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Abstract

For its relatively small geographical size, Great Britain (comprising England, Scotland, and Wales and their associated islands) is uniquely well endowed with estuaries, and these vary greatly in their geomorphologic origins, size, shape, extent of freshwater influence, tidal range, and their variety of coastal and marine habitats. They form a major component of the British natural environment and are of major significance for wetland biodiversity conservation and for the many ecosystem services they provide to people.

Keywords

Estuary · Tidal flats · Saltmarshes · Great Britain · Waterbirds · Land claim · Coastal squeeze · Managed realignment

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Introduction

For its relatively small geographical size, Great Britain (comprising England, Scotland, and Wales and their associated islands) is uniquely well endowed with estuaries, and these vary greatly in their geomorphologic origins, size, shape, extent of freshwater influence, tidal range, and their variety of coastal and marine habitats. They form a major component of the British natural environment and are of major significance for wetland biodiversity conservation and for the many ecosystem services they provide to people (see also UK National Ecosystem Assessment 2011).

The information summarized here is derived largely from a major late 1980s review of the distribution, features, importance of, and pressures on British estuaries (Davidson et al. 1991; summarized in Davidson 1991) and its underlying data, which remains the most contemporary national assessment. This review included all parts of the coast covered by an inclusive definition of “estuary” as “a partially enclosed area at least partly composed of soft tidal shores, open to saline water from the sea and receiving freshwater from rivers, land run-off or seepage.” Included were all parts of the British coastal zone with an intertidal channel or shoreline length of greater than 5 km.

Estuaries included were classified into nine estuary types: fjord, fjard, ria, coastal plain estuary, bar-built estuary, complex estuary (with characteristics of more than one other type), barrier beach, linear shore, and embayment. The only major estuary type which does not occur on the coast of Britain is the delta.

Further information on each estuary (derived from the 1991 review) is provided in the seven-volume *An inventory of UK estuaries* (Buck 1996–1997), and regional overviews are provided in the 16-volume *Coasts and seas of the United Kingdom* (Barne et al. 1995–1997).

The Size and Diversity of British Estuaries

There are 155 estuaries around the coast of Britain (Fig. 1). In addition there are a further eight estuaries wholly or partly in the Northern Ireland part of the United Kingdom of Great Britain and Northern Ireland. Their total area in Britain is almost 530,000 ha, of which over 303,400 ha are intertidal flats and marshes, with vegetated saltmarshes being 42,350 ha (14%) of that intertidal area – so much of the intertidal area of British estuaries is formed of unvegetated intertidal mud and sand flats. British estuaries have a total of 2,450 km of main tidal channels and a shoreline of just over 9,000 km: almost half of the total shoreline length of the British coast.

The most common types of estuaries in Britain are bar-built (47) and coastal plain (35) systems (Table 1). Because they are often large, coastal plain estuaries (35%) and embayments (25%) form the largest proportions of the British estuarine area.

Estuaries are distributed around all parts of the British coast, but most and the largest are on the southeastern and western shores of England, with fewer and

Fig. 1 The location and area (hectares) of British estuaries (From Davidson et al. 1991). The location and names of all 155 British estuaries are provided in Annex 1. © Joint Nature Conservation Committee



generally smaller estuaries on the rockier coastlines of Scotland and Wales. The largest estuaries are the Wash (66,600 ha) in eastern England and the macrotidal Severn Estuary (55,700 ha) in southwest England and Wales, which has the second largest tidal range in the world (after the Bay of Fundy in Canada).

Largest intertidal areas are found in Morecambe Bay (33,750 ha) in northwest England (Fig. 2), the Wash (29,770 ha), and the Solway Firth (27,550 ha) in

Table 1 The numbers of British estuaries of each estuary type and their percentage contribution to the total area of British estuaries

Estuary type	No. of estuaries	Percentage of total estuarine area
Fjord	6	2
Fjard	20	5
Ria	15	3
Coastal plain	35	35
Bar-built	47	6
Complex	10	18
Barrier beach	2	2
Linear shore	7	4
Embayment	13	25



Fig. 2 Morecambe Bay in northwest England has the largest intertidal area of any estuary in Britain (Photo credit: Nick Davidson© Rights remain with the author)

northwest England/southwest Scotland. Although many British estuaries are individually small (80 – 61.5% of the total – each have an intertidal area of less than 500 ha), their overall contribution to the diversity of estuarine resource and its wildlife importance is high.

The number and variety of British estuaries is unrivaled in Europe, and together they form about 28% of the total estuarine area of c. 1,895,000 ha on the Atlantic seaboard of western Europe. This is the largest national estuarine area in Europe, although the single largest contiguous estuarine area in Europe is the c. 764,000 ha of the Wadden Sea behind the North Sea barrier islands of the Netherlands, Germany, and Denmark, forming about 40% of the total estuarine area in Western Europe.

Biodiversity Importance of British Estuaries

Estuarine Habitats and Communities

Even small British estuaries are typically composed of a mosaic of four to nine major habitat types (subtidal, intertidal mudflats, intertidal sandflats, saltmarshes, shingles, rocky shores, coastal lagoons, sand dunes, and coastal wet grasslands, the last often having been converted from formerly intertidal habitats). Tidal flats occur in all, and saltmarshes and subtidal areas in almost all, British estuaries.

Saltmarshes larger than 0.5 ha occur on 135 estuaries, with saltmarsh plant communities (Fig. 3) being most diverse in southern and eastern England, where they include plants such as sea purslane *Halimione portulacoides* in low-mid marsh and sea lavender *Limonium* spp. and shrubby sea blight *Sueda fruticosa* in mid-upper marsh. Cord-grass *Spartina townsendii* swards now occur in 82 British estuaries and dominate the lower saltmarsh zone especially in southern and western England. First appearing in Southampton Water in the late nineteenth century, it has spread, both naturally and through planting for shoreline stabilization, but is now dying back in much of southern England.

Sand dunes are associated with 55 British estuaries, often being a major force in shaping the estuary through the formation of estuary-mouth spits. Of the seven nationally important shingle structures in Britain, five are associated with estuaries. As in the case of sand dunes, some shingle structures are a major influence on the geomorphological development of the estuary, for example, Orford Estuary. Often



Fig. 3 A diverse British natural upper saltmarsh community with sea purslane *Halimione portulacoides* and shrubby sea blight *Sueda fruticosa* on the North Norfolk Coast estuary in eastern England (Photo credit: Nick Davidson© Rights remain with the author)

associated with such shingle structures is the scarce and highly vulnerable habitat of coastal saline (or hypersaline) lagoons: about 83% of the area of British saline lagoons is associated with 37 estuaries in England and Wales, and they support a highly specialized flora and fauna often of very local distribution.

Aquatic estuarine communities in British estuaries are diverse, with 17 hard-shore and 16 soft-shore communities recognized. While each hard-shore community typically occurs either intertidally or subtidally, most soft-shore communities occur in both situations. Although diverse, hard-shore estuarine communities are generally small in area and restricted to the outer parts of a few estuaries. They are most diverse in the estuaries of southwest England and south Wales, and parts of Scotland.

Soft-shore communities are more widespread, with five occurring in over 20% of British estuaries and two occurring in over 80% of estuaries. One is a muddy sand community in areas of variable or normal salinity, dominated by lugworms *Arenicola marina*, but intertidally also with abundant cockles *Cerastoderma edule*, Baltic tellins *Macoma balthica*, and polychaete worms. The other is a mud community typical of more sheltered areas of variable or reduced salinity, with a benthic fauna dominated by bivalve mollusks and worms.

Other estuarine communities are important because of their rarity. These include the maerl beds of the Fal Estuary, Helford Estuary, and Milford Haven in western Britain; a sand or muddy sand community dominated by razor shells *Ensis* spp. in a few southwest English, Welsh, and western Scottish estuaries; and the rich fauna of a muddy gravel community in outer estuaries in south and southwest England.

Fish

Eighteen British fish species are considered estuarine, with five dependent on estuaries throughout their life cycles and seven others moving between estuaries and fresh or marine waters, including sea *Petromyzon marinus* and river *Lampetra fluviatilis* lampreys, salmon *Salmo salar*, sea trout *S. trutta*, and eel *Anguilla anguilla*. The sheltered waters of major estuaries such as Plymouth Sound, the Humber Estuary, and the Wash are important spawning and nursery areas for flatfish, and at least 32 estuaries in southern and western England and Wales support sea bass *Dicentrarchus labrax* nursery areas.

Waterbirds

The network of British estuaries is of major national and international importance as migratory staging and wintering areas for migratory waterbirds, chiefly wildfowl (ducks, geese, and swans) and waders (shorebirds), from a vast range of breeding areas from northern Canada to Siberia. In mid-winter in the 1980s over 1,740,000 waterbirds depended on British estuaries – 62% of the British wintering waterbird population and over 10% of the relevant international populations. Of these, there were 581,000 wildfowl (38% of the British and over 10% of the northwest European populations) and almost 1,159,000 waders (90% of the British and over 15% of the

East Atlantic Flyway populations). While waterbirds are widely distributed, the biggest concentrations are on the largest estuaries, notably the Wash and North Norfolk Coast, Morecambe Bay, and the estuaries of Essex and north Kent.

The wader assemblage is dominated by three species (together forming almost three quarters of all wintering waders): dunlin *Calidris alpina*, red knot *Calidris canutus*, and oystercatcher *Haematopus ostralegus*; over half the wildfowl are wigeon *Anas penelope*, dark-bellied brent geese *Branta bernicla bernicla*, and shelduck *Tadorna tadorna*.

British estuaries are of particular international importance for the large proportions of some waterbird populations they support in winter (Fig. 4), notably among waders red knot (67%), common redshank *Tringa totanus* (55%), bar-tailed godwit *Limosa lapponica* (50%), *C.a.alpina* subspecies of dunlin (27%), and oystercatcher (26%). Among wildfowl, British estuaries support over 75% of the small Svalbard-breeding population of light-bellied brent geese *Branta bernicla hrota*, over 50% of dark-bellied brent geese and 100% of the Svalbard population, and 70% of the greenland population of barnacle geese *Branta leucopsis*.

Many wintering waterbird populations reached peak numbers in Britain in the late 1990s. Since then some population sizes have leveled off, or in the case of waders, declined – by 11% since a peak in 2000–2001 (Eaton et al. 2012). Bigger declines have been noted for west coast than east coast estuaries, and there is also evidence of distribution shifts within northwest Europe, perhaps as a response to recent milder winters meaning that fewer birds are now moving on to British estuaries (Maclean et al. 2008). However, for some species such as dunlin and redshank, the declines may also reflect genuine declines in breeding populations (Eaton et al. 2012).



Fig. 4 A flock of wintering red knots *Calidris canutus* on the Wash estuary, eastern England. Britain's estuaries are of major importance for red knots, supporting two thirds of the *C. c. islandica* subspecies which breeds in Arctic Canada and Greenland (Photo credit: Nick Davidson © Rights remain with the author)

Conservation Status of British Estuaries

Much of the British estuarine resource is recognized as of major nature conservation importance. Under national legislation, about one quarter of the total area of Sites of Special Scientific Interest (SSSIs) is estuarine, associated with 136 British estuaries. Significant parts of the estuarine resource are also recognized as internationally important, under two mechanisms: Natura 2000 sites and Wetlands of International Importance (Ramsar Sites). Natura 2000 sites are designated under two European Union Directives: Special Protection Areas (SPAs) under the 1979 “Birds Directive” and Special Areas of Conservation (SACs) under the 1992 “Habitats Directive.” Ramsar sites are designated for their international importance as wetlands under the Ramsar Convention on Wetlands, the intergovernmental treaty addressing the conservation and wise use of wetlands worldwide. Sixty-six of the 128 Ramsar sites designated by the United Kingdom in England, Scotland, and Wales are estuarine, with a further seven estuaries designated in Northern Ireland (as at July 2013). Overall, 68 (44%) British estuaries or parts of them have been recognized as internationally important as Ramsar sites and/or Natura 2000 sites.

Land-Claim of British Estuaries

People have been converting and modifying natural estuaries in Britain for at least a millennium, since Roman times. Initially conversions were predominately for agriculture (with such land-claims continuing up to the 1970s) but increasingly in recent centuries also for ports and industry, and urban and infrastructure developments. Land-claim has affected at least 85% of British estuaries and has removed over 25% of the intertidal area from many estuaries and over 80% from some such as the Blyth, Tees (Fig. 5), and Tyne estuaries in eastern England.

The construction of linear sea defenses has had a major impact on British estuaries, with 85% of estuaries having some artificial embankments restricting natural tidal flows. Such sea defenses are particularly extensive along the low-lying coasts of southeastern England and with rising sea levels contribute to an increasing “coastal squeeze” since the natural inland migration response of intertidal systems is curtailed. One consequence has been extensive and continuing erosion and loss of saltmarshes especially in southern and eastern England, with, for example, 25% of Essex saltmarsh estimated to have been lost in the last quarter of the twentieth century (Covey and Laffoley 2002) and losses continuing at an estimated 100 ha per year.

Much of the past agricultural land-claim created freshwater coastal wet grasslands used for stock grazing, which now have considerable biodiversity importance. But much of this grazing marsh has subsequently been converted for intensive crop production and urban and industrial developments: between 30% and 70% of such marshes associated with different southeast England estuaries have been lost since 1930.



Fig. 5 The Tees estuary in northeast England has lost over 80% of its intertidal area since the eighteenth century, through land-claims for agriculture and more recently for port and industrial developments, but still provides many benefits to people (Photo credit: Nick Davidson © Rights remain with the author)

The largest area (47,000 ha) has been claimed from the Wash since Roman times. On just 18 of Britain's estuaries a total of at least 89,000 ha have been claimed: 37% of their former area and an almost 25% loss of the overall estuarine resource. Although mostly small scale, in the late 1980s further land-claims were underway – 123 land-claims in progress affecting 45 (29%) estuaries. Two thirds of these land-claims were for rubbish and spoil disposal, transport schemes, housing and car parks, and marinas, with at least 1,100 ha under claim, 62% of which was for rubbish and spoil disposal. Further development proposals in the late 1980s, mostly for urban development, marinas, and barrages, if implemented would have led to further estuarine losses from 55 British estuaries.

Rates of estuarine land-claim were low before the seventeenth century but accelerated in the eighteenth century, again in the late nineteenth century, and then again in the second half of the twentieth century, when losses averaged 0.3% per year, but have slowed greatly since then – in large part as a consequence of their protected status under international treaties (see above).

Threats and Future Challenges for British Estuaries

Although rates of British estuarine habitat loss appear to have slowed in the early part of the twenty-first century, and the major environmental and ecosystem services importance of British estuaries has been increasingly recognized in decision-making, some land-claims have continued, and changes in land-use planning, energy, and transport policies may lead to further estuarine habitat loss. For example, in the late

1990s an amenity barrage constructed to create a freshwater lake as part of the urban regeneration of Cardiff Docks impounded 200 ha of tidal flats and marshes of the Taff and Ely estuaries – a side arm of the internationally important Severn Estuary. But some estuarine restoration projects have also been initiated.

With a potentially major impact on the whole of the Severn Estuary, in the 1980s long-standing proposals for a barrage across the mouth of the estuary, primarily for tidal power generation, were resurrected and the subject of a major study and impact assessment, but the plans were rejected on economic and environmental grounds. Subsequently such plans have been revisited, following a 2007 report from the UK's Sustainable Development Commission (SDC) which supported such a barrage but noted that full compliance with the EU Birds and Habitats Directives would be vital, as would be a long-term commitment to create compensatory habitats on an unprecedented scale (Sustainable Development Commission 2007). Although a 2-year feasibility study revisiting much of the assessment work of the late 1980s was started, further work on this project was abandoned in 2010. But in 2011 further barrage proposals were again under discussion, which might also lead to proposals for trials of technology on smaller estuaries such as the Mersey and Duddon Estuaries in northwest England, both designated as internationally important Ramsar sites.

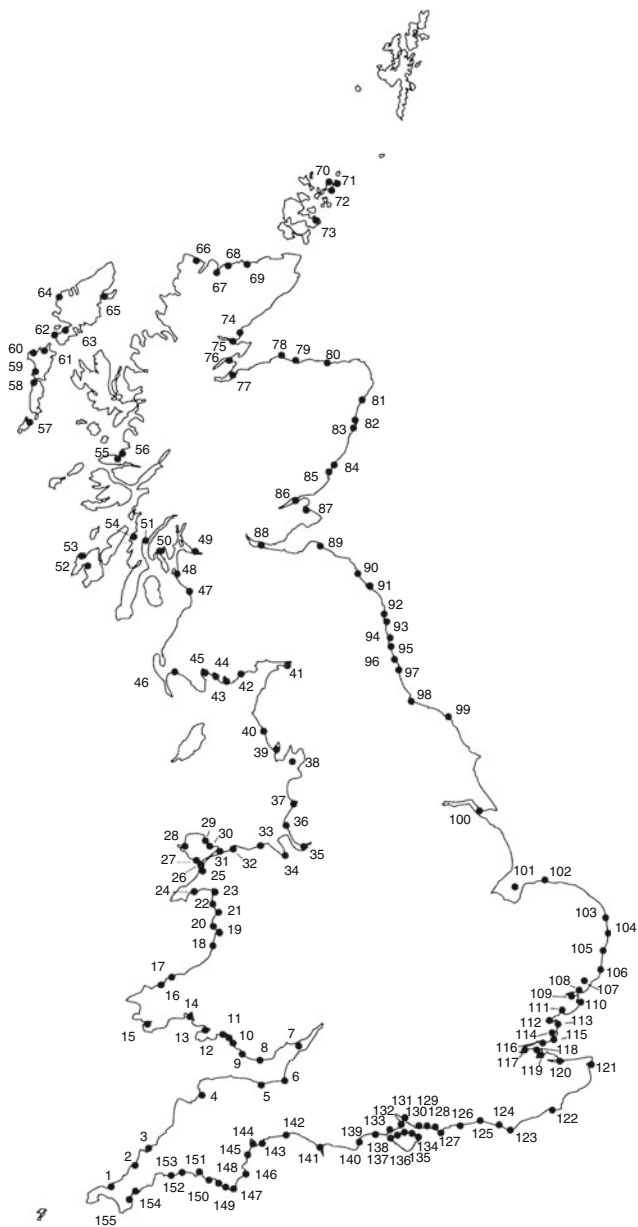
In a similar pattern to the Severn barrage proposals, a new Thames Estuary Airport has been proposed at various times since the 1970s. Several locations for a new airport have been proposed including Maplin Sands, Foulness on the north side of the estuary; Cliffe, Kent, and the Isle of Grain on the south side (all designated as internationally important wetlands); and on artificial islands to be created in the middle of the estuary. None of these proposals has been implemented, but some continue to be under review.

As a response to both “coastal squeeze” and the increasingly uneconomic costs of maintaining and raising sea defenses defending agricultural land, an increasing number of “managed realignment” projects have been done or are underway, mainly on eastern English estuaries. This is in the context that the UK's biodiversity action plan (JNCC 1997) aims to prevent net losses to the area of saltmarsh present in 1992. It is therefore a requirement that all losses in marsh area must be compensated by replacement habitat with equivalent biological characteristics. This equates to the need to restore approximately 140 ha of saltmarsh habitat per year in the UK.

Through breaching of seawalls, these realignments seek to reinstate tidal flows and restore saltmarshes and tidal flats in former intertidal areas. The restorations can be costly and challenging because rising sea levels since sea defense construction mean that land levels inside the realignments are often lower than those needed to support saltmarsh vegetation following tidal inundation. To date approximately 400 ha of salt marsh have been restored by managed realignment, but there is increasing evidence that while some biodiversity returns rapidly, saltmarsh plant and benthic communities can take at least hundreds of years to return towards their natural state (Atkinson et al. 2001; Mossman et al. 2012).

Annex 1

The locations and names of all 155 British estuaries covered in this chapter, from Davidson et al. (1991). © Nature Conservancy Council.



1	Hayle Estuary	57	Tràigh Mhór	112	Blackwater Estuary
2	Gannel Estuary	58	Bagh Nam Faoilean	113	Dengie Flat
3	Camel Estuary	59	Oitir Mhór	114	Crouch-Roach Estuary
4	Taw-Torridge Estuary	60	Tràigh Vallay	115	Maplin Sands
5	Blue Anchor Bay	61	Oronsay	116	Southend-on-Sea
6	Bridgwater Bay	62	Scarista	117	Thames Estuary
7	Severn Estuary	63	Tràigh Luskentyre	118	South Thames Marshes
8	Thaw Estuary	64	CamusUig	119	Medway Estuary
9	Ogmore Estuary	65	Laxdale Estuary	120	Swale Estuary
10	Afan Estuary	66	Kyle of Dumess	121	Pegwell Bay
11	Neath Estuary	67	Kyle of Tongue	122	Rother Estuary
12	Tawe Estuary & Swansea Bay	68	Torrisdale Bay	123	Cuckmere Estuary
13	Loughor Estuary	69	Melvich Bay	124	Ouse Estuary
14	Carmarthen Bay	70	Otters Wick	125	Adur Estuary
15	MilfordHaven	71	Cata Sand	126	Arun Estuary
16	Nyfer Estuary	72	Kettletoft Bay	127	Pagham Harbour
17	Teifi Estuary	73	Deer Sound & Peter's Pool	128	Chichester Harbour
18	Aberystwyth	74	Loch fleet	129	Langstone Harbour
19	Dyfi Estuary	75	Dornoch Firth	130	Portsmouth Harbour
20	Dysynni Estuary	76	Cromarty Firth	131	Southampton Water
21	Mawddach Estuary	77	Moray Firth	132	Beaulieu River
22	Artro Estuary	78	Lossie Estuary	133	Lymington Estuary
23	Traeth Bach	79	Spey Bay	134	Bembridge Harbour
24	Pwllheli Harbour	80	Banff Bay	135	Wootton Creek & Ryde Sands
25	Foryd Bay	81	Ythan Estuary	136	Medina Estuary
26	Traeth Melynog	82	Don Estuary	137	Newtown Estuary
27	Cefni Estuary	83	Dee Estuary (Grampian)	138	Yar Estuary
28	Alaw Estuary	84	St Cyrus	139	Christchurch Harbour
29	Traeth Dulas	85	Montrose Basin	140	Poole Harbour
30	Traeth Coch	86	Firth of Tay	141	The F1eet & Portland Harbour
31	Traeth Lavan	87	Eden Estuary	142	Axe Estuary
32	Conwy Estuary	88	Firth of Forth	143	Otter Estuary
33	Clwyd Estuary	89	Tynningame Bay	144	Exe Estuary
34	Dee Estuary & North Wirral	90	Tweed Estuary	145	Teign Estuary
35	Mersey Estuary	91	Lindisfarne & Budle Bay	146	Dart Estuary
36	Alt Estuary	92	Alnmouth	147	Salcombe & Kingsbridge Estuary
37	Ribble Estuary	93	Warkworth Harbour	148	Avon Estuary (Devon)
38	Morecambe Bay	94	Wansbeck Estuary	149	Erme Estuary
39	Duddon Estuary	95	Blyth Estuary (Northumberland)	150	Yealm Estuary
40	Esk Estuary (Cumbria)	96	Tyne Estuary	151	Plymouth Sound
41	Solway Firth	97	Wear Estuary	152	Looe Estuary
42	Rough Firth & Auchencairn	98	Tees Estuary	153	Fowey Estuary
43	Dee Estuary (Dumfries)	99	Esk Estuary (Yorkshire)	154	Falmouth
44	Water of Fleet	100	Humber Estuary	155	Helford Estuary
45	Cree Estuary	101	The Wash		
46	Luce Bay	102	North Norfolk Coast		
47	Garnock Estuary	103	Breydon Water		
48	Hunterston Sands	104	Oulton Broad		
49	Clyde Estuary	105	Blyth Estuary (Suffolk)		
50	Ruel Estuary	106	Ore-Alde-Butley		
51	Loch Gilp	107	Deben Estuary		
52	Tràigh Cill-a-Rubha	108	Orwell Estuary		
53	Loch Gruinart	109	Stour Estuary		
54	Loch Crinan	110	Hamford Water		
55	Kentra Bay	111	Colne Estuary		
56	Loch Moidart				

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