities where further proposed loss is recorded are Rye Harbour and Winchelsea, both in Sussex, where 30.0 and 5.0 ha, respectively, have been earmarked for aggregate extraction.

Many shingle beaches and banks are currently managed, particularly where they form a first line of sea defence. Re-profiling has been already been undertaken on a large scale in recent years, involving both bull-dozing and beach nourishment / recycling following storms. Examples of such schemes include Seaford, Dungeness and Hurst Castle Spit on the south coast and Snettisham - Heacham and Aldburgh on the east coast. Foreshore recharge is becoming increasing popular as a coastal engineering technique, and many more shingle beaches are likely to be replenished with marine- or land-derived material in the next 20 years, subject to the availability of suitable material (Payne & Riddell, 1992; Powell, 1992; Wright, 1992). Armourstone revetments, 'hard points' and offshore breakwaters are also being increasing used to fix the position of shingle beaches (e.g. Hook & Kemble, 1991). It is therefore unlikely that many beaches on the generally developed coast of southern England will be allowed to respond naturally to changes in environmental conditions.

6.7 Targets for habitat recreation

Net losses of shingle habitat due to natural processes are not expected to exceed 200 ha, and may be considerably less, in the next 20 years, but the potential risk of loss due to human activities is conisiderably greater. Creation of totally new shingle structures on a large scale would be both difficult and expensive, given the scarcity of suitable sedimentary materials, the volumes which would be required, and the competing demands of the aggregate industry (Murray, 1992). A more practical option is to therefore to attempt to maintain and possibly enhance the existing resource. This can be partially achieved by resisting proposals which will to lead to further loss or damage, particularly housing and industrial development, aggregate extraction and waste tipping. Greater protection to areas of vegetated shingle can also be accomplished by restricting vehicle and pedestrian access to defined routeways.

Where possible, shingle structures should be allowed to respond naturally to changing patterns of sediment supply. However, selection of appropriate coastal management practices must be undertaken on a site-specific basis, taking into account needs to conserve back-barrier habitats as well as the shingle itself. Where attempts to stabilize shingle structures are justified on sea defence and / or conservation grounds, beach nourishment and re-cycling schemes should be encouraged in preference to the construction of hard defences which would largely destroy the natural dynamic character of the features.

At present there is an apparent shortage of shingle materials suitable for beach recharge in some areas, (Payne & Riddell, 1992; Powell, 1992; Rochester & Young, 1992), but detailed survey work to identify potential sources between low water mark and the 18 m depth contour has not yet been undertaken around most of the coastline (Arthurton, 1992). Where deposits of suitable character do exist inshore, detailed studies will be required to assess the consequences and cost-effectivenes of their removal (e.g. Wright, 1992).

7 SALINE LAGOONS

7.1 Habitat definition

The definition proposed by Barnes (1988) and subsequently cited in the *Directory of Saline Lagoons and Lagoon-Like Habitats* (Smith & Laffoley, 1992) has been adopted here: 'bodies of salt water, from brackish to hyperhaline, partially separated from an adjacent sea by barriers of sand or other sediment'. Both natural features impounded by a coastal barrier and artificial or semi-natural features resulting from sediment extraction or other human interference are included.

Three features serve to identify a coastal lagoon (Barnes,1988):

(1) the presence of an isolating barrier beach, spit or island

(2) the retention of all or most of the water mass within the system during periods of low tide in the adjacent sea

(3) the persistence of natural water exchange between the lagoon and the sea by percolation through and / or overtopping of the barrier, or through inlet / outlet channels, thereby permitting the lagoon water to remain saline or brackish

7.2 Data sources and reliability

The *Directory of Saline Lagoons and Lagoon-like Habitats*, based on Nature Conservancy Council surveys undertaken between 1984 and 1989 (see references in Smith & Laffoley, 1992), provided details of the location and areas of all major sites around the coast of England, and the information contained therein has been used as the basis for the county and process cell area calculations. No details are given of the way in which areal extent data were obtained during preparation of the *Directory*, and so the accuracy of the information is difficult to assess.

A second, independent set of estimates of areas by county was provided by the *Coastwatch* database. A larger areal extent of 'saline' lagoons is reported in this survey than in the *Saline Lagoon Directory*. Although the *Coastwatch* survey sought to distinguish two categories of 'brackish' and 'freshwater' lagoons, mis-identification of some freshwater lagoons as brackish may have led to a slight overestimation of the latter, and the figures for 'saline' lagoons proposed by Smith & Laffoley (1992) may be more reliable.

No sources of systematic information about rates of habitat loss, whether due to natural processes or human activity, have been identified, but fragmentary information relating to specific sites has been obtained from the *Estuaries Review*, publications and unpublished regional reports.

7.3 Resource extent

7.3.1 National area

1216 ha (Smith & Laffoley, 1992) 1435 ha (*Coastwatch* database)

7.3.2 Regional distribution and habitat importance

Saline lagoons are found in all regions of England but are particularly concentrated on the eastern and southern coasts (Figure 7.1). The main sites are listed in Table 7.1 and area data are given by county and process cell in Table 7.2. Dorset has the largest reported area of saline lagoons, followed by Kent and Humberside. However, Hampshire contains the largest number, followed by Kent and Cornwall (Table 7.2). Several counties are reported to contain no saline lagoons or saline lagoon-like habitats.

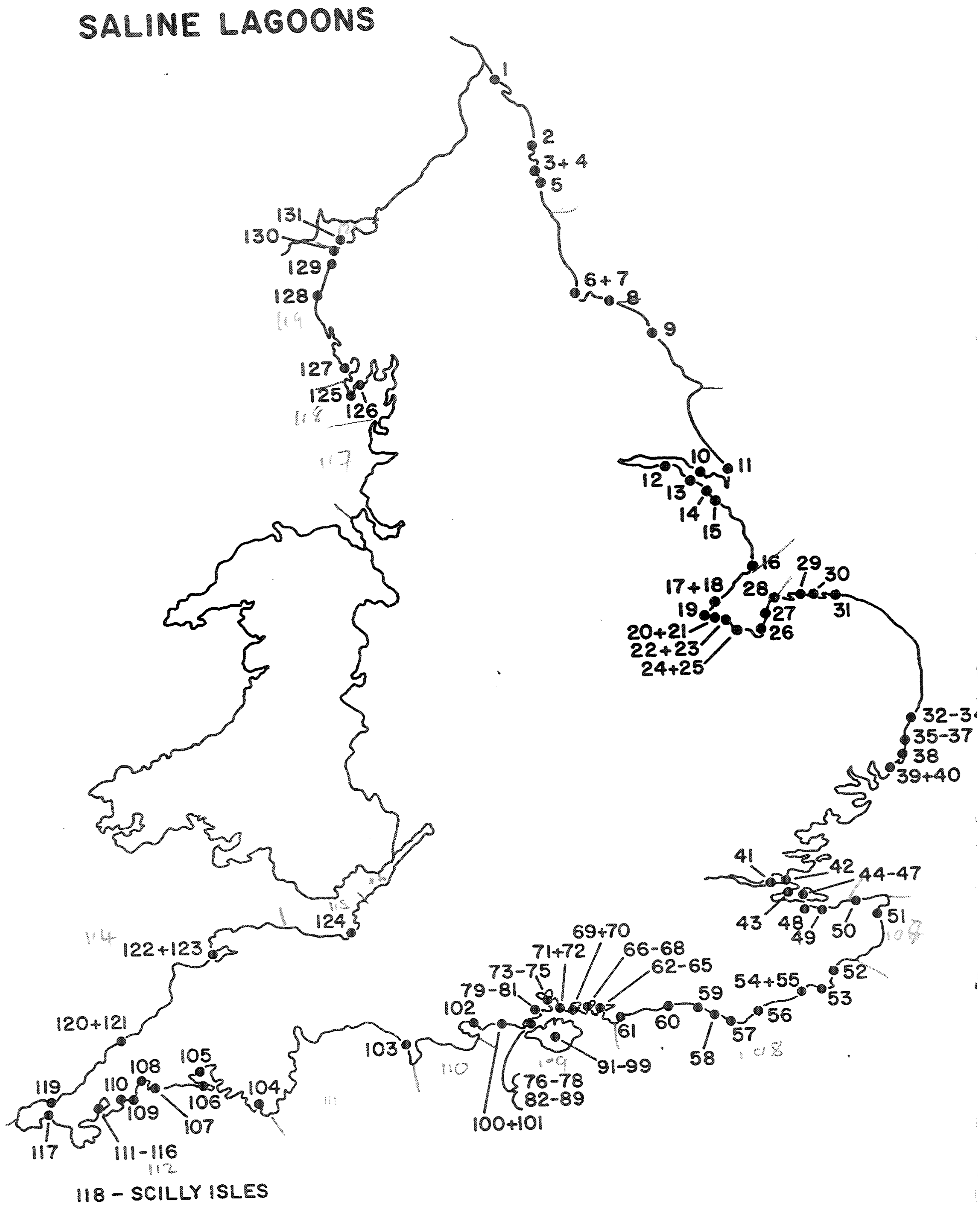

Figure 7.1. Location of saline lagoons and lagoon-like habitats in England.

Table 7.1: Location of saline lagoons and lagoon-like habitats in England

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
001	Cocklawburn Pond	NU 036 479	0.04	SSSI	Northumberland	1
002	Warkworth Harbour Lagoon	NU 257 062	1.75	SSSI, A, HC	Northumberland	1
003	Chevington Burn	NU 273 982	0.04	SSSI, A, HC	Northumberland	1
004	Cresswell Ponds	NZ 283 944	7.75	SSSI	Northumberland	1
005	Snab Point Lagoon	NZ 302 928	0.30		Northumberland	1
006	Cowpen Marsh Ponds	NZ 51 25 / 50 23	7.01	SSSI, R, (S), LNR, CNT	Cleveland	1
007	Saltholme Lagoons	NZ 50 23	6.00		Cleveland	1
008	Chattersty Lagoon	NZ 714 202	2.00		Cleveland	2
009	Cloughton Wyke Point	TA 022 955	0.01		Yorkshire	2
010	Welton Waters Ponds	SE 96 24 / 95 25	57.00	(R), S	Humberside	2
011	Easington Lagoons	TA 41 17 / 40 18 / 39 17	12.70	SSSI, (R), S	Humberside	2
012	Barton Pools	TA 04 23 / 05 23	48.90	SSSI, (R), S, (HC), CNT	Humberside	2
013	South Killingham Pools	TA 16 19	15.00	(R). S	Humberside	2
014	Humberston Fitties	TA 336 048	1.75	SSSI, RS	Lincolnshire	2
015	Northcoates Lagoon	TA 375 034	3.00	SSSI, RS	Lincolnshire	2
016	Gibraltar Point Lagoon	TF 56 58 / 55 55	7.18	NNR, SSSI, LNR	Lincolnshire	3
017	Wyberton Marsh Pond	TF 367 386	0.30	SSSI	Lincolnshire	3
018	Sandholme Farm	TF 353 366	0.25	SSSI	Lincolnshire	3
019	Lamming's Marsh	TF 340 341	0.10	SSSI	Lincolnshire	3
020	Ward's Farm	TF 359 345	0.10	SSSI	Lincolnshire	3
021	Lundy's Farm	TF 390 350	3.60	SSSI	Lincolnshire	3
022	Lawyers Farm Pool	TF 417 333	0.06	SSSI	Lincolnshire	3
023	R.A.F. Holbeach	TF 444 324	0.10	SSSI	Lincolnshire	3
024	Oldershaw Farm	TF 453 303	0.05	SSSI	Lincolnshire	3
025	Lutton Farm	TF 491 265	0.06	SSSI	Lincolnshire	3
026	Snettisham	TF 649 306	18.00		Norfolk	3
027	Heacham	TF 657 356	4.50		Norfolk	3
028	Broad Water	TF 716 447	4.50	SSSI, R, A, S, HC, B	Norfolk	3
029	Holkham Salts Hole	TF 886 451	0.50	NNR, SSSI, R, A, S, HC, B	Norfolk	3
030	Abraham's Bosom	TF 912 453	1.50	R, A ,S, HC, B	Norfolk	3
031	Blakeney Spit Pools	TG 066 447	4.00	R, A, S, HC, B	Norfolk	3
032	The Denes	TM 53 84 / 53 83	3.80	NNR, R	Suffolk	3
033	Benacre Broad	TM 532 828	8.00	NNR, SSSI,	Suffolk	3
034	Covehithe Broad	TM 523 808	0.50	NNR, SSSI	Suffolk	3
035	Easton Broad	TM 518 793	3.00	NNR, SSSI	Suffolk	3
036	Southwold Pool	TM 510 769	2.00	A, HC	Suffolk	3
037	Reedland Marshes	TM 487 729	0.40	SSSI, R, A, HC	Suffolk	3
038	Minsmere Lagoons	TM 47 66	20.41	NNR, SSSI, R, A, HC, RS	Suffolk	3
039	Aldburgh	TM 458 527	-.-	NNR, SSSI, A, HC	Suffolk	3
040	Shingle Street	TM 373 437	5.90	NNR, SSSI	Suffolk	3
041	Cliffe Lagoons	TQ 71 76 / 72 77 / 72 76	114.70	SSSI, (R), (S), CNT	Kent	4
042	Allhallows Lagoons	TQ 85 78	8.70	SSSI, (R), (S)	Kent	4
043	Stoke Marshes	TQ 84 75 / 85 75	6.20	SSSI	Kent	4
044	Queenborough Lagoons	TQ 908 730	2.20	R, S	Kent	4
045	Sheerness Lagoons	TQ 91 75	2.00	R, S	Kent	4
046	West Minster Lagoons	TQ 924 740	4.25	R, S	Kent	4
047	Minster Marshes Lagoon	TQ 935 747	12.00	SSSI, R, S	Kent	4
048	Murston Lagoons	TQ 93 65 / 93 66	41.71	SSSI, R, S	Kent	4
049	Oares Marsh	TR 010 648	0.25	SSSI, R, S, CNT	Kent	4
050	Plumpudding Island	TR 253 694	2.25	SSSI	Kent	4
051	Great Stonar Lake	TR 335 590	21.00		Kent	4
052	Romney Sands Pond	TR 082 217	0.46		Kent	4
053	South Brooks Ponds	TR 030 174	0.20	SSSI, R	Kent	4
054	Rye Harbour Lagoon	TQ 940 178	5.00	SSSI, (R), (S)	Sussex	4
055	Winchelsea Beach Pond	TQ 922 165	0.46		Sussex	4
056	Norman's Bay	TQ 69 06 / 69 05	5.01	SSSI, A	Sussex	4
057	Seaford	TV 51 99 / 51 97	13.30	SSSI, A, LNR	Sussex	4
058	Bishopstone Tide Mills	TQ 462 002	0.40		Sussex	4
059	Brighton Marina	TQ 336 034	10.00		Sussex	4
060	Widewater	TQ 200 042	3.70	(SSSI)	Sussex	4
061	Pagham Harbour	SZ 88 96 / 88 97 / 87 94 85 97	14.30	SSSI, R, LNR, CNT	Sussex	4

Continued.....

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
062	Birdham Pool	SU 825 010	3.90		Sussex	5
063	Great Deep	SU 755 040	18.00	SSSI, R, A, S	Sussex	5
064	Emsworth	SU 75 05 / 74 05	7.00	SSSI, R, A, S, LNR	Sussex/Hampshire	5
065	Stoke Bund Lagoons	SU 717 042	6.00	SSSI, R, A, S, LNR	Hampshire	5
066	Selmore Boating Lake	SZ 737 988	1.30	R,S	Hampshire	5
067	Shut Lake	SU 681 039	2.30	SSSI, R, S, LNR	Hampshire	5
068	Farlington Marshes	SU 680 043	0.10	SSSI, R, S, LNR	Hampshire	5
069	Great Salterns Lake	SU 673 018	3.50		Hampshire	5
070	Gosport	SZ 62 99 / 61 99 / 60 99 60 98 / 60 97	10.00	SSSI	Hampshire	5
071	Browndown Pools	SZ 573 993	0.90	SSSI	Hampshire	5
072	Titchfield Haven	SU 535 025	0.30	SSSI, LNR	Hampshire	5
073	Calshot Pond	SU 487 017	0.30	(R), (S)	Hampshire	5
074	Hook Lake	SU 790 051	2.60	NNR, SSSI, (R), (S)	Hampshire	5
075	Ashlett Pond	SU 465 045	4.30	(R), (S)	Hampshire	5
076	Lepe Crater Pond	SZ 466 991	0.01	NNR, SSSI	Hampshire	5
077	Stansore Point	SZ 464 987	0.10	NNR, SSSI	Hampshire	5
078	The Scrapes	SZ 464 987	0.20	NNR, SSSI	Hampshire	5
079	Beaulieu	SZ 41 96	2.40	NNR, SSSI, A	Hampshire	5
080	Gins & Blackwater	SZ 411 966	7.20	NNR, SSSI, A	Hampshire	5
081	Monks Pond	SU 385 024	5.10	NNR, SSSI, A	Hampshire	5
082	Sowley Lake	SZ 379 960	7.50	SSSI, (S)	Hampshire	5
083	Lisle Court Lake	SZ 351 951	0.20	SSSI, (S)	Hampshire	5
084	Normandy Farm Lagoon	SZ 332 947	0.70	SSSI, (S)	Hampshire	5
085	Pennington - Oxey	SZ 326 926	2.30	SSSI, (S)	Hampshire	5
086	Keyhaven - Pennington	SZ 324 923	0.70	SSSI, (S)	Hampshire	5
087	Salterns Lagoon	SZ 328 935	0.10	SSSI, (S)	Hampshire	5
088	Eight Acre Pond	SZ 327 938	2.90	SSSI, (S)	Hampshire	5
089	Hurst Point Pools	SZ 319 898	0.40	SSSI, (S), CNT	Hampshire	5
090	Sturt Pond	SZ 296 912	3.00	SSSI	Hampshire	5
091	Dodnor Lane Lagoon	SZ 504 915	-.-	LNR	Isle of Wight	5
092	The Old Mill Pond	SZ 547 919	14.80		Isle of Wight	5
093	Seaview Lagoon	SZ 625 917	2.20		Isle of Wight	5
094	Old Mill Ponds	SZ 635 890	9.40	SSSI, A	Isle of Wight	5
095	Bembridge	SZ 63 88	9.90	SSSI, A	Isle of Wight	5
096	Sandown Boating Lake	SZ 606 848	1.50		Isle of Wight	5
097	Yar Bridge Lagoon	SZ 639 897	0.50	SSSI, A	Isle of Wight	5
098	Newtown Quay Lagoon	SZ 418 911	0.80	SSSI, A, (S), HC, LNR	Isle of Wight	5
099	Newtown New Scrape	SZ 422 910	0.50	SSSI, A, (S), HC, LNR	Isle of Wight	5
100	Grimbury Pond	SZ 169 920	0.10	SSSI, LNR	Dorset	5
101	Hengistbury Head	SZ 178 907	2.00	SSSI	Dorset	5
102	Blue Lagoon	SZ 035 900	17.70	SSSI, (R), A, (S), HC	Dorset	5
103	The Fleet	SY 635 795	480.00	SSSI, R, A, S, HC	Dorset	6
104	Scobie Basin	SX 755 394	-.-	SSSI, A, HC, LNR	Devon	6
105	Landulph	SX 428 613	-.-		Cornwall	6
106	Millbrook	SX 425 523	3.30	SSSI	Cornwall	6
107	Polridmouth	SX 103 506	1.00		Cornwall	6
108	Par Sands	SX 085 534	3.50		Cornwall	6
109	Pentawan Harbour	SX 019 476	-.-		Cornwall	6
110	Caerhays	SW 974 415	1.50		Cornwall	6
111	Froe Mill Pond	SW 867 333	0.40		Cornwall	6
112	Kiggon Pond	SW 858 455	-.-		Cornwall	6
113	Tresemble Pond	SW 855 446	0.80		Cornwall	6
114	Trelissick Pool	SW 833 392	-.-		Cornwall	6
115	Swan Pool	SW 802 315	4.00		Cornwall	6
116	Maenport	SW 788 297	0.50		Cornwall	6
117	Marazion Pool	SW 506 314	0.40	SSSI	Cornwall	6
118	The Pool	SV 874 149	1.50	SSSI, A, HC	Cornwall	6
119	Hayle	SW 55 37 / 56 37	3.80	SSSI, A	Cornwall	7
120	Dennis Cove Pool	SW 921 744	0.60	(SSSI), A	Cornwall	7
121	Penquean	SW 963 738	-.-	(SSSI), A	Cornwall	7
122	Horsey Island Pond	SS 473 332	0.80		Devon	7
123	Saltpill Duck Pond	SS 505 331	1.30		Devon	7
124	Catsford Common	ST 42 45	0.90	SSSI	Somerset	7
125	South Walney	SD 225 623	15.00	SSSI	Cumbria	10

Continued.....

Site	Site Name	Grid Reference	Area (Ha)	Status	County	Cell
126	Cavendish Docks	SD 210 680	14.00	SSSI	Cumbria	10
127	Hodbarrow Lagoon	SD 170 780	13.00	SSSI, RS	Cumbria	10
128	Whitehaven Docks	NX 970 185	-.-		Cumbria	10
129	Workington Docks	NX 990 295	-.-		Cumbria	10
130	Maryport Docks	NY 030 365	-.-		Cumbria	10
131	Silloth Docks	NY 105 535	-.-		Cumbria	10

KEY
1. Status: Concerns the conservation status of each site. Blank areas indicate that no designations are known to apply to those particular sites. Where the code letters are within brackets, this indicates that the designation in question is proposed for that site.

Codes Used:

NNR -	National Nature Reserve	LNR -	Local Nature Reserve
SSSI -	Site of Special Scientific Interest	B -	Biosphere Reserve
R -	Ramsar Site	RS -	R.S.P.B. Reserve
A -	Area of Outstanding Natural Beauty	NT -	National Trust
S -	Special Protection Area	CNT -	County Naturalist Trust Reserve
HC -	Heritage Coast	C -	Coastal Protection Area

2. Cell: Refers to the process cell designated in the Macro Review of the Coastline of England & Wales (Hydraulics Research, see References). Cells 8 and 9 occur along the Welsh coast and as such, are not considered in this report.

{SOURCE: Smith & Laffoley (1992)}

Table 7.2: Estimated area of saline lagoons and lagoon-like habitats along the English coast (ha).

County	Coastwatch Database	Smith & Laffoley (1992) Area	Smith & Laffoley (1992) No.
Cumbria	112.52	42.00	7
Lancashire	5.84	0.00	0
Merseyside	27.20	0.00	0
Cheshire	0.00	0.00	0
Gloucestershire	0.00	0.00	0
Avon	190.90	0.00	0
Somerset	2.20	0.90	2
Devon	5.22	2.10	3
Cornwall	29.16	21.30	17
Isles of Scilly	-.-	1.50	1
Dorset	362.44	499.80	4
Hampshire	78.29	68.71	32
Isle of Wight	-.-	39.60	11
Sussex	78.86	72.27	19
Kent	163.32	215.92	25
Greater London	0.00	0.00	0
Essex	11.30	0.00	0
Suffolk	82.96	44.01	12
Norfolk	99.14	33.00	6
Cambridgeshire	0.00	0.00	0
Lincolnshire	31.56	16.55	14
Nottinghamshire	4.30	0.00	0
Humberside	136.56	133.60	13
Yorkshire	0.00	0.01	1
Cleveland	4.64	15.01	10
Durham	0.32	0.00	0
Tyne & Wear	1.00	0.00	0
Northumberland	7.60	9.88	5
Total	**1435.33**	**1214.66**	**182**

Process Cell	Lagoon Area (ha.) (Smith & Laffoley 1992)	No.
1	22.89	14
2	140.36	17
3	88.81	30
4	263.59	40
5	152.71	50
6	495.40	15
7	8.90	9
10	42.00	7
Total	**1214.66**	**182**

Barnes (1988) identified only 41 'natural' lagoons in Britain with a total area of 660 ha. However, many man-made features such as sand and gravel pits, drainage ditches and boating ponds have a similar water chemistry, lagoonal fauna and flora (Smith & Laffoley, 1992). Furthermore, a clear distinction between 'natural' and 'man-made' is often difficult to substantiate, since many 'natural' lagoons have been modified by human activities.

The rarity of true lagoons, both within England and on a European scale, is such that their conservation is of the highest importance. A total of 38 specialist lagoonal species have been identified in Britain, five of which are protected under Schedule 5 of the Wildlife and Countryside Act 1981. Two of these species, Ivell's sea anemone, *Edwardsia ivelli*, and the lagoon sand worm, *Armandia cirrhosa*, occur only at one lagoon site and have not been seen for several years. Other highly localized species include the lagoon sand shrimp, *Gammarus insensibilis*, which occurs in two Lincolnshire sites and one each in Suffolk, Kent and West Sussex, the Foxtail stonewort (*Lamprothamnium papulosum*) which is restricted to two sites in Hampshire and one in Dorset, and the Trembling sea mat (*Victorella pavida*) which is respresented at one site in Cornwall.

7.4 Threats to saline lagoons

Both natural and artificial lagoons are highly susceptible to damage, being typically small and shallow. Minor changes in the barriers which protect them, in the tidal inlets which connect them to the sea, or in streams which may drain in to them, can have a profound effect on the salinity. Water abstraction, pollution, land drainage and infilling can all lead to partial or total destruction of the habitat.

Sea level rise and possible increases in storminess are both potential threats to the survival of lagoons since they are increasingly likely to be overwhelmed by landward movememt of the barriers which protect them.

7.5 Recent habitat loss

No reliable data relating to the extent of recent habitat loss exist, although there are documented records of individual cases of loss due to drainage, waste tipping, dumping of industrial spoil and subsequent development (details are given in Smith & Laffoley, 1992).

7.6. Projected habitat loss

The extent of saline lagoons could be threatened in the next 20 years by landward movement of shingle ridges in the face of rising sea level and increased storminess (e.g. partial infilling of The Fleet by landward migration of Chesil Bank). However, the total amount of lateral movement of most shingle barriers in this period is likely to be small (<5m), since many are partially fixed by sea defence works and measures such as reprofiling and beach recharge are being increasingly used to maintain their stability.

The increased likelihood that some of the smaller, uprotected shingle barriers may be breached or overtopped in the next 20 years offers the prospect that new saline lagoons may be created.This trend could be encouraged in particular areas by artificially lowering parts of a ridge crest to enhance overtopping by tidal water.

A potentially more serious threat is posed by human activities to the many smaller sites which are not presently covered by statutory protection. Such threats principally involve drainage, infilling and recreational development (e.g. for water sports). However, continuing aggregate extraction in some areas will increase the area of open water. Opportunities exist for positive measures to manage the salinity of such sites and to increase their ecological value following the cessation of working.

7.7 Targets for habitat recreation

As a result of the surveys by Barnes (1988) and Sheader & Sheader (1989), 17 true lagoon and 12 lagoon-like sites have been identified as being good representatives of particular 'lagoon' types and worthy of conservation. Eighteen of these sites are currently notified as SSSIs, a further 1 site lies within an NNR, and the remainder have no form of protection (see Table 2 in Smith & Laffoley, 1992). Widewater in East Sussex and Swanpool in Cornwall have been identified as the two sites most urgently in need of statutory protection.

Steps should be taken to examine whether new and existing proposals for sand and gravel extraction, or other forms of development in near-coastal areas, can be influenced to include measures which will ultimately enhance the ecological benefits, including the formation of saline lagoons and lagoon-like habitats. A target of a minimum of120 ha of newly created saline lagoon habitat is considered attainable over a 20 year period. Further research is required to define more precisely the environmental requirements of certain key 'lagoon' species.

8 UNPROTECTED SOFT CLIFFS

8.1 Habitat definition

The definition of these features involves two aspects:

(i) unprotected - includes all cliffs which are not fronted by any form of contiguous shore-parallel coast protection structure (e.g. wall, revetment, gabions); cliffs fronted by shore-normal or oblique groyne structures are included since such structures do not necessarily prevent wave erosion of a cliff face.

(ii) soft - includes lithologies of any geological age which are poorly consolidated or poorly cemented, including glacial till, outwash deposits, head, friable sands, weakly consolidated clays and shales. Areas of variable lithology, for example limestones or sandstones overlying clays, are included where failure of the soft lithology at the base of the cliff leads to failure. Cases where soft sedimentary material overlies 'hard' rock are not included. Similarly, chalk and other Mesozoic limestones are not included in the definition used here although some varieties of these rocks are quite 'soft' and rates of chalk cliff recession are sometimes moderate to high.

8.2 Data sources and reliability

Information about total length of coastline, and of the proportion of cliffed coastline, is contained in the *Coastwatch* database (Table 8.1). However, as shown in Table 1.1, there is a significant difference between these data and the earlier estimates of total coastline length by county reported by Herlihy (1982). This appears to be mainly due to the exclusion of large sections of tidal rivers in the Herlihy survey, but other sources of error cannot be ruled out.

Since no systematic national survey of soft cliffs has been undertaken, such cliffs have been identified using information derived from publications and reports such as the *Macro Review of the Coastline of England and Wales* (Hydraulics Research Ltd., 1986 *et seq.*), the *Coast Protection Survey 1980* (Herlihy, 1982), the *SCOPAC Sediment Transport Study* (Bray *et al.*, 1991), the *National Landslide Databank* (Rendel Geotechnics, 1992), and the *Anglian Coastal Management Atlas* (Anglian Water, 1988a). Occurrences identified therein were transferred to 1:50,000 O.S. maps and lengths of coastline measured; information about lithologies was obtained mainly by reference to geological maps and memoirs.

Currently available information about the distribution and nature of coast protection and flood defence works is fragmentary and incomplete. MAFF maintain records of grant aid by district but does not keep information about the details of individual schemes in a readily accessible form. The *National Sea Defence Survey* currently being undertaken by the NRA contains some useful information, particularly about streches of coastline for which the NRA is responsible, but the data are not all in a form which is relevant in the present context. Consequently, the distinction between unprotected and protected sections of soft cliff coastline is subject to a degree of error.

Estimates of the length of unprotected soft cliff made specially for this report were based on transfer of information onto the most recent edition1:50,000 O.S. base maps and subsequent measurement. Accuracy is thus dependent on (a) the reliability of the original information about coast protection works, and (b) the accuracy and resolution of the 1:50,000 maps themselves. Overall, however, the figures quoted are thought to be accurate to within 10%.

8.3 Resource extent

8.3.1 National length

256 km (measured from O.S. maps)

8.3.2 Regional distribution and importance

The distribution of soft cliff localities is shown in Figure 8.1 and information relating to the length of soft cliff by county is presented in Table 8.1. Humberside (54 km), Yorkshire (33 km), Hampshire and the Isle of Wight (49 km) have the grestest lengths of remaining unprotected soft cliff, although there are also outcrops of significance in northeast Norfolk and Suffolk, Kent, Devon and Cumbria. The main lithologies involved are glacial till and associated outwash deposits (Yorkshire, Humberside, Norfolk, Suffolk, Cumbria), Pleistocene periglacial 'head' deposits (Devon and Cornwall), unconsolidated to poorly consolidated marine, estuarine and fluvial sediments of late Tertiary to early Quaternary age (Suffolk, Kent, Hampshire, Isle of Wight), and soft mudrocks of Jurassic age (Dorset, Yorkshire).

The importance of unprotected soft cliffs is three-fold:

(1) they provide a source of sediment for beaches and other coastal features in areas downdrift

(2) soft cliffs which are undergoing continued erosion provide important fresh exposures which are used for geological teaching and research

(3) some eroding sections of coastal cliff are characterized by the development of mass-movement and other landforms which are of major geomorphological interest

8.4 Threats to unprotected soft cliffs

Loss of this resource type is primarily related to the construction of coast protection works which isolate the cliff from the intertidal zone. In rare local situations, erosion may totally remove a narrow cliffed isthmus or other restricted outcrop, or cliff stabilization and degradation may follow as a consequence of spit progradation and marsh development. In general, however, retreat of coastal cliffs due to erosion does not lead to a loss of resource, but simply to its displacement.

8.5 Recent resource loss

8.5.1 Erosion loss

No systematic national study of cliff erosion rates in the last 20 years has been undertaken and the available published data for particular areas generally refer to average figures for the last century or longer.

A significant problem encountered in estimating rates of natural retreat arises from the fact that erosion at any location is often episodic, and within any given time interval rates of erosion may vary substantially along a section of coast (Cambers, 1976). At points on the Holderness coast, for example, rates of cliff recession show an apparent cyclic pattern, with surges of rapid erosion every four or five years followed by periods of relative quiescence. Cliff retreat typically takes the form of large-scale failures, induced by periods of high groundwater discharge from the land. It typically takes four or five years for the waves and tide to remove this debris and over-steepen the cliff to the point where another large-scale failure can occur (Pethick, 1992b). Superimposed on such behaviour may be longer-term progressive changes in retreat rates caused, for example, by changes in the nearshore profile and subsequent wave power expended at the shoreline.

Estimates based on map evidence, air photographs and archival information suggest that average retreat rates on the Holderness coast in the past century have been of the order of 1-1.8 m per year. Mean rates of long-term retreat show an increase from 1.2 m/yr in the north to 1.7 m/yr in the south (Clayton, 1989a). However, in some areas the rate of retreat has accelerated in recent years, reaching a maximum of 8 m/yr in some areas, particularly down-drift of points where hard defences

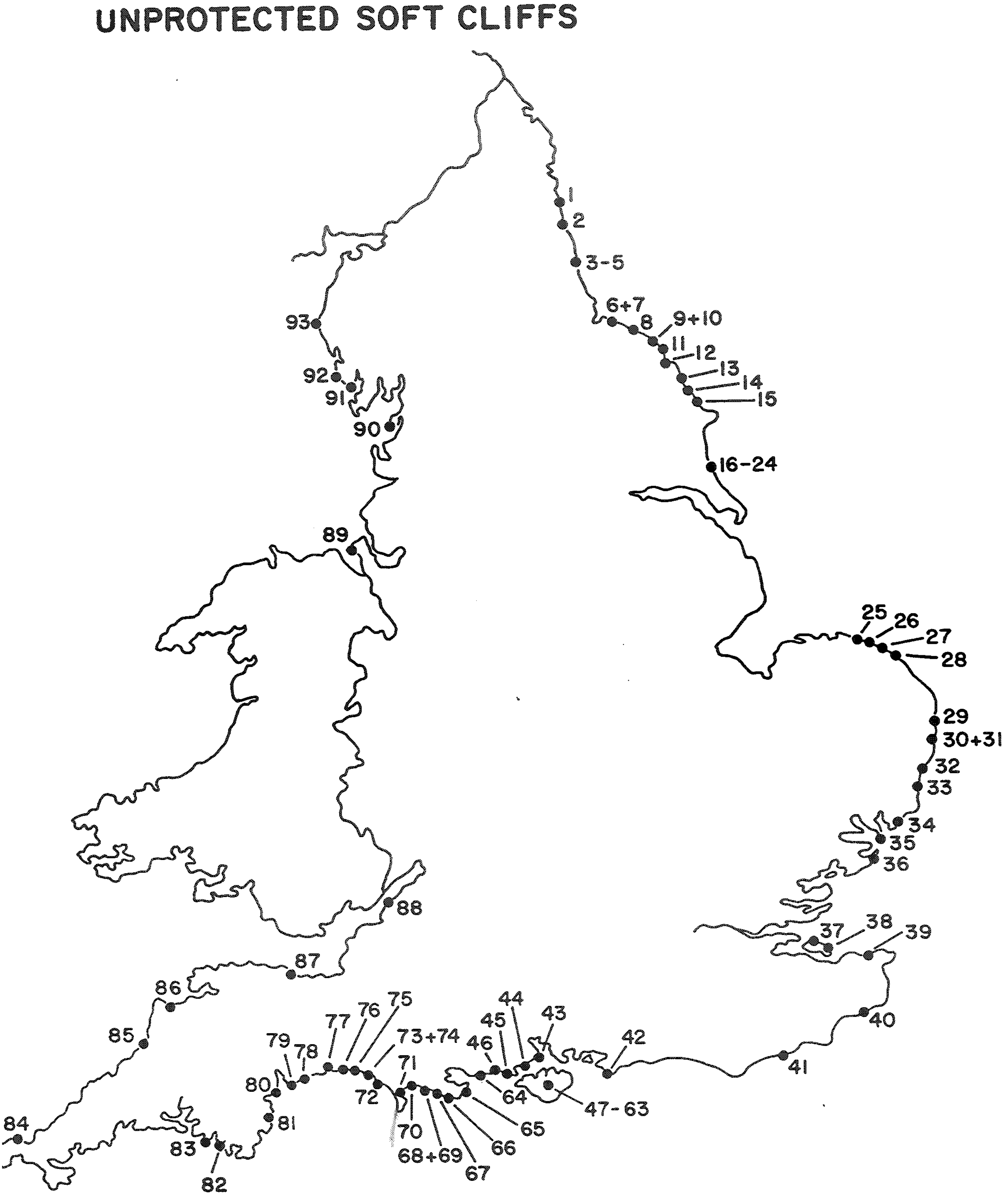

Figure 8.1. Location of unprotected soft cliff localities in England.

Table 8.1: Location of unprotected soft cliffs in England

Site	Site Name	Grid Reference	Length (Km)	County	Cell	Principal Lithology
01	Newbiggin Moor	NZ 31 88	1.50	Northumberland	1	Glacial till
02	Seaton Sluice	NZ 34 76	0.60	Northumberland	1	Shales
03	Hendon - Ryhope	NZ 40 55 - NZ 41 52	4.95	Durham	1	Shales/Limestone
04	Seaham	NZ 42 51 - NZ 42 50	1.50	Durham	1	Glacial till
05	Nose Point - Chourdun Point	NZ 43 47 - NZ 44 46	1.55	Durham	1	Glacial till
06	Redcar	NZ 62 23 - NZ 63 23	1.90	Cleveland	2	Glacial till
07	Stone Gap	NZ 65 22	1.55	Cleveland	2	Glacial till
08	Crowbar Nab	NZ 78 18	0.10	Yorkshire	2	Glacial till
09	Staithes - Runswick	NZ 79 18 - NZ 81 16	4.00	Yorkshire	2	Shales & clays
10	Runswick Bay	NZ 81 15 - NZ 82 15	2.80	Yorkshire	2	Glacial till
11	Upgang Beach	NZ 87 12	1.00	Yorkshire	2	Glacial till
12	Robin Hoods Bay	NZ 96 03	1.50	Yorkshire	2	Glacial till
13	Ravenscar - Scarborough	NZ 98 01 - TA 03 92	12.70	Yorkshire	2	Glacial till
14	Cornelian Bay - Cayton Bay	TA 05 86 - TA 07 84	4.45	Yorkshire	2	Glacial till
15	Filey Bay	TA 12 79 - TA 16 75	6.60	Yorkshire	2	Glacial till
16	Hilderthorpe - Hornsea	TA 17 64 - TA 20 49	16.60	Humberside	2	Glacial till
17	Rolston	⊤	⊤	Humberside	2	Glacial till
18	Mappleton			Humberside	2	Glacial till
19	Great Cowden	↑	↑	Humberside	2	Glacial till
20	Aldburgh	TA 21 46 - TA 33 29	21.90	Humberside	2	Glacial till
21	Ringborough	↓	↓	Humberside	2	Glacial till
22	Grimston - Waxholme			Humberside	2	Glacial till
23	Owthorne	⊥	⊥	Humberside	2	Glacial till
24	Withernsea - Easington	TA 35 26 - TA 40 19	15.50	Humberside	2	Glacial till
25	Weybourne	TG 11 43 - TG 14 43	3.90	Norfolk	3	Glacial till
26	East Runton	TG 18 43 - TG 21 43	2.50	Norfolk	3	Glacial till
27	Trimmingham	TG 26 40 - TG 29 38	3.80	Norfolk	3	Glacial till
28	Paston	TG 32 35 - TG 34 34	2.50	Norfolk	3	Glacial till & sands
29	Corton	TM 53 99 - TM 54 98	2.00	Suffolk	3	Glacial till & sands
30	Kessingland Cliffs	TM 53 89 - TM 53 87	2.50	Suffolk	3	Clay
31	Covehithe Cliffs	TM 53 82 - TM 52 81	1.50	Suffolk	3	Sands
32	Eastern Bavents	TM 51 78 - TM 51 77	1.20	Suffolk	3	Sands
33	Dunwich Cliffs	TM 47 69 - TM 47 67	2.50	Suffolk	3	Clays & sands
34	Bawdsey	TM 35 39 - TM 34 38	1.50	Suffolk	3	Sands & gravels
35	Cobbalds Point	TM 31 34	0.20	Suffolk	3	Clay
36	The Naze	TM 26 35	0.80	Essex	3	Clay
37	East End, Sheppey	TQ 96 73 - TQ 99 73	3.45	Kent	4	Clay
38	Warden	TR 02 71 - TR 03 70	0.95	Kent	4	Clay
39	Reculver	TR 21 69	1.40	Kent	4	Sands
40	The Warren	TR 26 38 - TR 24 37	3.50	Kent	4	Gault Clay
41	Fairlight Cove	TQ 88 12 - TQ 85 10	5.15	Sussex	4	Sands
42	Selsey Bill	TQ 84 92	0.80	Sussex	5	Clay
43	Stanswood Bay	SU 47 00 - SZ 46 98	2.60	Hampshire	5	Clay & Gravel
44	Stone Point	SZ 45 98	1.95	Hampshire	5	Sands & Gravels
45	Hordle Cliff	SZ 24 92 - SZ 26 92	2.10	Hampshire	5	Barton Beds
46	Highcliffe	SZ 22 93	0.50	Hampshire	5	Sands & Gravels
47	Osbourne Bay	SZ 54 93 - SZ 51 96	4.90	Isle of Wight	5	Clays
48	Woodside Bay	SZ 55 93	0.50	Isle of Wight	5	Clays
49	The Priory	SZ 63 90	0.60	Isle of Wight	5	Clays
50	East Cliff, Bembridge	SZ 65 88	0.70	Isle of Wight	5	Clays
51	Foreland	SZ 65 86 - SZ 66 87	1.25	Isle of Wight	5	Shales & Clays
52	Red Cliff	SZ 62 85	1.50	Isle of Wight	5	Sands & Clays
53	Dunnose	SZ 58 78	0.80	Isle of Wight	5	Chalk/U.Gs & Clay
54	St Lawrence Undercliff	SZ 52 76 - SZ 55 77	3.00	Isle of Wight	5	Chalk/U.Gs & Clay
55	South-West Isle of Wight Coast	SZ 37 84 - SZ 48 76	15.60	Isle of Wight	5	Sands & Clays
56	Totland - Alum Bay	SZ 31 86 - SZ 30 85	2.15	Isle of Wight	5	Sands & Clays
57	Colwell Bay	SZ 32 88	1.30	Isle of Wight	5	Sands & Clays
58	West Hill	SZ 33 89	1.10	Isle of Wight	5	Sands & Clays
59	Norton	SZ 34 89	0.70	Isle of Wight	5	Sands & Clays
60	Bouldner Cliff	SZ 39 91 - SZ 37 90	2.50	Isle of Wight	5	Muds
61	Burnt Wood	SZ 44 93 - SZ 42 93	2.10	Isle of Wight	5	Clays & Muds

Site	Site Name	Grid Reference	Length (Km)	County	Cell	Lithology
62	Northwood	SZ 46 95 - SZ 46 94	0.90	Isle of Wight	5	Marls over Clays
63	Gurnard	SZ 47 96	1.90	Isle of Wight	5	Lmt. over Clays
64	Warren Hill	SZ 17 90 - SZ 16 90	1.25	Dorset	5	-
65	Studland	SZ 04 82	0.30	Dorset	5	Bagshot Beds
66	Chapman's Pool - Houns Tout	SY 95 76 - SY 94 77	1.40	Dorset	5	Kimmeridge Clay
67	Kimmeridge Bay	SY 90 74 - SY 90 78	0.95	Dorset	5	Kimmeridge Clay
68	Gad cliff	SY 87 79 - SY 88 79	2.00	Dorset	5	Kimmeridge Clay
69	Ringstead Bay	SY 86 80 - SY 75 81	10.10	Dorset	5	Wealden
70	Ringstead Bay - Redcliffe Point	SY 75 81 - SY 71 81	5.40	Dorset	5	Shales & Mudstone
71	Furzy Cliff	SY 69 81 - SY 70 81	1.50	Dorset	5	Clays
72	West Cliff	SY 45 90	0.85	Dorset	6	U. Lias Clays
73	Thorncombe Beacon	SY 43 91 - SY 44 91	1.10	Dorset	6	U. & M. Lias
74	Seatown	SY 41 91	0.85	Dorset	6	L. & M. Lias
75	Golden Cap - Cains Folly	SY 37 92 - SY 39 92	3.50	Dorset	6	Lias Clays
76	Black Ven - The Spittals	SY 34 52 - SY 35 93	2.25	Dorset	6	Gst & Lias Clay
77	Lyme Regis - Seaton	SY 33 91 - SY 26 90	8.40	Devon	6	U.Gst & Gault
78	Ladrum Bay - River Otter	SY 09 85 - SY 08 82	3.90	Devon	6	Sands
79	Budleigh Salterton	SY 06 81 - SY 04 80	2.80	Devon	6	Marls & Sands
80	Shaldon	SX 93 71 - SX 93 70	2.20	Devon	6	T'mouth Breccia
81	Corbyn's Head	SX 90 63	0.20	Devon	6	Sandy Comglom.
82	Hope Cove	SX 67 39	0.30	Devon	6	Red Shales
83	Challaborough	SX 64 44	0.30	Devon	6	Shales
84	Porthmoer Beach	SW 51 40	0.95	Cornwall	7	Clay
85	Widemouth Bay	SS 19 01 - SS 19 02	1.30	Cornwall	7	Head
86	Bucks Mills	SS 35 24 - SS 36 24	1.95	Devon	7	Shales & Clays
87	Blue Anchor Bay	ST 03 43	0.50	Somerset	7	L. Lias
88	Aust Cliff	ST 56 89 - ST 57 90	0.70	Avon	7	Mudstone
89	Caldy Backs	SJ 21 85 - SJ 24 82	2.50	Merseyside	10	Clay
90	Sunderland Brows	SD 42 56	0.30	Lancashire	10	Clay
91	Borwick Rails	SD 19 79 - SD 18 78	1.35	Cumbria	10	Clay
92	Silecroft - Annaside	SD 11 81 - SD 08 56	5.60	Cumbria	10	Boulder Clay
93	St. Bees	NX 95 11 - NX 96 10	1.40	Cumbria	10	Clay

KEY
1. Cell: Refers to the process cell designated in the Macro Review of the Coastline of England & Wales (Hydraulics Research, see References). Cells 8 and 9 occur along the Welsh coast and as such, are not considered in this report.

{SOURCE: Various (See References)}

Table 8.2: Estimated length of unprotected soft cliffs along the English coast (Km).

County	Coastwatch Database*	Various
Cumbria	-.-	8.35
Lancashire	-.-	0.30
Merseyside	-.-	2.50
Cheshire	-.-	0.00
Gloucestershire	-.-	0.00
Avon	-.-	0.70
Somerset	-.-	0.50
Devon	-.-	20.05
Cornwall	-.-	2.25
Dorset	-.-	31.45
Hampshire	-.-	7.15
Isle of Wight	-.-	41.50
Sussex	-.-	5.95
Kent	-.-	9.30
Greater London	-.-	0.00
Essex	-.-	0.80
Suffolk	-.-	11.40
Norfolk	-.-	12.70
Cambridgeshire	-.-	0.00
Lincolnshire	-.-	0.00
Nottinghamshire	-.-	0.00
Humberside	-.-	54.00
Yorkshire	-.-	33.15
Cleveland	-.-	3.45
Durham	-.-	8.00
Tyne & Wear	-.-	0.00
Northumberland	-.-	2.10
Total	**-.-**	**255.60**

* No such category existed within the Coastwatch Database.

Process Cell	Cliff Length (Km) (Various)
1	10.10
2	90.60
3	24.90
4	14.45
5	72.35
6	26.65
7	5.40
10	11.15
Total	**255.60**

have been constructed around coastal settlements and installations (Pethick, 1992b). The effects of protecting these sections of coastal frontage have been to (1) locally reduce the amount of cliff erosion and the amount of sediment being suppied to the beach, (2) intercept sediment moving from up-drift sections of coast, and (3) enhance erosion of the downdrift coastal cliff sections. In some instances the formation of an artificial 'headland' by differential erosion may have slowed the fall in beach levels and cliff retreat on the updrift side, but this is not invariably the case.

Elsewhere in England, reported mean long-term rates of soft cliff retreat are lower, ranging from 0.12 to 0.6 m/yr (May, 1977; Clayton, 1989a), although values of 3-4 m/yr have been recorded locally (e.g.Steers, 1978). Typical retreat values for chalk cliffs are 0.05-0.5 m/yr (May, 1971) and for Mesozoic limestones 0.12 m/yr (Clayton, 1989a). In general, there is a weak relationship between cliff height and the rate of retreat (Cambers, 1976). In many places, rates of recession have declined substantially throughout this century due to the progressive construction of sea defence works (Clayton, 1989b).

8.5.2 Loss due to human activities

A full national survey of the pattern and rate of sea defence construction has not been undertaken, and information is available only on a fragmentary regional basis. On the Holderness coast, the defences around the principal settlements of Hornsea, Withernsea and Mappleton have been improved and slightly extended in recent years, and ad-hoc attempts have been made to give to give short-term protection to a number of caravan parks and industrial instalations such as the BP gas terminal at Easington. In Norfolk, there have been improvements and minor extensions to defences between Cromer and Happisburgh (Steers, 1978; Anglian Water, 1988a,b). Along the Devon coast, gabions have been installed along a 0.5 km stretch of coast at Budleigh Salterton, but elsewhere cliffs have been allowed to retreat. In west Dorset, the policy has generally been to allow unprotected cliffs to retreat, although some protection has been undertaken around Weymouth and in Bridport Bay. Further east, around the Isle of Purbeck, rock armour defences have recently been constructed at Durleston Cliffs to protect housing, and there have been improvements to the cliff-foot promenade at Swanage. Further recent attempts to stabilise cliffs and coastal land slips in the built-up areas around Ventnor, Isle of Wight, have also been made. At present, no figures for the total length of new defences constructed in the last 20 years are available.

8.6 Projected resource loss

8.6.1 Erosion loss

A significant rise in sea level can be expected to lead to increased soft cliff instability in most areas (e.g. Clayton, 1990; Kalaugher & Grainger, 1991). Based on a consideration of the relationship between recent rates of cliff retreat and nearshore morphology, it has been suggested that the average rate of retreat will increase by about 0.35 m/yr for each 1 mm/yr rise of sea level (Clayton, 1989a). However, an upper limit of retreat will be set by the rate at which sediment can be removed from the cliff base. This is probably at least 3 m/yr for cliffs >40 m high, 6 m/yr for 20 m cliffs and >10 m/yr for 10 m cliffs (Clayton, 1989a). Even if there is no increase in present cliff retreat rates, between 10 and 40 m of cliff top recession can be expected in the next 20 years, rising to between 50 and 200 m by the end of the next century. If sea level rises by 18-25 cm between 1990 and 2030, as forecast, the total amount of retreat by that date will range from 40 - 160 metres.

8.6.2 Human activities

It is inevitable that there will be some further extension of coastal protection works in areas where buildings or installations are threatened. Plans have already been anounced for further extensions to the sea defences around Hornsea, and between Withernsea and Easington on the Holderness coast. In the latter case, however, it is likely that the works will be of timber construction and have a short design life. The total national extent of future works is difficult to predict with certainty. However, it is reasonable to assume that, if present policies continue, within the next 50 years it may become necessary to consider defending any significant development which currently lies within 100 m of an eroding cliff edge. Based on this assumption, an examination of Ordnance Survey maps has suggested that new cliff protection works may be considered at more than 21 locations around the coast within the next 50 years (Table 8.3).

Table 8.3: Predicted areas of new protection works within the next 50 years (location of sites shown on Figure 8.1)

County	Sites
Northumberland	1 & 2
Durham	4 & 5
Cleveland	6
Yorkshire	8
Suffolk	33 & 35
Kent	37 & 40
Sussex	41 & 42
Isle of Wight	55, 57, 59, & 63
Devon	79,81,82 & 83
Cornwall	84

No figures for length of new defences are given in Table 8.3 since this will depend on the morphology of the cliff edge, the degree of urban expansion in the next 20 years, and the degree to which new defences are extended beyond the limit of the urban areas. However, the total length of new defences constructed over the 50 year period would be almost certain to exceed 25 km, or 10% of the present extent of unprotected soft cliff defined in this report. The pro-rata figure for the next 20 years would be at least 10 km, or 4% of the present unprotected soft cliff length.

8.7 Targets for habitat recreation

In view of the importance of soft cliff erosion in providing a source of sediment for beaches and other coastal features down-drift, complete stabilisation of cliffs should be avoided except where there is an overwhelming economic or other justification for such action (e.g. direct threat to large settlements, industrial installations with a long remaining design life, heritage sites of national imporance etc.). Elsewhere, the consequences of erosion, including the loss of isolated properties, should be accepted. In this event, there will be a requirement for appropriate compensation (Kay, 1990).

If such a policy option is to remain open, it would be prudent not to permit further development of 'permanent' structures within a 'buffer zone' adjacent an eroding cliff edge, or one which is currently protected but where abandonment of coastal defences might be contemplated in the future. A number of local authorities (e.g. Canterbury, North Norfolk, Humberside) have already accepted this philosophy. The appropriate width of the 'buffer zone' will vary from area to area, depending on historic rates of cliff recession, lithological characteristics and existing patterns of development, but in many instances is likely to lie in the range 100 - 300 m.

The possibility of removing coastal defences in some areas, or replacing hard defences such as revetments and walls by alternative systems (e.g. offshore breakwaters and artificial cliff foot-boulder beaches) which limit, rather than prevent erosion (Hyrdraulics Research, 1991; Powell, 1992), should be investigated. Likely sites are those where there is only limited existing development within 100-300 m of the cliff edge, where the benefits to beaches and other coastal features downdrift are clearly demonstrable, and where current protection consists mainly of wooden revetment and groyne systems which will shortly require replacement. If the length of unprotected soft cliff is to be maintained at 1992 levels, a working objective should be to 'free-up' a minimum of 10 km of currently protected soft cliff over the next 20 years and 25 km over the next 50 years.

9 MARITIME CLIFF GRASSLAND

9.1 Habitat definition

In strict terms, this habitat refers to maritime grassland communities which occur on cliff tops and cliff slopes, are substantially unimproved by human activities, are moderately influenced by salt spray, and therefore contain a high proportion of maritime species. Included are *National Vegetation Classification (N.V.C.)* community types MC8 - MC12. *Festuca rubra* is usually very abundant, with *Armeria maritima* and *Silene vulgaris* ssp. *maritima* present, particularly nearer the coast. *Plantago* sp. are also often abundant, especially in grazed areas. There may be a transition inland to calcicolous grassland (A2) communities. *Festuca ovina - Carlina vulgaris* grassland (CG1) may occur near the coast in localities with a sunny, southerly aspect, or as inliers within MC communities.

In practice, salt spray influence varies with cliff height and orientation with regard to prevailing winds (Malloch, 1972; Mitchley & Malloch, 1991). Similarly, the landward limit of 'unimproved' grassland is sometimes difficult to define, although it may generally be taken to be the first field boundary, urban development or transition to other vegetation community. In many instances this distance is only a few metres or tens of metres from the cliff top, but in exceptional cases it may be a few hundreds of metres.

9.2 Data sources and reliability

A number of the areas of maritime grassland were included in the survey of sea cliff vegetation commissioned by NCC and carried out by Lancaster University between 1985 and 1989. Details for five English sites are contained in a series of reports by Cooper (1988) entitled *Vegetation Maps of British Sea Cliffs and Cliff Tops*, and reference is made to the information in the *Sea Cliff Management Handbook* (Mitchley & Malloch, 1991). However, only a very small proportion of the English coastline was covered in this survey.

An estimate of the extent of maritime cliff grassland by county has been derived from the *Coastwatch* database. The latter contains entry information for 'cliff-top vegetation' and ' vegetated cliffs' , categories which include other communities in addition to maritime grassland . The data should therefore be regarded as an overestimate of the area of maritime cliff grassland habitats *sensu stricto*.

9.3 Resource extent

9.3.1 National area

1895 ha *(Coastwatch* database)

9.3.2 Regional distribution and vegetation communities

The distribution of the habitat is primarily controlled by that of 'hard' and 'soft' rock cliffs. Consequently, 'cliff' vegetation communities show a high concentration in the southwest (Devon and Cornwall), on the south coast (particularly Dorset, East Sussex and Kent), on the northeast coast (Northumberland, Yorkshire), and in Cumbria.

The areas of 'cliff-top' and vegetated cliff' for each county, reported in the *Coastwatch* database, are shown in Table 9.1. Cornwall has by far the largest reported area (50% of the total resource), followed by Devon, Yorkshire and Cumbria.

The five areas highlighted in the series of reports by Cooper (1988) are: the Lizard (Cornwall), Cape Cornwall (Cornwall), Robin Hood's Bay (Yorkshire), Trimingham (Norfolk), and Isle of Purbeck (Dorset).

Within the Lizard area, grassland communities (including NVC classification units MC8-12, MG1, MG4, CG4 & U46) cover a total of 28 ha. *Festuca-Plantago* grassland (MC12) and *Festuca - Armeria*

Table 9.1: Estimated area of maritime cliff grassland along the English coast (ha).

County	Coastwatch Database
Cumbria	106.05
Lancashire	3.00
Merseyside	0.00
Cheshire	0.00
Gloucestershire	17.50
Avon	8.61
Somerset	16.59
Devon	299.85
Cornwall	937.48
Dorset	57.30
Hampshire	51.62
Isle of Wight	0.00
Sussex	32.50
Kent	74.08
Greater London	0.00
Essex	5.30
Suffolk	12.06
Norfolk	23.90
Cambridgeshire	0.00
Lincolnshire	0.00
Nottinghamshire	0.00
Humberside	46.39
Yorkshire	143.39
Cleveland	24.68
Durham	15.69
Tyne & Wear	2.28
Northumberland	16.26
Total	**1894.80**

NB, No sources of information, other than the Coastwatch Database, were available for this habitat. The figures given represent combined 'cliff top' and 'cliff-face' categories.

grassland (MC8) are dominant. The principal lithologies are serpentinite and schist. Similar assemblages are found at Cape Cornwall (total area 40 ha).

The Robin Hood's Bay area contains 10.4 ha of grassland communities, mainly *Arrhenatherium elatius* (MG1), *Lolium perenne* (MG7) and *Festuca rubra* (MG9) on glacial till.

The Trimingham area is reported to contain 12.8 ha of *Arrhenatherium elatius* grassland (MG1) and *Avenula pubescens* grassland (CG6) growing on glacial drift deposits.

The Purbeck area contains 16.1 ha of variable grassland communities growing on Jurassic limestones and shales.

9.4 Threats to cliff grassland habitats

The principal natural threat arises from coastal erosion. This is clearly more serious on 'soft' lithologies with higher erosion rates, and where the grassland communities are unable to retreat landwards due to the existence of cultivated fields or settlements.

The main threats from human activities involve land-use change, including pasture improvement, conversion to arable agriculture, or development (e.g. to caravan parks or camping grounds).

Heavy grazing usually leads to a reduction in the variability of the vegetation. The three-sub-communities of the *Festuca-Armeria* grassland (MC8) are replaced by the short, tight sward of the *Plantago* sub-community. If sheep grazing is heavy, the *Festuca-Holcus* grassland (MC9) may be replaced by *Festuca-Plantago* ssp. grassland (MC10).

9.5 Recent habitat loss

9.5.1 Erosion loss

As noted in Section 8.5.1. average rates of soft cliff erosion on undefended sections of coast range from 0.4 to 1.8 m/yr. Average rates of recession of chalk cliffs are about 0.21 m/yr, and of Mesozoic limestones and mudrocks 0.12 to 0.43 m/yr (Clayton, 1989a). Hard rock lithologies, including many granites, metamorphic rocks and older sedimentary rocks in the southwest, have present recession rates of less than 0.1 m/yr. Consequently maritime grassland sites on soft lithologies at locations such as Robin Hood's Bay and Trimingham have suffered the greatest losses in recent decades.

9.5.2 Loss due to human activities

There is currently no information about the regional or national extent of recent losses to maritime grasslands caused by human activities. However, loss of cliff-top habitats generally in the last 20 years is well documented, and is exemplified by development of caravan parks on many parts of the coast (e.g. Durdle Door, Dorset, Holderness, Filey). Loss and damage has also been caused by development of tourist facilities including car parks and walking trails (e.g. at Land's End).

9.6 Projected habitat loss

9.6.1 Erosion loss

Erosion losses on sections of unprotected coast are likely to continue and may accalarate due to sea level rise in the next 20 to 50 years. However, the impact on 'hard' rock coasts is likely to be minimal. Precise estimates of the extent of the likely loss are impossible given the poor definition of the extent of the existing resource.

9.6.2 Human activities

Pressures on maritme grassland due to conversion to arable agricultural land and improved pasture may become less strong than they have been in the past, as changes in European and British agricultural policy make it less attractive for farmers to produce on marginal land. However, there may be increased pressure from new proposals to extend holiday parks and recreational facilities. There is also a danger that the abandonment of grazing and other forms of management in such areas may lead to the expansion of scrubland and woodland at the expense of grassland.

9.7 Targets for habitat recreation

Although the magnitude of the existing habitat resource, let alone that of future habitat changes, is impossible to quantify at present, it is clear that a significant reduction in habitat extent may be expected unless positive steps are taken to prevent it.The most realistic option would appear to be maintenance of existing maritime grassland areas through the continuance, or modification of existing management practices. This could be accomplished by the setting up of new local management agreements, possibly involving the Countryside Stewardship Scheme where appropriate. A reduction in grazing pressure in some currently heaviliy grazed areas could be encouraged as a means of increasing the likelihood that MC8 - MC12 communities may re-establish themselves. A realistic target would be the recreation of a minimum of 150 ha of maritime grassland in the next 20 years.

10 COASTAL HEATH

10.1 Habitat definition

Coastal heaths are defined in this study as those areas characterized by typical heath community types, according to the *N.V.C.* classification system, and whose floristic characteristics are not significantly modified by anthropogenic factors. Areas of managed heath are included where the typical heath floral communities have been maintained. No distinction is made between maritime heaths, which are influenced by sea spray (typically H7) and other heath communities which occur close to the shore but which have little spray influence (including H5, H6, H7 and H8). A clear separation between maritime and inland heath communities is difficult to make, since one may be transitional to the other.

10.2 Data sources and reliability

The coastal heaths of England have not been the subject of a dedicated national inventory, although areas of dune heath were included in the *National Sand Dune Inventory* and some areas of maritime heath were included in the *Sea Cliff Survey*. Maps of heath community distributions are contained in Rodwell's (1991) *'British Plant Communites Volume 2: Heaths & Mires'* and Webb's (1986) book on *'Heathlands'* However, areal extent data are not provided by either publication.

An estimate of the areal extent of the coastal heath resource by county has been made using information in the *Coastwatch* database, which includes a category of 'other habitats; i.e. heath'. Since other communities are also included in some areas, the figures presented overestimate the actual extent of coastal heath communities in the areas surveyed.

10.3 Resource extent

10.3.1 National area

462 ha (*Coastwatch* database)

10.3.2 Regional distribution and habitat importance

The distribution of major coastal heath occurrences, including dune heath, is shown in Figure 10 .1 and a list of sites is presented in Table 10.1.

Estimates of the area of 'other habitats, including heath', contained in the *Coastwatch* database are shown in Table 10.2. Cornwall is the county with the largest reported total area, followed by Devon, Norfolk and Dorset. However, the figures cited refer only to a fraction of the total heathland present in these counties. Dorset alone contains more than 1000 ha of heathland, including inland heath (Moore, 1962), and there are additional large areas in Suffolk (Table 10.2). The national area of dune heath is reported by Radley (1992) to be 278 ha, concentrated mainly in Dorset, Cumbria, Norfolk, the Isles of Scilly and Merseyside.

One of the largest and best studied areas with extensive heath communities is the Lizard Peninsula in Cornwall (Coombe & Frost, 1956; Malloch, 1971; Hopkins, 1983; Bristol University, 1987). Within a total heath-coverd area of 56 ha area, *Calluna - Scilla* maritime heath represents 10.9 ha (Cooper, 1988).

10.3.3 Vegetation communities

Maritme heath is represented mainly by the *Calluna vulgaris - Scilla verna* community (NVC class H7), which includes five sub-communities. Sub-shrubs are a characteristic feature, and are often wind-pruned and salt-scalded on their windward side. *Calluna* is the most frequent sub-shrub, accompanied by *Erica cinerea* on drier soils. In the north, particularly on wetter soils, *Empetrum nigrum* ssp. *nigrum*

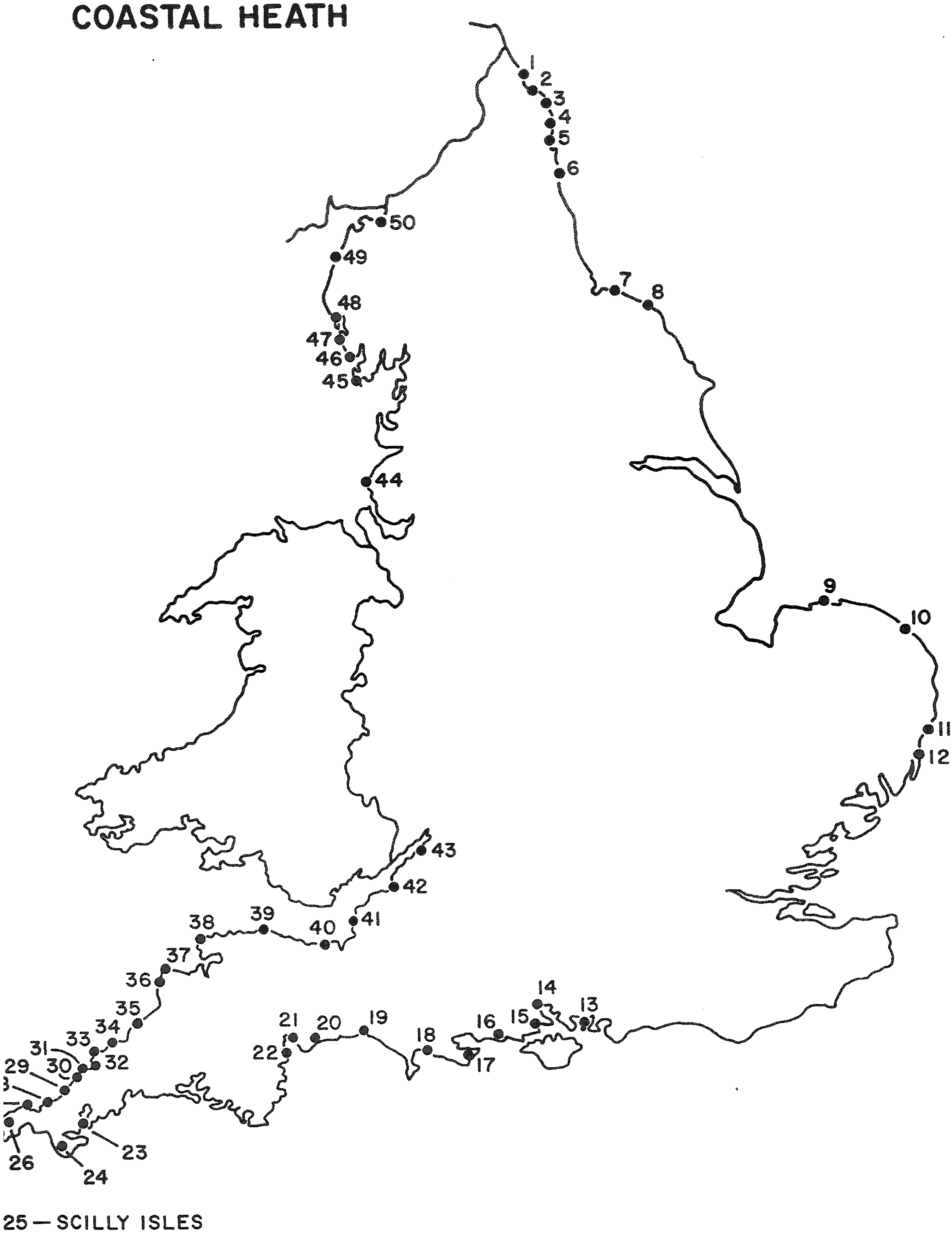

Figure 9.1. Location of coastal heath localities in England.

Table 10.1: Location of coastal heaths in England

Site	Site Name	Grid Reference	Area (Ha)	County	Cell
01	North Northumberland Coast	NU 06 45 - NU 03 47	0.09	Northumberland	1
02	Ross Links	NU 14 37	3.81	Northumberland	1
03	-	-	-	Northumberland	1
04	Embleton	NU 24 22 - NU 24 23	0.25	Northumberland	1
05	Alnmouth	NU 24 10 - NU 25 08	0.42	Northumberland	1
06	Lynemouth	NZ 30 91	1.70	Northumberland	1
07	-	-	-	Cleveland	2
08	Port Mulgrave	NZ 79 19	-	Yorkshire	2
09	Holkham Meals	TF 90 45	-	Norfolk	3
10	Winterton - Horsey	TG 45 25 - TG 50 18	59.67	Norfolk	3
11	Walberswick	TM 493 742	514.00	Suffolk	3
12	The Sandlings	TM 47 67	85.60	Suffolk	3
13	Hayling Island	SU 72 02	8.91	Hampshire	5
14	New Forest	-	-	Hampshire	5
15	New Forest	-	-	Hampshire	5
16	-	-	-	Dorset	5
17	Studland	SZ 03 84	1156.00	Dorset	5
18	-	-	-	Dorset	5
19	-	-	-	Dorset	6
20	-	-	-	Devon	6
21	-	-	-	Devon	6
22	Dawlish Warren	SX 99 80	1.31	Devon	6
23	-	-	-	Cornwall	6
24	The Lizard	-	400.00	Cornwall	6
25	Scilly Isles	-	25.16	Cornwall	6
26	Lands End	-	-	Cornwall	7
27	-	-	-	Cornwall	7
28	-	-	-	Cornwall	7
29	-	-	-	Cornwall	7
30	Chapel Porth	SW 697 495	-	Cornwall	7
31	-	-	-	Cornwall	7
32	-	-	-	Cornwall	7
33	-	-	-	Cornwall	7
34	-	-	-	Cornwall	7
35	-	-	-	Cornwall	7
36	-	-	-	Devon	7
37	Hartland Point	SS 22 27	-	Devon	7
38	-	-	-	Devon	7
39	Exmoor	-	-	Devon/Somerset	7
40	Quantocks	-	-	Somerset	7
41	-	-	-	Avon	7
42	-	-	-	Avon	7
43	-	-	-	Avon	7
44	Sefton Coast	SD 27 08	14.21	Merseyside	10
45	Walney Island	SD 17 73	19.39	Cumbria	10
46	Haverigg	SD 15 78	8.05	Cumbria	10
47	Eskmeals	SD 01 93	3.83	Cumbria	10
48	Drigg	SD 05 97	41.20	Cumbria	10
49	Silloth	NY 06 40	19.72	Cumbria	10
50	Solway	-	-	Cumbria	10

KEY
1. Cell: Refers to the process cell designated in the Macro Review of the Coastline of England & Wales (Hydraulics Research, see References). Cells 8 and 9 occur along the Welsh coast and as such, are not considered in this report.

{SOURCE: Radley (1992) for data on Dune Heath, with additional data from other sources.}

Table 10.2: Estimated area of coastal heath along the English coast (ha).

County	Coastwatch Database*	Radley (1992)**	Various
Cumbria	14.15	92.19	-.-
Lancashire	2.25	0.00	-.-
Merseyside	3.50	14.21	-.-
Cheshire	1.90	0.00	-.-
Gloucestershire	0.60	0.00	-.-
Avon	2.40	0.00	-.-
Somerset	9.02	0.00	-.-
Devon	73.34	1.31	0.01
Cornwall	212.29	0.56	399.44
Isles of Scilly	-.-	25.16	-.-
Dorset	18.26	70.03	1085.97
Hampshire	8.61	8.91	-.-
Isle of Wight	-.-	0.00	-.-
Sussex	4.25	0.00	-.-
Kent	41.03	0.00	-.-
Greater London	0.00	0.00	-.-
Essex	2.85	0.00	-.-
Suffolk	8.35	0.00	599.60
Norfolk	35.68	59.68	-.-
Cambridgeshire	0.00	0.00	-.-
Lincolnshire	0.00	0.00	-.-
Nottinghamshire	0.00	0.00	-.-
Humberside	7.72	0.00	-.-
Yorkshire	0.00	0.00	-.-
Cleveland	2.15	0.00	-.-
Durham	0.00	0.00	-.-
Tyne & Wear	0.00	0.00	-.-
Northumberland	13.20	6.27	-.-
Total	**461.55**	**278.33**	**2085.02**

* The Coastwatch figures refer to the category of 'other habitats', which includes coastal heath.

** Data from Radley (1992) is for dune heath only.

Process Cell	Area (ha.) Radley (1992) & Various
1	6.27
2	0.00
3	659.27
4	0.00
5	1164.92
6	426.47
7	0.00
10	106.41
Total	**2363.34**

or *E. tetralix* are frequent associates. Grasses and herb species such as *Scilla verna* are also common.

Calluna-Scilla heath occurs over a wide range of base-poor soils on the less exposed maritime cliffs and lowland coasts. It is distinguished from other heath communities by the influence of salt spray, and is virtually restricted to sections of shore which are exposed to the prevailing southwesterly winds. However, salt influence is less than in the *Festuca -Holcus* (MC9) and *Festuca-Plantago* spp. (MC10) grasslands which are often found to seaward of the maritime heath communities. In many places in England there is a sharp inland boundary to improved grassland which is heavily grazed.

Calluna-Ulex gallii heath (H8) is quite extensively developed in coastal regions of lowland England where the soil is generally unimproved and salt influence is not great. Since *Ulex gallii* is intolerant of salt spray this community typically ocurs to landward of the H7 communities. *Erica vagans- Schoenus nigricans* heath (H5) tends to occur mainly in areas of base-rich, calcium-poor soils which are subject to winter flooding. *Erica-vagans-Ulex europaeus* heath (H6) occurs on similar soils which are free-draining.

10.4 Threats to coastal heath

The major natural threat to maritime heath arises from erosion, although changes in wind strength and extent of salt spray influence might also cause changes in the vegetation structure. The main anthropogenic threat to both maritime and inland heaths is presented by changing agricultural practice, involving the improvment of soil fertility by fertilizer applications and establishment of rye grass / clover swards (Heil & Dimont, 1983).

10.5 Recent habitat loss

A number of maritime heath shorelines have suffered net erosion in recent decades, but the area of heath lost due to this cause appears to be small.

Based on old Tithe and O.S. maps, Hopkins (1983) reported a 20% loss of heathland (both maritime and inland) area on the Lizard Peninsula, Cornwall, between 1908 and 1983, due to agricultural activity. Webb and Haskins (1980) also reported an 85% loss of lowland heath in Dorset between 1850 and 1978, with further losses between 1978 and 1987 (Webb, 1990). However, the extent of loss of maritme heath is uncertain.

10.6 Projected habitat loss

Future rates of maritime and other coastal heath community loss will be partly dependent on rates of coastal erosion. This is likely to be a significant problem in a relatively small number of cases where maritime heath occurs on soft sediments or rocks. However, even in such circumstances, no net loss of habitat area should take place where the habitat is free to move landwards as the shoreline recedes, since the transition zone between maritime heath and inland heath may also be expected to move landwards. Where there is a sharp landward boundary to improved pasture, however, the zone of maritime heath may become squeezed. Under such circumstances steps could be taken to change the land-use management in order to allow the improved pasture or grassland to revert to maritime heath.

10.7 Targets for habitat recreation

The present areal extent of maritime heath comunities is poorly defined and there is little firm information about rates of loss in recent decades. However, based on a best estimate of the present resource, a working objective should be to create a minimum of 50 ha of new maritime heath over the next 20 years. This can probably be best achieved by changing land-use management practices to allow reversion of some improved pasture to heath communities. A number of techniques for reducing soil fertility in the context of heath conservation are discussed by Mars (1985). Further proposals to improve areas of inland heath for agricutural purposes should be resisted.

11 CONCLUSIONS AND RECOMMENDATIONS

Information about the present areal extent of several of the habitat types considered in this report is severely deficient. The best data are available for salt marsh and sand dune habitats, both of which have been the subject of comprehensive national inventories. Partial data of variable reliability are available for intertidal flats, shingle formations, saline lagoons and unprotected soft cliffs. Information about maritime cliff grassland and coastal heaths is the least complete and least reliable. Additional studies are urgently required to provide a better definition of all habitats with the exception of sand dunes and saltmarshes.

Information about losses affecting all habitat types in the past 20 years is fragmentary. Detailed studies have been carried out only in a very few localized areas, and extrapolation to regional or national scales is surrounded by uncertainties.

Even greater uncertainties surround the magnitude and effects of future changes in sea level and wind/wave climate, and the scale of possible further habitat losses due to human activities. However, consideration of all the evidence currently available suggests that, if counteractive measures are not undertaken, national habitat losses from combined natural and anthropogenic causes in the next 20 years may be of the following approximate magnitude:

		% of existing resource
sand dunes	240 ha	(3%)
saltmarsh	2750 ha	(8%)
intertidal flats	10,000 ha	(4%)
shingle formations	200 ha	(4%)
saline lagoons	120 ha	(10%)
soft cliff	10 km	(4%)
maritime cliff grassland	150 ha	(?)
coastal heath	50 ha	(?)

These figures should be viewed as minimum targets for habitat recreation.

Loss of sand dune habitat will mainly involve erosion of frontal dunes on the more exposed sections of coast and at the up-drift end of coastal sediment cells, together with some further anthropogenic loss chiefly to recreational activities. All regions of the country are likely to be affected, although losses may be particularly significant in the northeast and southwest. The best means of compensating for these losses may be provided by (1) encouraging frontal dune accretion in areas where there is a natural accretionary trend (e.g. at the downdrift end of coastal sediment cells and at points of wave divergence), (2) enouraging foredune stability by beach recharge and 'soft'protection works; and (3) where frontal dune erosion cannot be avoided, allowing sand drifts to move inland over former backbarrier deposits, pasture or cultivated land.

Saltmarsh and intertidal flat loss will mainly involve further erosion in southeastern and southern England, mainly within estuaries which have already suffered significant loss in the past two decades. Several options exist to counter the loss of these habitats: (1) construction of offshore breakwaters and artificial spits to reduce wave erosion on sections of more open coast; (2) restoration of intertidal flat levels in some areas by foreshore recharge; (3) creation of new marsh and mudflat habitats through managed retreat; (4) modifications to the hydraulic geometry and tidal flow charcteristics within certain estuaries; and (5) opposition to further development proposals which threaten these habitats, either directly or indirectly. In the short to medium term, managed retreat probably provides the best method of habitat recreation, although further research is required to evaluate its suitability in specific areas. In the longer term, large scale modifications to the flow and sediment transport regime within selected estuaries or parts of estuaries offers a possible alternative which requires further detailed consideration.

Further loss to shingle formations and saline lagoons, a high proportion of which occur in southeastern and southern counties, is expected to arise mainly due to human activities such as aggregate extraction, infilling and expansion of existing residential settlements. Wherever possible, shingle structures should be allowed to respond naturally to sea level rise. Where free landward movement is undesirable, shingle recharge using material dredged from offshore or derived from onshore sources should be promoted. The likely reduction in area of saline lagoons and lagoon-like habitats can be countered relatively easily by artificiil creation of new lagoons or engineered modifications to freshwater ponds formed by aggregate extraction.

Loss of part of the remaining length of unprotected soft cliff is most likely around urban developments which are already partially protected, mainly on the east and south coasts. In order to compensate for these additional losses, existing defences along some sections of cliffed coast with little development, currently reaching the end of their design lives, could be allowed to decay and not be replaced. Further development within a 'buffer zone' inland of the cliff edge should be discouraged in rural areas where sacrificial cliff erosion could be considered now or in the future.

The distribution of both maritime cliff grassland and coastal heath shows a high degree of concentration in the southwest. Owing to the relatively hard nature of many of the cliffs in this area a rapid acceleration of losses due to erosion is unlikely, even if sea level rise accelerates. Losses are likely to be more significant on soft rock coasts elsewhere, notably in Yorkshire, East Anglia and parts of Dorset. The most practical means of recreating these lost habitats is to encourage a change of land use at the landward margin to allow the existing habitats to move landwards in parallel with coastal recession. A suggested working target is the recreation of 150 ha of new maritme grassland and 50 ha of coastal heath in the next 20 years. Additional research is required to define more precisely the ecological requirements of certain key species which exist in these habitats.

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