Marine Pollution Bulletin 61 (2010) 115–123

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Birds of the Severn Estuary and Bristol Channel: Their current status and key environmental issues

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ARTICLE INFO

Keywords:
Habitat loss
Oil-spills
Shell-fishing
Tidal barrages
Waterbirds
Water quality

ABSTRACT

The Severn Estuary and Bristol Channel encompass a number of designated sites supporting populations of waterbirds and seabirds that are of national or international importance, including the Severn Estuary and Burry Inlet Special Protection Areas (SPAs)/Ramsar Sites and Carmarthen Bay, the UK's first marine SPA. Here, we provide an overview of the present numbers and trends of the waterbirds and seabirds using these sites, updating previous reviews undertaken prior to these designations. We further provide a summary of the main issues that have affected the status of the area's bird populations. Declines in the numbers of waders on the Severn Estuary and the southwest over the last two decades have been linked to climate change. The *Sea Empress* oil-spill impacted both breeding seabirds and the wintering Common Scoters in Carmarthen Bay, though numbers of the latter recovered 3 years after the spill. At the Burry Inlet, Oystercatcher numbers have fallen over the last 25 years and considerable research has been undertaken into the conflict with cockle and mussel fisheries. A long-term study at Cardiff Bay, at the mouth of the Severn, revealed a significant impact on the survival of Redshanks following its impoundment and has helped to further understanding of responses of waterbirds to estuarine habitat loss. The potential impacts of the construction of a tidal power scheme on the Severn Estuary are also discussed.

1. Introduction

The area of the Severn Estuary and Bristol Channel encompasses a number of designated sites supporting populations of waterbirds and seabirds that are of national or international importance. Key among these are the Severn Estuary and Burry Inlet, both designated as Special Protection Areas (SPAs) under the EC 'Birds Directive' (79/409/EEC) and Wetlands of International Importance under the Ramsar Convention, and Carmarthen Bay, the UK's first marine SPA (Fig. 1). The Severn Estuary and the Carmarthen Bay & Estuaries (which encompasses the Burry Inlet) have also been designated as Special Areas of Conservation (SACs) under the EC 'Habitats Directive' (92/43/EEC).

The Severn Estuary SPA (according to the SPA Review: Stroud et al., 2001) supports populations of European importance of six over-wintering species and one passage species, and populations that are of national importance of a further 11 species, in an overall assemblage of 93,986 waterbirds (excluding gulls). The Ramsar designation for the site also notes its importance for breeding gulls and four further waterbird species. The Burry Inlet SPA supports populations of European importance of two waterbird species, and nationally important numbers of a further seven species, in an assemblage of 34,962 waterbirds. The Carmarthen Bay SPA was designated (after the SPA Review) for its European importance for wintering Common Scoters *Melanitta nigra*. Although not considered further here, the Castlemartin Coast, at the mouth of the Bristol Channel in Dyfed, is also designated a SPA for its national importance for breeding and wintering Choughs *Pyrrhocorax pyrrhocorax*, a terrestrial species.

This paper first provides an overview of the present numbers and trends of the waterbirds and seabirds using these sites, updating previous reviews undertaken by Ferns (1977, 1984, 1994), Clark and Prŷs-Jones (1994), Fox and Salmon (1994) and Salmon and Fox (1994) prior to these designations. Information on the birds using other regionally important sites, such as Sites of Special Scientific Interest (SSSIs), is also provided. Both as a consequence of the avian importance of the area and the environmental issues that they have faced, the birds of the Severn Estuary and Bristol Channel have been the focus of a number of important studies. This paper also draws on these studies, to provide a summary of the main issues that have affected the status of the area's bird populations.

The paper follows the same geographical scope as used by Ferns (1984), i.e. that the Bristol Channel is delimited from St. George's Channel by a line between St. Anne's Head, Dyfed (at the mouth of Milford Haven) and Hartland Point, Devon and that the Severn Estuary is delimited from the Bristol Channel by a line between Lavernock Point, South Glamorgan to Hinkley Point, Somerset.

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doi:10.1016/j.marpolbul.2009.12.018

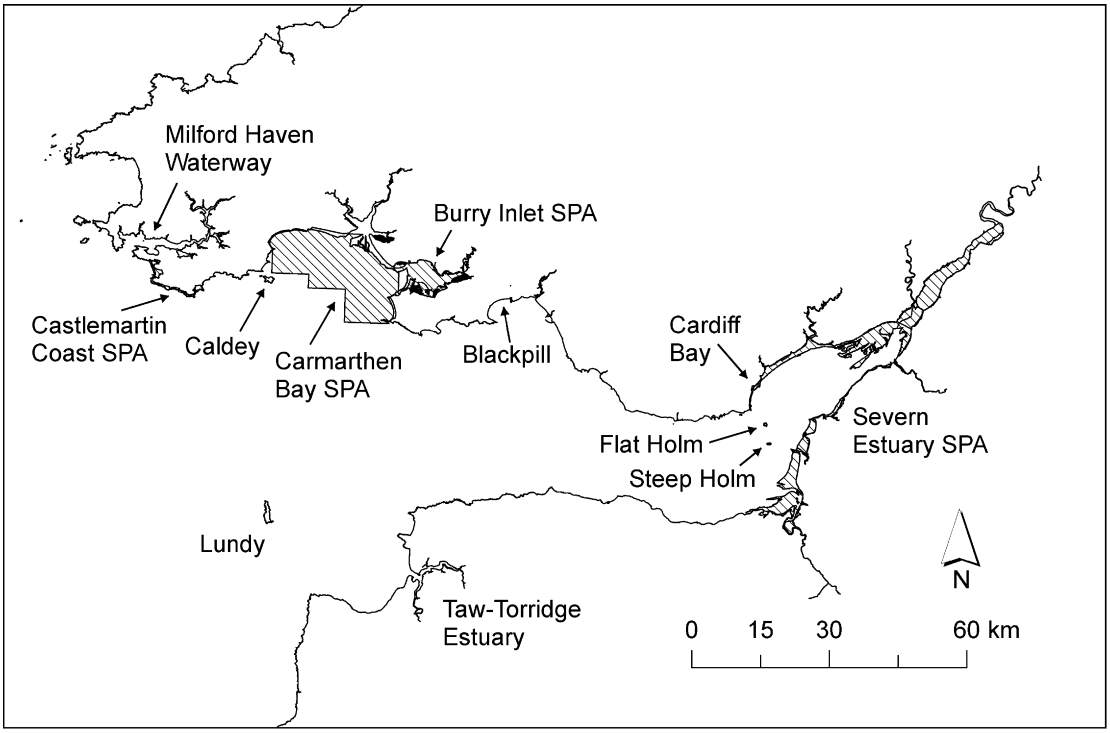

Fig. 1. The Severn Estuary and Bristol Channel showing Special Protection Areas (SPAs) and other important sites discussed in the text.

2. Key sources of data

Data on the numbers and population trends of the birds of the Severn Estuary and Bristol Channel reported in this paper are primarily derived from national surveys.

2.1. Waterbirds

The UK's non-breeding waterbirds are monitored by the Wetland Bird Survey (WeBS, formed in 1993 as an integration of the previous long-running Birds of Estuaries Enquiry and National Wildfowl Counts). Monthly 'Core Counts' (undertaken on coastal sites primarily at high tide) are used to estimate populations and trends at national and site-levels (resulting in an annual report, e.g. Austin et al., 2008, and assessments of the status of features of SPAs, e.g. Maclean and Austin, 2008). In addition, intermittent WeBS Low Tide Counts aim to assess the relative importance of different parts of estuaries for inter-tidally-feeding waterbirds. WeBS Low Tide Counts were undertaken on the Severn in 1998/99 and 2002/03 (Burton et al., 2003a), building on a previous series of surveys undertaken between 1987/88 and 1991/92 as part of previous assessments of the feasibility of proposals for tidal power proposals on the estuary (Clark, 1988, 1990; Warbrick et al., 1991). Low Tide Counts have also been undertaken for the Burry Inlet and Carmarthen Bay (Burton et al., 2008), Swansea Bay, the Milford Haven Waterway (Cleddau Estuary) and the Taw-Torridge Estuary.

2.2. Gulls and other seabirds

Information regarding the numbers and species of seabirds using the Severn Estuary and Bristol Channel come from a variety of sources. National surveys undertaken in 1969–1970 (Cramp et al., 1974), 1985–1988 (Lloyd et al., 1991) and 1999–2002 (Seabird 2000: Mitchell et al., 2004), and the JNCC's Seabird Monitoring Programme (Mavor et al., 2008), have provided information on the numbers of breeding seabirds at major colonies. Further data have come from detailed studies on Lundy and targeted surveys of urban-nesting gulls.

Table 1
Numbers of feature species currently supported by the Severn Estuary, Burry Inlet and Carmarthen Bay SPAs.

Species	Severn Estuary[a]	Burry Inlet[a]	Carmarthen Bay[b]
Bewick's Swan *Cygnus columbianus*	**244**[W]		
European White-fronted Goose *Anser a. albifrons*	748[W]		
Shelduck *Tadorna tadorna*	**3492**[W]	710[W]	
Wigeon *Anas penelope*	7956[W]		
Gadwall *Anas strepera*	255[W]		
Teal *Anas crecca*	3949[W]		
Mallard *Anas platyrhynchos*	3334[W]		
Pintail *Anas acuta*	**1033**[W]	**4491**[W]	
Shoveler *Anas clypeata*	432[W]	321[W]	
Pochard *Aythya ferina*	775[W]		
Tufted Duck *Aythya fuligula*	571[W]		
Common Scoter *Melanitta nigra*			**18,242**[W]
Oystercatcher *Haematopus ostralegus*		**14,292**[W]	
Ringed Plover *Charadrius hiaticula*	**884**[P]		
Grey Plover *Pluvialis squatarola*	386[W]		
Lapwing *Vanellus vanellus*	13,193[W]		
Knot *Calidris canutus*		4832[W]	
Dunlin *Calidris alpina*	**21,430**[W]	6882[W]	
Black-tailed Godwit *Limosa limosa*		558[W]	
Whimbrel *Numenius phaeopus*	186[P]	131[P]	
Curlew *Numenius arquata*	**2974**[W]	2156[W]	
Redshank *Tringa totanus*	**2312**[W]		

Bold highlighting indicates that the species qualifies as a feature because it occurs in numbers of European importance.

[a] Figures represent means of the annual peak numbers recorded over the five-year period 2002/03–2006/07 for the Severn Estuary and Burry Inlet WeBS sites (following Austin et al., 2008).

[b] Figure represents the mean of the peak numbers estimated by aerial surveys over the five-year period 2003/04–2007/08 (taken from Maclean et al., 2008).

[W] Species included as a feature of the SPA due to its importance during winter.

[P] Species included due to its importance during autumn or spring passage.

Data on the numbers of gulls using the estuary in winter derive from national Winter Gull Roost Surveys undertaken once a decade since January 1953 (Banks et al., 2009), the most recent being the 2003/04–2005/06 Winter Gull Roost Survey (WinGS: Banks et al., 2007).

3. Status of the birds of the Severn Estuary and Bristol Channel

3.1. Waterbirds

The Severn Estuary is one of the largest estuaries in the UK, with an approximate inter-tidal area of 22,000 ha (Buck, 1993), approximately 90% being mudflats and sandflats and 10% rock (Ferns, 1984; Kirby, 2010). The excessive scouring and mobility of sediments, that are a consequence of the estuary's large tidal range, mean that the invertebrate community of the estuary's central sandflats is highly impoverished (Ferns, 1983; Warbrick et al., 1991; Mettam et al., 1994). As a result, in terms of the numbers of waterbirds that it supports, the estuary does not rank as highly in a UK context as its size would suggest. A mean peak number of 66,022 waterbirds was recorded on the Severn Estuary by WeBS between 2002/03 and 2006/07 (Austin et al., 2008), a decline from the assemblage of 93,986 birds reported for the period 1991/92–1995/96 in the SPA Review (Stroud et al., 2001). Mean peak numbers for 2002/03–2006/07 of the 18 species listed as features of the Severn Estuary SPA are provided in Table 1. Trends in the numbers of those species for which the SPA is of European importance are shown in Fig. 2.

Seven species of wader are included as features of the SPA, five of which – Ringed Plover *Charadrius hiaticula*, Grey Plover *Pluvialis squatarola*, Dunlin *Calidris alpina*, Curlew *Numenius arquata* and Redshank *Tringa totanus* – as well as Shelduck *Tadorna tadorna*, predominantly forage intertidally. Winter low tide counts of the estuary indicate that the highest densities of waterbirds are found along the Gwent shore, from Rhymney and Peterstone to the Welsh Grounds, on mudflats adjacent to the New Grounds at Slimbridge, on the Axe Estuary and within Bridgwater Bay (Ferns, 1984; Clark and Prŷs-Jones, 1994; Burton et al., 2003a). Prior to its impoundment by a barrage, the mudflats at Cardiff Bay also supported high densities of several species (see below). Most intertidally foraging species are widely distributed across the estuary, with the exception of the central sandflats, though each favours different areas.

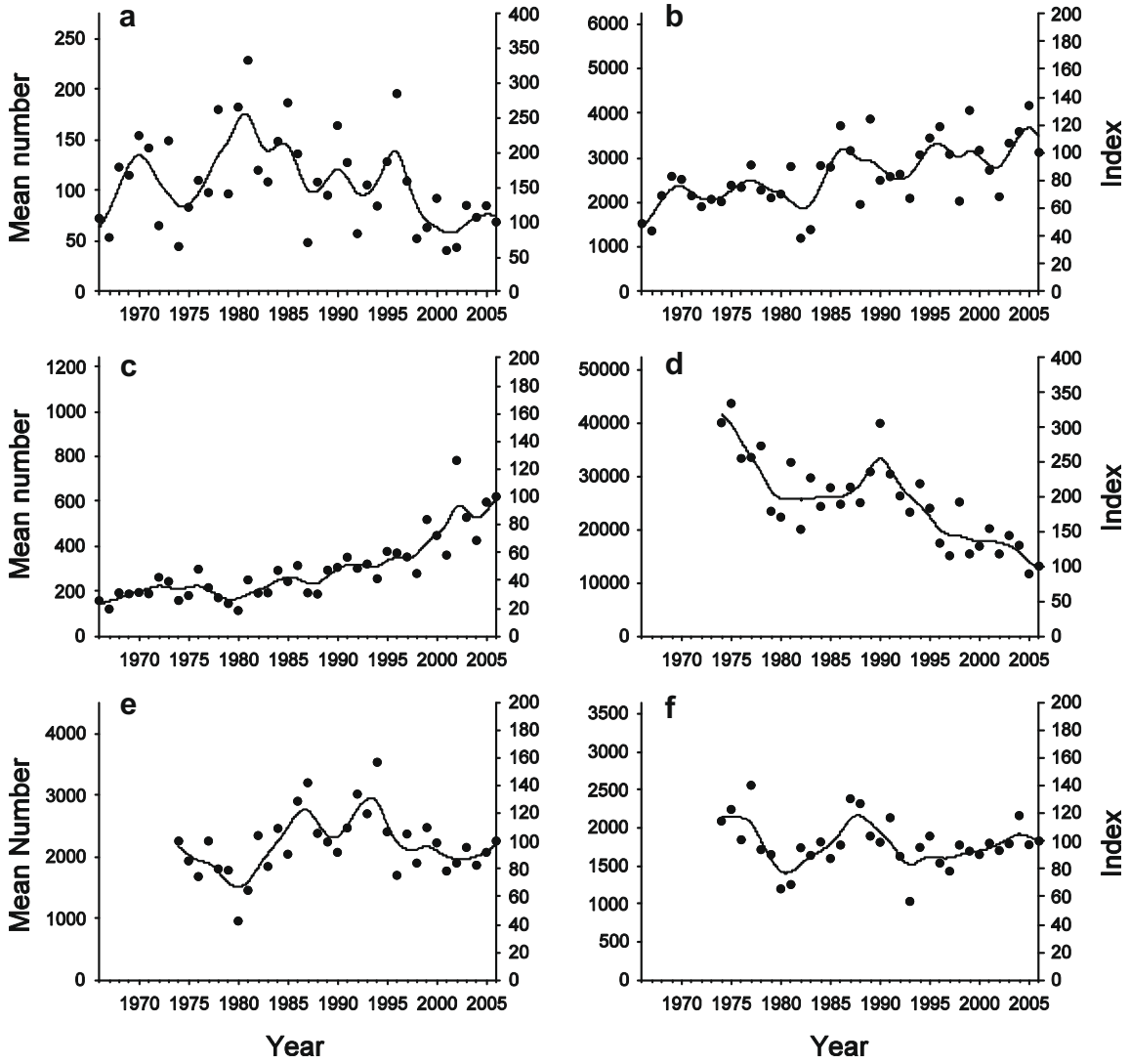

Fig. 2. Mean winter numbers and indices for (a) Bewick's Swan (b) Shelduck (c) Pintail (d) Dunlin (e) Curlew and (f) Redshank on the Severn Estuary SPA. Indices are produced following the methodology of the 'WeBS Alerts' (Maclean and Austin, 2008) using Generalized Additive Models (GAMs) with the level of smoothing determined by giving the model (n/3) degrees of freedom. This level of smoothing, while removing temporary fluctuations not likely to be representative of long term trends, captures those aspects of the trends that may be considered to be important. Year: 1970 = 1970/1971 etc.; winter = September-March for wildfowl and November-March for waders.

Shelducks are most abundant in Bridgwater Bay, which was formerly the most important autumn moulting area for the species away from the Wadden Sea and still holds nationally important numbers of birds at this time of year (Eltringham and Boyd, 1963; Morley, 1966; Fox and Salmon, 1994). Grey Plovers and Curlews are also found in high concentrations in Bridgwater Bay, the former additionally between Peterstone and the Newport Wetlands Reserve and the latter in the inner Severn (Fig. 3a). In contrast, Redshanks favour river mouths and other sites where there are freshwater inputs into the estuary, for example at the mouth of the Rivers Parrett, Axe and Rhymney (Fig. 3b). Densities of Dunlin – numerically the most important species on the Severn – have been shown to be strongly positively correlated with the percentage of silt and clays in estuary sediments (McCulloch and Clark, 1992). Ringed Plovers occur on the estuary in small numbers in winter, and the species is included as a feature of the SPA due to the large passage of migrants through the estuary in the spring and autumn.

The overall numbers of waders wintering on the estuary have declined in size in the last two decades, with the most striking declines being in the numbers of Grey Plovers and Dunlins (Fig. 2d). Average winter Dunlin numbers have fallen from over 40,000 in the mid-1970s to around 15,000 in recent years, though peak numbers are still of international importance (Austin and Rehfisch, 2005). In contrast, there has been a steady increase in the winter Shelduck population over the last 30 years (Fig. 2b). Some species' distributions within the estuary have also changed. Comparing Fig. 3a and b with equivalent figures from low tide surveys in the 1980s and 1990s, for example, suggests a decline in Curlew numbers around Weston Bay and an increase in Redshank numbers at Sand Bay, as well as losses of birds in and adjacent to Cardiff Bay (see below).

The SPA also encompasses areas of adjacent freshwater habitat, including the New Grounds at Slimbridge, which are important for several wildfowl species and Lapwing *Vanellus vanellus*. Bewick's Swans *Cygnus columbianus* and European White-fronted Geese *Anser a. albifrons*, for example, are restricted to this area and adjacent mudflats and saltmarsh. Wigeons *Anas penelope* and Lapwings are similarly abundant in the same area, in Bridgwater Bay (due to its proximity to the Somerset Levels) and on the Newport Wetlands Reserve and the adjacent Welsh Grounds. Teals *Anas crecca*, Mallards *A. platyrhynchos*, Pintails *A. acuta*, Shovelers *A. clypeata*, Pochards *Aythya ferina* and Tufted Ducks *A. fuligula* may also use both freshwater and inter-tidal areas, though Gadwalls are largely restricted to freshwater habitats. Teals, in common with Redshanks, particularly favour river mouths within the estuary. Pintails and Shovelers are restricted to the New Grounds and adjacent mudflats and the Welsh shore between Rhymney and the Welsh Grounds; Pochards and Tufted Ducks are now largely limited to the New Grounds area and the Newport Wetlands Reserve and adjacent Welsh Grounds. Whimbrel *Numenius phaeopus* also forage on inland pastures adjacent to the estuary, though only occur during passage periods. In spring, nationally important numbers can forage on the Somerset Levels (Ferns et al., 1979), these birds roosting at night at Steart. Numbers have decreased over the last two decades, however, with a peak of just 197 recorded in Somerset in spring 2006 (Gibbs, 2007). This decline may be linked to changes in agricultural practices, notably the switch from hay to silage, which may have affected invertebrate prey availability.

Numbers of Bewick's Swans (Fig. 2a) and European White-fronted Geese have decreased on the Severn Estuary SPA over the last two decades, while those of Pochards have also fallen since the mid-1990s. In contrast, there have been long-term increases in the numbers of Teals, Pintails (Fig. 2c), Shovelers, Tufted Ducks and Lapwings.

The Burry Inlet SPA, the relatively enclosed estuary of the river Loughor, has a considerably lower suspended sediment load than the Severn Estuary. The sandy sediments support considerable numbers of cockles *Cerastoderma edule*, as well as beds of mussels *Mytilus edulis*, which are eaten by important populations of Oystercatchers *Haematopus ostralegus* and Knots *Calidris canutus*. Four further wader species – Dunlin, Black-tailed Godwit *Limosa limosa*, Whimbrel (as a passage species) and Curlew – are included as features of the SPA, together with Shelduck, Pintail and Shoveler. Low tide counts indicate that wildfowl are most concentrated on the southern side of the estuary, where there are extensive areas of saltmarsh. Large numbers of Oystercatchers and Knots also use adjacent areas of coast, notably the Pembrey Shore and the Three Rivers Complex within the Carmarthen Bay and Estuaries Special

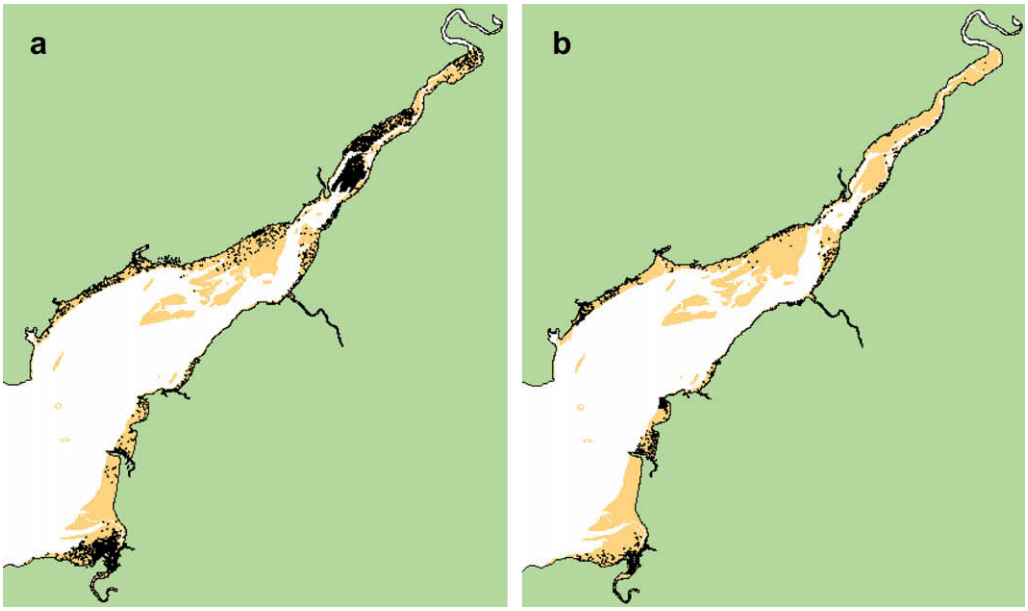

Fig. 3. The low tide distributions of (a) Curlew and (b) Redshank on the Severn Estuary in the winter of 2002/2003 (taken from Burton et al., 2003a). Each dot represents one bird.

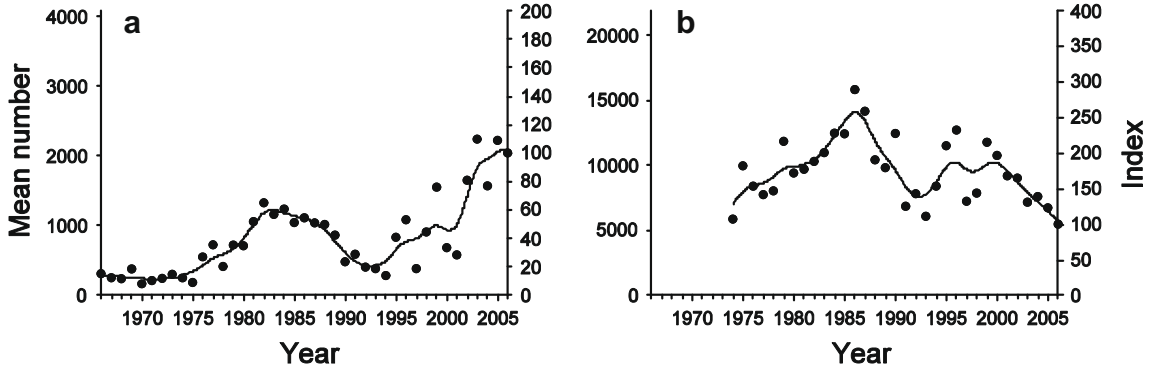

Fig. 4. Mean winter numbers and indices for (a) Pintail and (b) Oystercatcher on the Burry Inlet SPA (taken from Maclean and Austin, 2008). Year: 1970 = 1970/1971, etc.

Area of Conservation (SAC) (Burton et al., 2008). Both Pintails and Oystercatchers occur in internationally important numbers in the Burry Inlet SPA, though their populations have shown differing trends. After a peak during the 1980s, Pintail numbers fell during the early 1990s, but have since risen sharply (Fig. 4a). In contrast, numbers of Oystercatchers have shown a long-term decline over the same 25-year period (Fig. 4b).

Carmarthen Bay was badly affected by the oil-spill from the *Sea Empress* oil tanker which went aground at the mouth of Milford Haven in February 1996 (see below). A programme of ground and aerial counts begun in 1994/95 has indicated that wintering Common Scoters numbers were greatly reduced following the spill, but subsequently recovered, although numbers have recently dropped again for reasons unknown. A mean annual peak of 12,105 birds was recorded between 2003/04 and 2007/08 by ground counts, compared to a mean estimate from aerial surveys of 18,242 (Maclean et al., 2008).

Other sites within the area of the Bristol Channel that support notable numbers of wintering and passage waterbirds include the Blackpill, Swansea and Milford Haven Waterway SSSIs in Wales and the Taw-Torridge Estuary SSSI in England. Blackpill, situated in Swansea Bay, is particularly important for Ringed Plover and Sanderling *Calidris alba* and the Milford Haven Waterway for Little Grebe *Tachybaptus ruficollis*, Shelduck, Wigeon, Teal, Dunlin and Curlew. The Taw-Torridge Estuary is important for wintering Lapwing, Curlew and Redshank.

3.2. Gulls and other seabirds

Both Lesser Black-backed Gull *Larus fuscus* and Herring Gull *L. argentatus* are featured on the Severn Estuary Ramsar designation due to the national importance of their local breeding populations. Numbers of Apparently Occupied Nests (AONs) of Lesser Black-backed Gulls on Flat Holm (part of the Ramsar site) rose from 1800 in 1985–1988 to 3309 in 1998–2002 (Mitchell et al., 2004) and an average of 3733 between 2003 and 2008 (Taylor, personal communication). On Steep Holm, numbers of nests averaged 459 between 2003 and 2008 (Parsons, personal communication). On the Lundy SSSI, numbers rose from a low of 36 pairs in 1956 to 444 pairs in 2004 (Davis and Jones, 2007), while on Caldey in Dyfed, numbers rose from 371 AONs in 1986–2005 to 735 in 2006 (Mavor et al., 2008). Increasing numbers now also nest in urban areas, including Bristol (518 AONs in 1985–1988, 400 pairs in 1994, 850 AONs in 1998–2002) and Gloucester (450 AONs in 1985–1988, 255 pairs in 1994, 2250 AONs in 1998–2002) (Raven and Coulson, 1997; Mitchell et al., 2004; see also Rock, 2004, 2005a,b).

Numbers of Herring Gulls breeding in the estuary and wider Bristol Channel have also recently increased, though numbers at individual colonies have shown differing trends. Numbers of AONs on Steep Holm (also part of the Severn Estuary Ramsar site) and Caldey rose from 750 and 684 respectively in 1985–1988 to 956 and 2134 in 1998–2002 (Mitchell et al., 2004). Numbers on Steep Holm and Flat Holm averaged 1109 and 338 respectively between 2003 and 2008 (Taylor and Parsons, personal communication). There were 1897 AONs of Herring Gulls on Caldey in 2006 (Mavor et al., 2008). In comparison, numbers on Lundy fell from at least 3500 in 1966 to 1117 in 1986 and 708 in 2004 (Davis and Jones, 2007). An estimated 175 and 45 pairs of Herring Gulls also bred in Bristol and Gloucester respectively in 1994 (Raven and Coulson, 1997). Smaller numbers of both species now also breed in other coastal towns along the Severn Estuary and Bristol Channel (Raven and Coulson, 1997).

Numbers of wintering gulls on the Severn Estuary (as elsewhere in the Great Britain: Banks et al. (2009) have increased greatly over the last 50 years as a whole, though numbers of some species have declined recently. In winter 2003/04, the estuary held 56,622 gulls, including at a minimum 20,080 Black-headed Gulls *Chroicocephalus ridibundus*, 6471 Lesser Black-backed Gulls and 5997 Herring Gulls, figures which surpassed the respective international 1% thresholds for these species (Banks et al., 2007; note, wintering gulls have not, to date, been included as features of SPAs in the UK). Low tide counts indicate that, diurnally, the latter two species are particularly concentrated in the lower estuary, notably around Flat Holm, Steep Holm and Cardiff (Burton et al., 2003a), although the largest nocturnal roost (drawing birds from the surrounding land as well as the Bristol Channel) is in the upper estuary at Frampton and Waveridge Sands (Vernon and Walsh, 1965; Banks et al., 2007). Counts from this roost provide a good indication of the rise in gull numbers between the 1953 and 1993 winter surveys (Table 2), but also the recent declines that have occurred in the numbers of Black-headed Gulls, Common Gulls *Larus canus* and Great Black-backed Gulls *L. marinus*.

Changes in the populations of seabirds breeding on Lundy, which holds the largest colonies in the Bristol Channel, have been summarised by Davis and Jones (2007). Aside from Lesser Black-backed and Herring Gulls, small numbers of Great Black-backed Gulls and Kittiwakes *Rissa tridactyla* also breed. Numbers of the latter fell from an estimated 3000 pairs in 1939 (Perry, 1940) to 148 in 2004. The Guillemot *Uria aalge* population also fell from an estimated 19,000 pairs in 1939 (Perry, 1940) to 1647 individuals in 1969 and the Razorbill *Alca torda* population from 10,500 pairs in 1939 to 761 individuals in 1986. Numbers of these species in 2004 were 2321 and 841 individuals respectively. A population of 3500 pairs of Puffins *Fratercula arctica* in 1939 was reduced to a low of just nine pairs in 2003. Estimates of the numbers of Manx Shearwaters *Puffinus puffinus* breeding on Lundy have varied greatly, from 100 to 1000 pairs (Dymond, 1980) to 1000 to

Table 2
Numbers of gulls recorded at the Frampton and Waveridge Sands roost on the Severn Estuary during Winter Gull Roost Surveys (1953–2004).

Species	1953	1963	1973	1983	1993	2004
Black-headed Gull *Chroicocephalus ridibundus*	500	0	6500	33,052	42,998	7133
Mew (Common) Gull *Larus canus*	20,000	20,000	20,000	41,376	17,803	3483
Lesser Black-backed Gull *Larus fuscus*	0	0	750	5790	4672	6003
Herring Gull *Larus argentatus*	50	0	1750	1656	240	1279
Great Black-backed Gull *Larus marinus*	0	0	40	826	6	20
Other unidentified gulls	0	0	0	0	70,422	19,591
Total	20,550	20,000	29,040	82,700	136,141	37,509

10,000 pairs (Thomas, 1981). A more comprehensive study using tape playback suggested a population of 166 pairs in 2001 (Price and Booker, 2001). In addition to these species, Fulmars *Fulmarus glacialis*, Shags *Phalacrocorax aristotelis* and possibly Storm Petrels *Hydrobates pelagicus* also breed in small numbers. Seabirds on Lundy were formerly subject to heavy human persecution, though the declines of most species in the latter half of the 20th century have been particularly associated with predation by both Brown Rats *Rattus norvegicus* and Black Rats *R. rattus*. A Seabird Recovery Programme instigated by English Nature (now Natural England) in 2001 led to the island being declared rat-free in 2006, helping both Manx Shearwaters and Puffins to nest successfully (Appleton et al., 2006; Lock, 2006; Davis and Jones, 2007).

Populations of 10,235 Guillemots and 597 Razorbills were recorded at Elegug Stacks, along the Castlemartin Coast in Dyfed in 2006, compared to respective averages of 7466 and 630 between 1986 and 2005 (Mavor et al., 2008). Smaller numbers of auks and Shags also breed on St. Margaret's Island in Dyfed and Worms Head on the Gower, while Cormorants *Phalacrocorax carbo* also breed on St. Margaret's Island and on Steep Holm. Numbers of auks at these colonies also declined during the mid-20th century (Ferns, 1984).

4. Key environmental issues

4.1. Climate change

While many local environmental issues have affected and continue to affect the birds of the Severn Estuary and Bristol Channel, it is also clear that the changes observed in the numbers of several species are likely to reflect factors operating elsewhere or at a much larger scale. Research on the changing status of waterbirds in Great Britain has revealed that nine wader species are now wintering in decreasing proportions in southwest Britain. For seven of these species – Oystercatcher, Ringed Plover, Grey Plover, Knot, Sanderling, Dunlin and Bar-tailed Godwit *Limosa lapponica* – the proportion wintering in the southwest is also negatively correlated with winter temperature (Austin and Rehfisch, 2005). The recent declines of Grey Plovers and Dunlins on the Severn Estuary, in particular, may thus be largely a consequence of broader patterns rather than site-related issues. Given that current climate change scenarios predict further increases in temperatures for Great Britain (Hulme et al., 2002) it might thus be predicted that the proportions and overall numbers of waders wintering on the Severn Estuary and in southwest Britain as a whole would continue to decrease. However, set against this trend, it should be noted that species and populations of waterbird that currently winter further south or west, in France, Spain, Portugal or Ireland, could move north to winter in the Severn Estuary.

4.2. Oil-spills and water quality

Approximately 72,000 tonnes of oil was spilt when the *Sea Empress* oil tanker went aground in February 1996. This not only impacted the important breeding seabird populations of the Dyfed islands (Votier et al., 2005), but also wintering waterbirds. An estimated 3600 Common Scoters in Carmarthen Bay died having been poisoned or immobilised by the spill (Stewart et al., 1997) and 1000 more birds were thought likely to die within a year of their rehabilitation (Hughes et al., 1997). Peak numbers recorded by ground counts fell from 17,650 in winter 1994/95 to 2895 by 1997/98, but had recovered to 18,197 the following year. Numbers maintained this same pre-spill level up to winter 2006/07 (Banks et al., 2008) but fell to just 6189 in 2007/08 (Maclean et al., 2008), though the reasons for this are unclear. Common Scoters frequent Carmarthen Bay due to the rich populations of benthic invertebrate prey, notably bivalves and polychaetes, which they are able to exploit due to the shallow depth of the bay. Following the oil-spill, the distribution of the wintering birds shifted away from preferred feeding areas to deeper waters where obtaining prey would have been energetically less profitable (Banks et al., 2008).

This was by far the worst oil-spill that has affected waterbirds in the area of the Bristol Channel and Severn Estuary. Among smaller incidents, the spillage of 4000 tonnes of crude oil from the *Christos Bitas* in October 1978 impacted seabirds in the vicinity of the important breeding seabird populations of the Dyfed islands and at the mouth of the Bristol Channel (Ferns, 1984), while Common Scoter were also affected by earlier incidents in Carmarthen Bay. Small numbers of Shelducks, Dunlins and Redshanks were affected by a much smaller spill of 20 tonnes of oil from the Llanwern steelworks on the Severn Estuary in February 1991, though mortality was low and there appeared to be no lasting impact on the numbers subsequently using affected mudflats (Rehfisch et al., 1991).

Over the last two decades, there have been major improvements to the treatment and discharge of sewage in the UK as a result of the 1991 EC Urban Waste Water Treatment Directive (EC Directive 91/271/EEC), see also Jonas and Millward (2010). Despite sewage historically being a source of considerable contamination to estuaries including the Severn (Langston et al., 2003) and thus potentially to waterbirds (Ferns, 1984), these changes have raised some concern as discharges may provide considerable food supplies to coastal waterbirds, either as directly edible matter or by enhancing invertebrate populations (see review by Burton et al., 2002). There have been no direct attempts to ascertain the impacts of these changes on the waterbirds of the Severn Estuary and Bristol Channel. However, one previous study has shown the importance of sewage outfalls on the Severn for gulls, in particular (Mudge and Ferns, 1982; Ferns and Mudge, 2000). On the Tyne Estuary, closure of a sewage outfall led to numbers of Common and Great Black-backed Gulls declining by 93% and 91% respectively between 1969/70 and 1993/94 following improved sewage treatment and an 86% decrease in the volume of untreated waste discharged into the river (Raven and Coulson, 2001). In Scotland, closures of outfalls led to notable declines in the numbers of diving duck species in the 1980s (Campbell, 1984; Fox and Salmon, 1988) and on the Severn, there is some circumstantial evidence of similar effects on ducks. Peak numbers of Pochards recorded at the Rhymney Estuary fell from 350 in 2001/02 to 19 in 2002/03, following

instillation of a new Cardiff eastern sewer outfall and improved sewage treatment; numbers also fell in Cardiff Bay at the same time, having increased following the closure of the Cardiff Bay barrage in 1999 (see below; Burton et al., 2003b). The overall reduction in the volume of untreated sewage entering the Severn may have also impacted invertebrate populations, and so potentially also been a factor in the declines and within estuary redistributions of some wader species, including Dunlin.

4.3. Shell-fishing

Ten thousand Oystercatchers were shot in the Burry Inlet between 1972 and 1974 due to their potential impacts on the important local shell-fishery (Ferns, 1984). Since then the potential conflict between Oystercatchers, and Knots, and both the cockle and mussel fisheries of the Inlet have been the subject of considerable research. Shell-fishing removes the large-sized prey that are favoured by Oystercatchers and also disturbs birds, thereby leading to increased competition, reduced intake rates and thus potentially starvation (Stillman et al., 2001). An individual behaviour-based model (IBM) developed by the Centre for Ecology and Hydrology (CEH) has used estimates of the food requirements of the two species to predict the potential impacts of different management scenarios on their condition and survival (West et al., 2003, 2005). These models suggest that bird distributions would change significantly if cockle stocks in the Burry Inlet were poor, leading to birds switching to feed on mussels and other food sources, or moving to areas of cockles elsewhere locally, such as the Three Rivers Estuary in Carmarthen Bay.

Norris et al. (1998) found that the numbers of Oystercatchers on the Burry Inlet during spring (but not winter) were positively correlated with cockle biomass at the start of the winter, and negatively correlated with the biomass landed by the fishery over the winter. They suggested that birds may disperse from the site earlier in spring when the biomass of cockles at the start of the winter is small and/or the biomass landed by the fishery is large. Recently, numbers of wintering Oystercatchers in the SPA have fallen (Fig. 4b), while numbers on adjacent areas – which birds from the SPA have been shown to use – have been more stable (Burton et al., 2008; Maclean and Austin, 2008).

4.4. The Cardiff Bay barrage

The Taff-Ely SSSI, or Cardiff Bay, a 200 ha area of inter-tidal mudflats and saltmarsh at the mouth of the Severn Estuary, was enclosed by an amenity barrage in November 1999 to create a freshwater lake that has since formed the centre point for the redevelopment of Cardiff's former docklands. A long-term study that monitored the impacts of this development has helped to further understanding of responses of waterbirds to estuarine habitat loss. Almost all the Shelducks, Oystercatchers, Dunlins, Curlews and Redshanks that formerly used the bay were displaced by its inundation (see Fig. 3a and b for the distributions of the latter two species in 2002/03), only using the site since closure to roost over high tide (Burton, 2006). Intensive monitoring of a marked population of Redshanks indicated that most displaced birds settled in neighbouring sites, notably the Rhymney Estuary (Burton and Armitage, 2008), reflecting their previous fidelity to the bay (Burton, 2000). Reduced survival over the following three winters among displaced adults (Burton et al., 2006) was in line with that predicted by an IBM (Goss-Custard et al., 2006) and was not thought to be an effect of the birds moving to a lower quality site, as the survival rate of birds that previously wintered on the neighbouring site remained unchanged at the previous level. This suggests that the displaced birds were incapable of learning how to survive in their new environment and were either at a competitive disadvantage or subdominant to the resident birds. Such studies show that it cannot be assumed that displaced birds will find new wintering areas; for Redshank, at least, it is likely that the impacts on the local wintering population will have affected the population of the estuary as a whole.

The Newport Wetlands Reserve was established in March 2000 as part of measures intending to compensate (though not mitigate) for the loss of the Taff-Ely SSSI. Two targets were set for the first five years following the establishment of the reserve: firstly, that it should support at least two species of wintering waterbird in nationally important numbers and, secondly, that it would have the potential to qualify for SPA status either alongside or within an extended Severn Estuary SPA boundary. These targets have, in part, been met: the newly created saline lagoons and freshwater marshes supported nationally important numbers of Black-tailed Godwits between 2000/01 to 2004/05, while use of these habitats by roosting waders and wildfowl suggests that they have become a functional component of the Severn Estuary SPA (Austin et al., 2006).

4.5. Proposals for tidal power

Knowledge of the potential effects of tidal power schemes on birds, particularly barrages, largely stems from the work undertaken in the 1980s and 1990s under programmes of research primarily for the then Department of Trade and Industry's Energy Technology Support Unit (ETSU) and the Severn Tidal Power Group (STPG). These studies considered not only proposals for a Cardiff-Weston barrage on the Severn Estuary, but also schemes on other British estuaries (for the Severn see: Clark, 1988, 1990; Clark et al., 1993; STPG, 1989; Warbrick et al., 1991; McCulloch and Clark, 1992) and are key to understanding the potential impacts of recent proposals. A synopsis of the conclusions of these studies was presented by Clark (2006).

Construction of a large tidal power scheme on the Severn Estuary would be likely to have considerable short-term and long-term impacts on waterbird populations (Clark, 2006). As demonstrated by the Cardiff Bay study, most waders exhibit high winter site-fidelity (Burton, 2000), and initially following construction most birds whose habitat is lost would be displaced to the nearest available habitat (Burton and Armitage, 2008). This will lead to increased waterbird densities and intense competition for available food resources (Goss-Custard, 1985; Goss-Custard et al., 2002) and so increased mortality. Waterbird populations would be affected in the longer term by several inter-related factors. Firstly, the inter-tidal habitat available for feeding birds would be greatly reduced due to a reduction in the tidal range within the area encompassed by the scheme. However, the effect of this would not be directly proportional to the amount of habitat lost due to the variation in inter-tidal habitat quality across the estuary (see above). Secondly, changes in the tidal range and curve would reduce the time available for waterbirds to feed. The importance of this depends on the height distribution of the inter-tidal areas favoured by each species and the duration of the high water period. Some duck species, such as Wigeon for example, prefer to feed on the falling and rising tide. Changes in the tidal curve that reduce these periods by extending the low or high tide periods might thus disproportionally affect such species. Delaying the ebb tide to maximise power generation, however, would increase the time available for feeding at high tide for some wildfowl, while reducing it for waders. Thirdly, the nature of invertebrate communities would be changed by reduced salinity and changes in the balance between the rates of sediment deposition and erosion. Reduced suspended sediments in the water column and increased rates of deposition could lead to an increase in invertebrate communities and thus possibly increased densities of birds in remaining habitat.

However, wave erosion could also increase, for example, through the under-cutting of mudflats or saltmarsh squeezed by seawalls, which would be exacerbated if high and low tide points become less variable. After construction of a storm surge barrage on the Oosterschelde in the Netherlands in the 1980s, mudflats have been lowered through a process of erosion of upper mudflats and deposition in the channels. Associated with this, there has been a continuing decline in Oystercatcher numbers (Duriez et al., 2009). Changes in shore gradient, sediment supply and the effect of wave action would additionally affect the extent and quality of saltmarsh, potentially impacting roost sites and breeding waders. Maintenance of high water levels on the estuary to generate power on ebb tides may lead to a higher water table in surrounding catchments. Although there may be a need for drainage pumping to avoid flooding in some areas, a balance could potentially be achieved that would benefit birds using freshwater habitats.

5. Conclusions

Since the previous reviews undertaken by Ferns (1977, 1984, 1994), Clark and Prŷs-Jones (1994), Fox and Salmon (1994) and Salmon and Fox (1994), the Severn Estuary, Burry Inlet and Carmarthen Bay have all been designated as SPAs due to their importance for waterbirds (and the two former sites also as Ramsar sites). Over the same time period, however, the status of waterbirds, and seabirds, on these sites and in the wider area of the Bristol Channel has been affected by a number of issues. Climate change has likely led to declines in the numbers of waders on the Severn Estuary and the southwest in general; the 1996 *Sea Empress* oil-spill impacted both breeding seabirds and the wintering Common Scoters in Carmarthen Bay; on the Burry Inlet, there is ongoing debate as to the impact of the local cockle shell-fishery on the site's declining Oystercatcher population, while on the Severn Estuary itself, large numbers of waterbirds were impacted by the impoundment of Cardiff Bay.

The studies and monitoring undertaken in the area of the Severn Estuary and Bristol Channel have provided a good understanding of these issues and the numbers and status of its bird populations. However, to be able to fully investigate the impacts of any future developments, such as the tidal power schemes proposed for the Severn, it is important that high-quality data continue to be collected, a firm baseline is established, and further detailed studies are undertaken. Construction of a tidal power scheme could impact the integrity of the Severn Estuary SPA/Ramsar Site and potentially also have impacts on sites downstream along the Bristol Channel, both through physical effects and the displacement of birds. The extent of compensation or mitigation that would be required to offset these impacts is presently unknown but could be considerable.

Acknowledgments

Data were obtained for this paper from the Wetland Bird Survey (WeBS) and the 2003/04–2005/06 Winter Gull Roost Survey (WinGS) and our thanks go to all those volunteers who have taken part in these surveys. WeBS is a partnership scheme between the British Trust for Ornithology, the Royal Society for the Protection of Birds and the Joint Nature Conservation Committee (JNCC) – the last on behalf of the Countryside Council for Wales (CCW), Natural England (NE), Scottish Natural Heritage (SNH) and the Northern Ireland Environment Agency (NIEA) – in association with the Wildfowl and Wetlands Trust. WinGS was funded by NE, SNH, CCW, NIEA, JNCC and Northumbrian Water Ltd. Data on numbers of gulls nesting on Flat Holm and Steep Holm were kindly provided by Natalie Taylor and Tony Parsons respectively.

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