DECC

SEVERN TIDAL POWER

A strategic level review of the issues surrounding potential habitat creation mitigation / compensation measures for SPA waterbirds affected by tidal power development on the Severn Estuary

April 2010

Prepared by
British Trust for Ornithology
The Nunnery
Thetford
Norfolk
IP24 2PU

Prepared for
Parsons Brinckerhoff Ltd
and
Black and Veatch Limited

DECC
3 Whitehall Place
London
SW1A 2HD

Report Title	**:**	**Severn Tidal Power - A strategic level review of the issues surrounding potential habitat creation mitigation / compensation measures for SPA waterbirds affected by tidal power development on the Severn Estuary**
Report Status	**:**	**FINAL**
Date	**:**	**April 2010**
Prepared by	**:**	**Lucy J. Wright, Philip W. Atkinson, Niall H.K. Burton & Nigel A. Clark..............................**
Checked by	**:**	**Nigel A. Clark ....**
Approved by	**:**	**Nigel A. Clark ....**

Revision	**Status**	**Date Issued**
A	Draft for DECC Review	18th February 2010
B	Draft for DECC Issue / Country Agency Review	6th March 2010
C	Final Draft	1st April 2010

CONTENTS

ABBREVIATIONS

ABBREVIATIONS

The following abbreviations are used in this paper:

BAP	Biodiversity Action Plan
BTO	British Trust for Ornithology
DECC	Department of Energy and Climate Change
EC	European Commission
SAC	Special Area of Conservation
SEA	Strategic Environmental Assessment
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
WeBS	Wetland Bird Survey

NON TECHNICAL SUMMARY

NON TECHNICAL SUMMARY

This report comprises a strategic level review of the issues surrounding potential habitat creation mitigation and compensation measures for SPA waterbirds affected by tidal power development on the Severn Estuary. In particular, we compare the likely effectiveness of providing compensatory habitat at a distance from the Severn Estuary to the effectiveness of creating new habitats within or adjacent to the estuary.

Waterbird species that regularly occur on the Severn Estuary were divided into six species guilds based on habitat use and feeding preferences. A range of life-history parameters that may influence the effectiveness of mitigation and compensation measures for each species was gathered from the available literature. These traits were used to inform a range of issues relating to potential mitigation and compensation measures.

Few studies have monitored the impact of intertidal habitat creation on waterbirds and the majority of papers about managed realignment in the UK have concerned non-biological processes. One of the largest issues, rarely tackled in most studies, has been a detailed assessment of the physical, temporal and biological factors that determine the resulting habitats and communities and how these relate to the range of variation found in natural areas. Generally, once habitats are created, benthic fauna and birds respond fairly quickly if conditions are suitable, but created sites may exhibit a lower diversity of habitats and species than natural sites. However some recent examples have shown that good quality diverse habitats that support a range of bird species can be created if the correct methods are used. To maximise the likelihood of creating a fully functioning wetland encompassing the range of variation found in natural areas, it is thought that larger-scale projects are more likely to be successful.

Whatever measures were used to provide mitigation or compensation if a tidal power option were implemented, it would be important to provide a range of habitats that fulfil the range of ecological requirements of each species guild in close proximity to each other. Species that feed on intertidal areas would require areas of intertidal habitat that are exposed at low tide adjacent or in close proximity to areas that are exposed and available for feeding on the rising and falling tide. These species would also require high tide roost sites adjacent or close to feeding areas.

The main effect on waterbirds if any of the tidal power options were implemented would be the loss of intertidal habitat. However, the creation of freshwater wetland habitat at sites close to the Severn Estuary has been put forward as a potential compensation measure. In order to assess the likely effectiveness of this measure for different species guilds it is important to understand the habitat equivalency. In other words, for each species guild can freshwater wetlands support similar densities of birds to intertidal habitat, and fulfil all their ecological requirements. It is thought likely that the creation of freshwater wetlands would be an effective or partially effective measure for species that regularly use freshwater sites (primarily freshwater species, generalist wetland species, gulls and piscivores), but further research is required to determine the ratios of compensatory freshwater habitat compared to lost intertidal habitat that would be required. However freshwater wetlands tend to support only low densities of species that primarily feed on intertidal mudflat invertebrates or bivalves, thus this measure is likely to be effective at only a very low level for these species guilds. This means that for some key SPA species including Shelduck, Dunlin, Redshank, Ringed Plover and Grey Plover this measure is unlikely to provide effective compensation.

The creation of new intertidal habitats at distance from the Severn through managed realignment is likely to be less effective than implementing such measures locally, and some species may take many years to re-distribute to new sites created at a distance. There is a risk that this measure may not be effective for some species and that some of the functions of the Severn Estuary may not be met. Furthermore, creating new sites at a distance from the Severn is not within the scope of current guidance on compensation. Colonisation of sites created to the east of the UK may be aided in the long-term by eastward distribution changes of some species in response to climate change. However,

many of the intertidal invertebrate feeders, intertidal bivalve specialists and generalist wetland species that would benefit from these measures are very site-faithful. These include key SPA species such as Dunlin, Redshank, European White-fronted Goose, Ringed Plover, Grey Plover, Whimbrel and Curlew. The re-distribution of these species to new sites could take many years, with risk of population declines in the interim period and the possibility that these populations could take years to recover from such declines. Furthermore, sites created on the east coast of the UK would be unlikely to fulfil the current role of the Severn as a refuge for waterbirds in severe weather, because winter temperatures broadly tend to be milder in the south west UK but colder further east. There is also uncertainty as to whether sites on the east coast would fulfil the role of the Severn as a stop over site for passage migrant birds, notably Ringed Plover, Whimbrel and the *schinzii* race of Dunlin, particularly during spring migration when these species primarily occur on the west coast. However, despite these limitations it is likely that intertidal habitat creation at sites elsewhere in the UK could be partially effective for a range of species.

There are a number of significant gaps in knowledge in relation to all the reviewed habitat creation measures for waterbirds. Further research to fill these gaps could greatly improve the levels of certainty surrounding predictions of the likely response of waterbirds to the various habitat creation mitigation and compensation measures.

SECTION 1

INTRODUCTION

1 INTRODUCTION

The Waterbirds Topic Paper for the Severn Tidal Power Strategic Environmental Assessment (SEA) considers 50 receptors (comprising 45 waterbird or gull species and five assemblages). These waterbird species will be affected to varying degrees by each tidal power option and thus if an option is implemented, mitigation and compensation needs will vary between species in what is required and its scale. In this report, we review the issues around mitigation and compensation at a strategic level to inform the assessment of need to ensure that the integrity of the SPA network is not compromised.

The objectives of this report are as follows:

1. To identify a series of 'species guilds' with similar ecological requirements;
2. To identify the scope for mitigation / compensation provision for waterbirds in the same or different ecological functional units (i.e. within or close to the Severn or at distance);
3. To identify the likely responses of species to the provision of new habitat 'in unit' and 'out of unit';
4. To identify the barriers to successful provision of compensatory habitat.

The study first identifies species guilds and defines the traits that are common to all members. These are tabulated along with information on life history parameters that might influence the success of mitigation or compensation, for example site fidelity and longevity. The information on species guilds and their traits has then been used to consider the likely issues surrounding mitigation and compensation within and outside the ecological functional unit. The ecological functional unit for SPA birds for this purpose is taken to be the existing SPA together with areas that are adjacent or close and actually or potentially (through compensation measures) ecologically linked. For example for species that feed on intertidal mudflat the ecological functional unit would provide feeding opportunities at low tide and on the rising and falling tide, as well as high tide roost sites. These sites would need to be close enough together to be within the normal distances that birds would move during the tidal cycle. Note that there is uncertainty regarding the range of distances that birds of each species normally move during the tidal cycle and further studies to reduce this uncertainty are discussed later in the report. The following issues are considered:

'In unit' mitigation and compensation

- Identification of factors that limit potential for 'in unit' mitigation/compensation for SPA birds within the Severn.
- Review of design criteria for optimising inter-tidal habitat creation for SPA birds.
- Consideration for SPA species of the definition of ecologically linked areas.
- Habitat associations and the potential for substitution of habitats to provide similar ecological functionality.
- Consideration of likely effectiveness of measures in terms of providing equivalent functionality for birds, to inform the potential for 'in unit' habitat substitution.

'Out of unit' compensation

- Implications for flyway populations of delivering compensatory habitat 'out of unit'.
- Consideration of the likely effects on species which might result from radical re-distribution of intertidal habitats from the Severn Estuary to other parts of UK.
- Discussion of the mechanisms that would apply to each species in adjusting to different distribution of habitat.
- Discussion of climate change effects on distribution.

SECTION 2

REVIEW

2 REVIEW

2.1 Species guilds

In the SEA, the waterbirds topic paper considers three groups of species (and species assemblages) as receptors. The majority of these are waterbird species that regularly occur within the Severn Estuary and are features of the Severn Estuary SPA or Ramsar Site or component SSSIs, or listed as UK Biodiversity Action Plan (BAP) species, Section 41 BAP Species of Principal Importance in England, Section 42 BAP Species of Principal Importance in Wales, Amber- or Red-listed Birds of Conservation Concern (BoCC) in the UK or Wales, or IUCN Red list species (Appendix 1). The other two groups are species that occur in the study area floodplain, and species that may be affected by far-field effects of the alternative options such as changes in water-levels or displacement. Eight species that are considered as receptors in the topic paper because of effects on the study area floodplain or far-field effects are not considered here (Greenland White-fronted Goose *Anser albifrons flavirostris*, Dark-bellied Brent Goose *Branta bernicla bernicla*, Common Scoter *Melanitta nigra*, Great Crested Grebe *Podiceps cristatus*, Bittern *Botaurus stellaris*, Little Ringed Plover *Charadrius dubius*, Woodcock *Scolopax rusticola* and Green Sandpiper *Tringa ochropus*). These species are not considered because there are predicted to be fewer significant effects of the proposed tidal power options outside the area of the Severn Estuary, and the magnitude of the effects is considerably less certain than within the Severn, therefore the compensation need is difficult to quantify.

For the purposes of this high-level review of potential mitigation and compensation measures, we focus on those species listed in the SPA designations or those that are not listed but occur on the Severn Estuary in nationally or internationally important numbers (Table 1). Species are classified as occurring in internationally or nationally important numbers if the Severn Estuary supports more than 1% of the international or national population respectively.

The Severn Estuary SPA was originally designated in 1995, and at this time there were 15 species listed in the designation either because they occurred in internationally important numbers, or they were components of the waterbird assemblage that occurred in nationally important numbers. In 1999, an updated designation (the Natura 2000 standard data form) listed only six species (one Annex 1 species that occurred in nationally important numbers, and five other species that occurred in internationally important numbers), without listing all the nationally important components of the waterbird assemblage. In 2001, the SPA review (Stroud *et al*. 2001) recognised that other species also occurred in nationally or internationally important numbers and would be eligible for future inclusion. Furthermore, surveys carried out during 2008/2009 for the purposes of the SEA demonstrated that six additional species not mentioned in either of the SPA designations or the SPA review occurred in either nationally or internationally important numbers on the Severn Estuary. All species mentioned in any of the SPA designations, the SPA review or that occurred in nationally or internationally important numbers on the Severn Estuary in 2008/09 are included in this review. Brief consideration is given to the other SEA receptor species in the appendices.

Species have been divided into six guilds with similar traits including feeding habitat and method, habitat dependence, site dependence, site fidelity and lifespan. The guilds are as follows:

- Primarily intertidal invertebrate feeders (except bivalve specialists)
- Primarily intertidal bivalve specialists
- Piscivores
- Primarily freshwater species
- Generalist wetland species
- Gulls

Generalist wetland species are those that use both freshwater and estuarine habitats; some of these species may have specific habitat requirements, and therefore they are not true generalists, but they will all use both freshwater and estuarine habitats. It is important to note that many species may fall into more than one of the categories. In these cases, species have been assigned to their primary guild (Table 2, Appendix 2). However such species may benefit from measures that are beneficial for other guilds with which their niche overlaps. For example, Black-tailed Godwits (a generalist wetland species) tend to feed on bivalves when using intertidal habitat, so they would be likely to benefit from any measures that are beneficial to intertidal bivalve specialists. Other waders, including Whimbrel and Curlew, which have been assigned to the generalist wetland species guild, tend to feed on intertidal invertebrates when using estuarine habitats, so are likely to benefit from any measures that are beneficial to intertidal invertebrate feeders. Within some guilds it is possible to further subdivide the constituent species into families, for example wildfowl *Anatidae* (ducks, geese and swans) and waders *Charadriiformes*.

Table 1. SPA designations of waterbird species, and waterbird species that occur in nationally or internationally important numbers on the Severn Estuary. International and national importance is based on whether numbers of each species recorded on the Severn exceed the 1 % threshold for either the international or national population (Holt *et al*. 2009). Numbers are based on the five-year mean of annual peak counts for 2004/05 - 2008/09. Where the 2008/09 count is higher than the five-year mean and results in a higher level of importance this is shown in parentheses. For some species the five-year mean of peaks for the whole year is higher than that for the winter period. Where this difference would increase the level of importance this is shown in square brackets.

Species	SPA Designation			Internationally Important	Nationally Important
	Original citation (1995)	Natura 2000 Standard Data Form (updated 1999)	SPA Review (2001)		
Mute Swan				+	+
Bewick's Swan	+	+	+	+	+
European White-fronted Goose	+	+	+		+
Shelduck	+	+	+	+	+
Wigeon	+		+		+
Gadwall		+	+		+
Teal	+		+		+
Mallard			+		
Pintail	+		+	+	+
Shoveler			+	+	+
Pochard	+		+		+
Tufted Duck	+		+		
Avocet					[+]
Ringed Plover	+		+	+	+
Golden Plover					+
Grey Plover	+		+		(+)
Lapwing			+		+
Knot					+
Dunlin	+	+	+	+	+
Black-tailed Godwit					+
Whimbrel	+		+		
Curlew	+		+		+
Spotted Redshank	+				
Redshank	+	+	+	(+)	+
Lesser Black-backed Gull				[+]	+

Table 2. Species guilds, and traits of species within each guild.

Species	Population Status[1]	Habitat Dependence[3]	Site Dependence[4]	Site Fidelity[5]	Typical Lifespan (years)[6]	Migration Distance[7]	Migration Direction[7]
Primarily Intertidal Mudflat Invertebrate Feeders (except bivalve specialists)							
Shelduck	Increasing	High	High	Low	10	Short	E
Ringed Plover	Declining[2]	High	Low	High	5	Long	Passage: NW Wintering: UK & NE)
Grey Plover	Declining	High	High	High	9	Long	NE
Dunlin	Declining	High	High	High	5	Long	Passage: NW Wintering: NE
Spotted Redshank	Declining[2]	High	High	High[4]	No data	No data	NE
Redshank	Stable[2]	High	Low	High	4	Long / Short	NW (some NE)
Primarily Intertidal Mudflat Bivalve Specialists							
Knot	Stable[2]	High	High	Low	7	Long	NW
Primarily Freshwater Species							
Gadwall	Increasing[2]	Low	Low	Low	No data	Long	E & UK
Generalist Wetland Species							
Mute Swan	Increasing[2]	Low	Low	Low[4]	10	Short	Local
Bewick's Swan	Declining	High	High	Low	9	Long	NE
European White-fronted Goose	Declining	High	High	High	6	Long	NE
Wigeon	Increasing[2]	High	Low	Low	3	Long (short)	E
Teal	Increasing	High	Low	Low	3	Long (short)	E (some NW)
Mallard	Declining[2]	Low	Low	Low	3	Long / Short	E & UK
Pintail	Increasing	High	High	Low	3	Long (short)	E (some NW)
Shoveler	Increasing	High	Low	Low	3	Long	E
Pochard	Declining	Low	Low	Low	3	Long (short)	E
Tufted Duck	Increasing	Low	Low	Low	4	Long (short)	E & UK (some NW)
Avocet	Increasing[2]	High	High	High	No data	No data	No data
Golden Plover	Increasing[2]	Low	Low	High	4	Long	NW & NE
Lapwing	Increasing	Low	Low	High	No data	Long	UK & E
Black-tailed Godwit	Increasing[2]	Low	High	High	18	Long	NW
Whimbrel	Declining[2]	High	High	High[4]	11	Long	NW
Curlew	Increasing	High	Low	High	5	Long (short)	UK & E
Gulls							
Lesser Black-backed Gull	Stable[2]	Low	Low	Low[4]	15	Short (long)	NW, NE & Local

Species highlighted in blue are the six species for which the SPA is designated on the Natura 2000 Standard Data Form (updated in 1999). Those highlighted in green are the 10 additional species cited as nationally important components of the waterbird assemblage in the original SPA designation in 1995. Those highlighted in yellow were listed as components of the waterbird assemblage in the SPA review (Stroud *et al*. 2001). Species not highlighted occur in nationally or internationally important numbers on the Severn but are not included in any of the SPA listings.

[1] Whether the species has undergone a >25% decline (or >33% increase) over a 5-, 10- or 25-year period either on the Severn Estuary or nationally (Maclean & Austin 2008).

[2] Species for which trends were only available at the national level.

[3] Qualitative assessment based on BTO expert judgement.

[4] Assessed using 2007/08 WeBS data: species for which 50% of the Great Britain population was found on 10 or fewer sites are classified as having High site dependence.

[5] Based on the 'WeBS Alerts Biological Filter' (Maclean & Austin 2008) in which a scoring system is used to assess the natural fluctuations in species' numbers between winters. Species with scores of five or below (for which a filter would be applied to 'High Alerts' in this system) are classified as typically exhibiting low site-fidelity, those with scores of 6-8 as typically exhibiting high site-fidelity. This method of defining site fidelity is a standard approach used in the WeBS Alerts system which monitors changes in the populations of designated waterbird species on SPAs and SSSIs (Maclean & Austin 2008).

[6] Longevity figures from "BirdFacts" (Robinson 2005).

[7] Migration distances and directions are taken from the Migration Atlas (Wernham *et al*. 2002) in conjunction with expert knowledge. Where two migration distances are stated, the first is the migration distance of the wintering population, with the second (in brackets) the breeding population. In most cases wintering populations are considerably larger than breeding populations, for example for many duck species. Migration direction is the direction the species moves from the Severn in the breeding season. Species that move NW mostly breed in Greenland or Iceland, those that move NE breed in Fennoscandia or Russia, those that move E breed in Eurasia, UK indicates the species breeds elsewhere in the UK and winters on the Severn.

2.2 Potential habitat creation mitigation or compensation measures and their scope

The potential mitigation and compensation measures considered here involve habitat creation either on the Severn Estuary, close to the Estuary or at a distance.

Mitigation measures
a. Topographical modification, i.e. intertidal habitat creation (Severn Tidal Power 2009)
b. Creation of roost sites where they have been lost, e.g. due to loss of saltmarsh

Compensation measures include:
a. Managed re-alignment adjoining the Severn Estuary to create intertidal habitat.
b. Managed re-alignment at distance from the Severn Estuary to create intertidal habitat.
c. Creation of freshwater wetland habitat close to Severn Estuary.

2.3 Factors that may limit the effectiveness of mitigation or compensation measures

2.3.1 Within versus out of out-of-site limitations

A range of factors is likely to influence the effectiveness of mitigation or compensation measures. These include:
- Optimising the design of intertidal habitat creation for birds
- The need for ecologically linked areas
- Habitat equivalency
- Implications for flyway populations

These issues are discussed in detail in sections 2.3.2 - 2.3.5 below.

2.3.2 Design criteria for optimising intertidal habitat creation for SPA birds

The science behind the restoration and creation of many terrestrial habitats is well advanced. However, intertidal habitats pose special problems for restoration because they are topographically and ecologically complex and they support many species of animals, some of which require specific habitats and linkages to other terrestrial or marine habitats. Moreover they exist and evolve within dynamic coastal settings, subject to changing tidal levels, salinities and long term mechanical processes that are associated with sea-level rise and climate change. Often these complexities are ignored and there has been a tendency for created coastal habitats to lack the diversity seen in natural areas and support only generalist species.

In NW Europe the experience of creating new habitat, especially mudflats, is fairly limited but expanding at a rapid rate. It has included the use of dredged material or managed realignment to create or restore areas. Few studies have monitored the impact on waterbirds and the majority of papers about managed realignment in the UK have concerned non-biological processes such as geo-chemical changes, tidal exchange, persistence of salt marsh in unmanaged retreat sites and policy related to managed realignment.

It is perhaps not surprising that little has been published in the peer-reviewed literature on the biological aspects, as sites at which habitat creation or restoration has been practised in the UK are relatively young and generally less than 10 years old. Within this short timeframe, the potential for ecological communities to develop and change is relatively limited. Elsewhere in north-west Europe, large areas of man-made marshes and mud flats are found in the Wadden Sea. Although only a fraction of the area present about 2,000 years ago, these intertidal habitats are still the largest contiguous area of salt marsh in Europe and in the Netherlands, there are over 17,000 ha of man-made salt marshes, created specifically for flood defence purposes rather than for any other environmental benefit (Esselink 1998). This policy is changing and salt marshes on the North Sea coasts of Germany, Belgium, The Netherlands and Denmark, which are of high conservation importance because of the large concentrations of wintering, passage and breeding waterbirds that they support, are now increasingly being managed for nature conservation purposes (Esselink 2000). Again little has been published in the peer-reviewed literature although the created marshes at Sieperda in The Netherlands are a notable exception (Castelijns et al. 1997, Eertmann et al. 2002).

Elsewhere in the world, Japan has led the way in creating tidal mudflats and, according to the Environment Agency of Japan, 37 areas covering approximately 900 ha were created between 1973 and 1998 (WAVE 2001a, b). This is small compared to the loss of nearly 4,000 ha (42% to reclamation) over the same time period (WAVE 2001a, b), and most of the sites are also relatively small in scale.

Research has therefore been geographically rather limited and focussed on particular habitats or ecosystems. One of the largest issues, rarely tackled, has been a detailed assessment of the physical, temporal and biological factors that determine the resulting habitats and communities and how these relate to the range of variation found in natural areas. Most studies have simply described the biological communities and the changes within them. Restoration schemes have also generally been small (both in extent and number) compared with surrounding "natural" areas and this small scale will affect the use made of such areas by birds in ways independent from the type and quality of habitat created. Where comparisons are made, the high variability exhibited by natural areas often hides differences in the sampled attributes between created and restored sites and surrounding natural areas. This means that results from many studies may not be applicable at a larger (i.e. regional rather than site) scale.

This makes the definition of a "successful" restoration quite difficult, given that natural habitats are very varied and restoration sites have tended to be small. It may be that we can only create a subset of coastal wetland habitats. To be able to restore or create habitats for birds successfully, they should exhibit the functions and processes within the variation found in surrounding natural habitats at a range of spatial scales. In many cases, this will mean allowing dynamic change to take place, e.g. allowing habitats to shift upshore in relation to sea level rise. In estuaries, it means taking a strategic approach at the flood plain level, using the whole estuary as a functional unit rather than concentrating on particular vulnerable areas within the estuary. This type of approach has the advantage of allowing ephemeral habitats such as saline lagoons and fresh/brackish water transitional habitats, which are important for waterbirds, to remain.

Are created/restored salt marshes equivalent to natural marshes?

Experience from the both the UK and United States has led to the conclusion that created salt marshes provide an approximation of the habitat required by the target birds, but do not necessarily lead to the development of the same plant, invertebrate or bird species assemblage as is to be found on surrounding natural salt marshes. The reasons for these differences are often due to the nature of the sites. Created marshes tend to be on land that was previously used for agriculture. This land has tended to be smooth, flat or gently sloping, and microhabitats that are important for many bird species such as ephemeral pools and creeks were rare. Often restored/created marshes were at an overall higher elevation, had less edge habitat and where present, creeks or channels tended to be deep and steep-sided.

Given the very different soil characteristics, one frequent difference between restored and natural marshes in both the UK and US, is the consolidated nature of the sediments in restored and created salt marshes (soil structure collapses due to re-wetting with salt water), as well as their lack of natural creek systems, smooth topography and poor drainage. Re-wetted sediments in the UK tend to be extremely hard and tabular in form and thus, if sediment does not come in from the surrounding area and settle, these hard mud habitats are inhospitable environments for invertebrates and plants. This has lead to reduced structural diversity and differences in vegetation communities on some of the naturally-regenerated marshes in SE England.

Some kinds of saltmarsh can never be created. The ancient saltmarshes of North Norfolk, which may be 10,000 years old, feature a very intricate topography of pools and creeks. The pools are remnants of old creeks and as a result of this very varied topography these marshes are amongst the most species-rich in the UK. In contrast, marshes in higher energy, sandier, environments (such as the

Severn) tend to be species-poor and dominated by species such as *Puccinellia.* This forms an important food source for many species of wildfowl. These marshes are probably easier to recreate in a suitable tidal environment.

Do created mudflats function in a similar manner to "natural" ones?

Although mudflat creation is most highly developed in Japan (WAVE 2001a, b), there are few accessible reports of bird usage from there and success has to be inferred from studies of benthic invertebrates. The best examples of how birds use areas of created or restored mudflats are from UK studies.

Much of the realignment in the UK has been in low energy environments on the east coast. At two of the most intensively studied managed realignment sites in the UK (Tollesbury and Orplands on the Blackwater estuary in Essex), the sediments became consolidated as re-wetting with saltwater occurred. However, accretion of soft sediments was quite rapid and benthic invertebrates colonized relatively quickly and shorebirds and wildfowl soon began to use the site. Shelduck *Tadorna tadorna*, Dunlin *Calidris alpina*, Grey Plover *Pluvialis squatarola* and Redshank *Tringa totanus* probably exploited the polychaetes and *Hydrobia* that initially colonised the sites. In three to four years *Macoma balthica* colonised and particularly at Tollesbury this coincided with increasing usage by Red Knot *Calidris canutus*. Other species such as Eurasian Oystercatcher *Haematopus ostralegus*, which feed mainly on larger bivalves, tended to show very low usage of the site. Studies of managed realignment sites on the Wash and the Humber Estuary also suggest that waterbirds colonise within about three years (Badley & Allcorn 2006; Mander *et al*. 2007).

Many more studies look at changes in invertebrate numbers. The speed with which invertebrates colonise these sites tends to be in line with what can be predicted through knowledge of life history traits. Mobile species, and those that have a planktonic larval phase, such as *Nereis* and other polychaetes, and *Hydrobia* colonise in the first year or two. Bivalves and other species that have no planktonic larval phase or take time to grow to a suitable size, such as oligochaetes and larger bivalves, either fail to colonise or take several years to appear. This has implications for the rates of colonisation by particular guilds of birds, so that species that feed on small polychaetes are likely to colonise before those that feed on large bivalves, a feature observed at various UK realignment sites.

Apart from realignment, another common way in which intertidal mudflats are created is through the use of dredged material. These mudflats have been created in a number of countries and invertebrates rapidly colonise these if they are in the correct position in the tidal frame. The exact nature of the invertebrate assemblage is determined by the make up of the sediment used (sand/silt/mud content) and often are different to surrounding reference areas and both higher and lower densities of invertebrate prey have been reported.

How can new habitat creation schemes maximise benefits to waterbirds?

In summary, coastal intertidal habitats can be created or restored. The majority of cases where habitat has been recreated involved coastal sites that were created for reasons other than supporting wildlife and success, however it was measured, was often a very hit or miss affair. Most sites supported populations of waterbirds, but often failed to capture the diversity observed on natural areas.

Most studies looking at the processes underlying restoration/creation have been carried out at small scales in comparison with surrounding areas and often fail to capture the range of natural variation found at the larger scales at which migratory waterbirds usually operate. Successful restoration/creation may take time but, once the general roles of hydrodynamics, sediment dynamics and other forcing factors are understood, then wetland habitats can be created. An adequate supply of sediment is crucial to success. On the east coast of the UK, there is a plentiful supply of sediment and therefore it has been possible to recreate functioning mudflats that support waterbirds in 3-5 years. For example, at a managed realignment site at Paull Holme Strays on the Humber Estuary, a waterbird assemblage of similar composition to that of adjacent existing intertidal areas was supported within three years of creation (Mander *et al*. 2007). Despite this there are still many uncertainties surrounding the methods required to create habitats that will support specific waterbird species.

Studies of the beneficial use of dredged material have shown that invertebrates colonise and that as the sediments dewater and consolidate, and the created mudflats are shaped by the environmental factors, these assemblages change and produce the varied assemblages found on a natural mudflat. For the Severn, if dredged material is to be used to create mudflats, its success may well depend on the subsequent movement of sediment in the development through processes such as dredging, erosion or deposition – i.e. will new sediment be deposited and/or will existing sediment be re-suspended and deposited through tidal action. As sediments are deposited, they will dewater and consolidate and the makeup of the sediment as well as availability of soft sediment (through deposition, resuspension and deposition or bio-turbation) is important in determining invertebrate assemblages and densities. If sediment is resuspended or slumps lower in the tidal frame then these mudflats may not be viable in the long term. In managed realignment areas on the east coast of England, there has been a sufficient supply of new sediment being deposited in these newly-created areas through the sediment cells in the North Sea that bring new supplies of sediment down the east coast of the UK. Vertical accretion of these new areas has meant that there has been sufficient new soft sediment for invertebrates to colonise rapidly. A major uncertainty in the Severn is that going from a high- to lower energy environment might mean that there will be less movement of sediment which could lead to different conditions for benthic invertebrates. The tidal range and prism will be altered and detailed sediment modelling will be required to predict the range and areas of different types of sediment that will result. Sediment is key to any creation/restoration attempts and an understanding of they resulting types will give more confidence to the prediction of the impacts on benthic invertebrates and birds. In the Severn, specifically, benthic invertebrate densities are currently very low, and individual size is small, due to the high energy environment. Reducing the energy may well lead to mudflats that have fine-grained muddy sediments that are more stable and have increased densities of invertebrates which are likely to support different relative densities of wetland bird species than they do now.

Engineering of any created mudflat or saltmarsh is also key to success; it is important that small-scale habitat diversity is recreated. Restored sites have often lacked this range of micro-habitats and tend not to show such habitat diversity at a fine-scale. More recent (and larger scale) realignments have undertaken such surface modifications and have shown that if environmental conditions are suitable and there is a varied topography, the outcome is one where there is a complex mix of microhabitats that support a wide range of waterbirds. A successful outcome is therefore largely a case of “getting the recipe right”. Whatever the case, to maximise the likelihood of creating a fully functioning wetland encompassing the range of variation found in natural areas, it is thought that larger-scale projects with a varied topography are more likely to be successful (Atkinson *et al*. 2001). At present, our knowledge is limited and it is essential that new projects adopt an experimental approach and ensure that adequate monitoring is carried out at appropriate timescales.

Generally, once habitats are created, benthic fauna and birds respond fairly quickly if conditions are suitable. This is because coastal wetlands are often high-energy environments, at low elevations, and with high soil-water tables. As such, they are likely to resemble the surrounding natural environment in a relatively short time-frame, i.e. years rather than centuries. For example, created marshes in the high energy sandy environments of the Severn Estuary are virtually indistinguishable from surrounding marshes (e.g. Cone Pill in Gloucestershire). However, marshes in the muddy, lower-energy environments of some estuaries in SE England are often of a very different structure and support different vegetation types than surrounding natural marshes.

The track record in creating good quality habitats has, until recently, not been particularly good in terms of their biodiversity benefit, often because this has not been the primary reason for the work, as most realignment schemes have tended to be for flood protection purposes. In particular saltmarsh creation has not happened as predicted, often producing habitats of much lower quality and species diversity than surrounding natural marshes. This is because many early realignment schemes tended to make holes in sea walls without undertaking the engineering required to develop the creek systems that are needed to create habitats of high conservation value. In the longer term, a partnership is needed between ecologists, conservation bodies, governments and engineers. Only in this way will it be possible to set up the kind of large capital projects required to take the science forward and reach an understanding, not only of how to create coastal habitats, but also the impact they will have on waterbird populations.

In summary, sediment is key to any restoration process. Having a good understanding of the sediment dynamics post development will allow a much better prediction of the likely outcome of mudflat or saltmarsh creation in terms of its value to waterbirds and long-term persistence. There is sufficient knowledge to undertake the engineering to create habitats through managed realignment and some knowledge of how to modify them (for example including small scale topographic variation) but as this is a relatively new science taking an experimental approach and following up with longer-term monitoring is important if this science is to develop. In terms of the large-scale creation of mudflats in estuaries through use of dredged material there is less experience of this in NW Europe and bringing in expertise from other parts of the world will be necessary (e.g. Japan).

2.3.3 The need for ecologically linked areas

For the purpose of this study, the ecological functional unit for SPA birds is taken to be the existing SPA together with areas that are adjacent or close and actually or potentially (through compensation measures) ecologically linked. Note that for each of the species guilds described below generalisations have been made based on available information. Were any of the options to be taken forward it would be possible to provide more detailed information regarding the within-winter and through-the-tide movements of species from existing bird ringing and recovery data, and through detailed studies of waterbird movements on the Severn and elsewhere including colour-marking and resighting and using radio, satellite or GPS tracking techniques. This study would be key to optimising the design of such measures.

Primarily intertidal mudflat invertebrate feeders and intertidal mudflat bivalve specialists

Species in the guilds that primarily use intertidal habitat (intertidal invertebrate feeders and intertidal bivalve specialists) require areas of habitat to support their populations at all stages of the tidal cycle. This means that areas of intertidal feeding habitat that are exposed at low tide must be ecologically linked (i.e. in relatively close proximity, and preferably adjacent) to intertidal feeding sites that can be used by birds on the rising or falling tide. Birds also require relatively undisturbed high-tide roost sites either on saltmarsh, farmland or on other habitats adjacent to the intertidal feeding area. The creation of intertidal habitat that is exposed at low tide away from areas where there is intertidal habitat exposed on the rising and falling tide and suitable high-tide roost sites is therefore unlikely to provide satisfactory mitigation or compensation, particularly for species that are primarily intertidal invertebrate feeders or intertidal bivalve specialists.

Generalist wetland species and gulls

Generalist wetland species and gulls also use intertidal habitat at some stages of the tidal cycle. However, these species are likely to use freshwater habitats adjacent to (or within one or two kilometres of) the estuary at stages of the tidal cycle where intertidal habitat is not available. It is therefore more likely that the provision of freshwater habitats adjacent to intertidal areas as part of any mitigation or compensation package at sites either close to or far from the Severn could be of benefit for species in these guilds.

Primarily freshwater species and piscivores

These species use a wide range of freshwater habitats and are therefore less affected by intertidal loss as a result of option implementation than other species. Indeed no significant negative effects on the species in these guilds are predicted in the SEA as a result of implementation of any of the tidal power options. Unless significant negative effects to these species are predicted at a later stage (e.g. in any Environmental Impact Assessment that may be carried out if any tidal power option is taken forward) then there may not be any compensation requirement for these species. However they are considered in this report for completeness. A summary of WeBS counts for these species suggests that the numbers of freshwater sites of international or national importance for species in these two guilds at least equals, if not exceeds, the number of intertidal sites (Holt *et al.* 2009).

Site fidelity and habitat equivalency

In this report, site fidelity has been assessed using the 'WeBS Alerts Biological Filter' (Maclean & Austin 2008). This scoring system is used to assess the natural fluctuations in species' numbers within and between winters, and is calculated using a combination of measures of population size fluctuation, longevity, between-winter movements of birds and within-winter movements of birds. The score assigned reflects the typical behaviour of each species at a UK level. Species with the lowest scores are those that tend to have fluctuating population sizes, are short-lived and are highly mobile (i.e. large between- and within-winter movements). Conversely species with the highest scores are those that tend to have relatively stable populations, are long-lived and are site faithful (i.e. small between- and within-winter movements). Species with scores of five or below are classified as typically exhibiting low site-fidelity, those with scores of 6-8 as typically exhibiting high site-fidelity (Table 2).

Populations of site-faithful bird species are likely to take longer than other species to respond to any compensatory measures provided away from the Severn Estuary. Birds that are not site-faithful are likely to move to other sites away from the Severn fairly quickly if habitat were lost as a result of the implementation of a tidal power option, as it is thought that such species distribute themselves in response to food resources. However, it is uncertain how far birds would be likely to move or what differences there might be between species with differing migration strategies. Conversely, it is likely that individual birds of site-faithful species would not move far away from the Severn Estuary even if habitat were lost as a result of implementation of a tidal power option. Instead, colonisation of any new habitat provided away from the site would be most likely to occur through the recruitment of first-winter birds of these species, and the reduction of the population on the Severn is likely to occur through increased mortality of adult birds. This colonisation mechanism has been shown to occur in Redshank following the closure of the Cardiff Bay Barrage, even when alternative habitat was available a relatively short distance away (Burton *et al*. 2003; Burton & Armitage 2008), and we assume that other site-faithful species would behave in a similar way, although this is uncertain. This means that populations of relatively short-lived site-faithful species may develop at new sites more quickly than populations of longer-lived site-faithful species. It is likely that there would be an initial decline in the national (and possibly the flyway) population of site-faithful species following the implementation of a tidal power option, although it is possible that the population may recover in the longer term as any new sites provided away from the Severn are colonised. In order to minimise the likelihood of such population declines it would be necessary to provide any compensatory habitat creation at sites far from the Severn Estuary several years in advance of option implementation. The typical lifespan of the bird species the habitat is targeted to (given in table 2) should provide a reasonable guide to the likely time for species with high site-fidelity to colonise a new site. However it is important to note that in the case of newly created intertidal habitat, intertidal bivalve specialists would be likely to colonise several years after other intertidal invertebrate feeders as their bivalve prey have been shown to take several years to colonise such habitats, therefore it is several years before the habitat is suitable for specialist bivalve feeders.

Site fidelity of each species is shown in Table 2. At a guild level, almost all species that are primarily intertidal invertebrate feeders have high site fidelity, while all wintering gulls are thought to have low site-fidelity (although breeding gulls may have higher site-fidelity). Within the other species guilds there is a mixture of species with low and high site fidelity, although in general waders tend to have high site fidelity while wildfowl tend to have low site fidelity. The exceptions to this general pattern are European White-fronted Goose (which has high site fidelity) and Knot (which has low site-fidelity). This guild-level pattern suggests that any compensatory intertidal habitat created at a distance from the Severn would only slowly be colonised by those species that most depend on intertidal habitat for feeding (intertidal invertebrate feeders and some intertidal bivalve specialists). Site-faithful birds that winter on the Severn immediately prior to the implementation of a tidal power option would be likely to return to the site but experience increased mortality in the years following barrage closure until a stable population size, which could be supported on the modified Severn following implementation, is reached.

Mitigation and compensation measures based on managed realignment and topographic modification aim to compensate or mitigate for the intertidal habitats lost as a result of option implementation. The relative functionality of managed realignment compared to natural intertidal areas is outlined in section 2.3.2 above. Topographic modification is untested at this scale and therefore the likelihood of creating functional intertidal habitat using this method is unknown. Details of the potential for habitat creation using topographic modification are given in the topographic modification annex of the SEA (Severn Tidal Power 2009).

One potential compensatory measure is the creation of freshwater wetland habitat at sites close to the Severn Estuary. The creation of freshwater wetlands could not compensate for the predicted losses of intertidal invertebrate feeders or intertidal bivalve specialists. It is only likely to be effective as compensation for predicted losses of the generalist wetland species and some gulls (it is also likely to support freshwater species, although no significant effects are predicted to the species in this guild as a result of the tidal power options on the Severn, so compensation may not be necessary).

The likely effectiveness of this measure (for the guilds that use freshwater habitats) can be summarised by the proportions of UK sites supporting internationally or nationally important numbers of each species that are primarily freshwater habitat (Holt *et al*. 2009). Species in the generalist wetland species, gulls and primarily freshwater species guilds tend to be found in reasonable numbers at freshwater sites, with the proportion of nationally or internationally important sites that are freshwater ranging from 9% to 85% for these species. It is important to also note that even at estuarine sites some these species may be using freshwater wetlands adjacent to the estuary as well as tidal areas. Therefore the creation of freshwater wetlands close to the Severn may be at least partially effective as a compensation measure for the following designated SPA species: Bewick's Swan, European White-fronted Goose, Wigeon, Teal, Pintail, Pochard, Tufted Duck, Whimbrel and Curlew, as well as for other species that occur in nationally or internationally important numbers on the Severn (Mute Swan, Mallard, Shoveler, Avocet, Golden Plover, Lapwing, Black-tailed Godwit and Lesser Black-backed Gull). If the creation of freshwater wetlands were considered as a compensatory measure after the SEA stage, it would be possible to conduct more detailed analyses of WeBS data to calculate the proportion of these species' populations that are recorded on freshwater sites, the size of freshwater sites supporting each species, and estimates of the average density of each species supported at freshwater and intertidal sites. This would reduce the uncertainty regarding the habitat equivalency of freshwater wetlands compared to intertidal sites for these species.

The majority of species in the two intertidal guilds (primarily intertidal invertebrate feeders (except bivalve specialists), and bivalve specialists) rarely use freshwater habitats; therefore there are no nationally or internationally important freshwater sites in the UK. Although a number of the species in these guilds will use freshwater habitats at some times of the year, or at certain stages of the tidal cycle, they are only supported at very low densities on freshwater sites in comparison to intertidal habitat. The creation of freshwater wetlands would not provide equivalent habitat for species in these guilds to compensate for the intertidal habitat that would be lost as a result of the implementation of a tidal power option. This means that for several key SPA species that feed on intertidal habitat (Shelduck, Dunlin, Redshank, Ringed Plover, Grey Plover and Spotted Redshank) the only habitat creation measures that are likely to provide effective mitigation/compensation are a combination of topographic modification and managed realignment within/adjoining the Severn, or managed realignment at a distance from the Severn to create new mudflats.

2.3.5 Implications for flyway populations of delivering compensatory habitat 'out of unit'

If compensatory habitat were delivered at a distance from the Severn (i.e. in other parts of the UK) then there is considerable uncertainty as to whether it would be colonised by the bird populations currently using the Severn. Creating new sites at a distance from the Severn is arguably not within the scope of current guidance on compensation, therefore consideration would also need to be given as to the legal implications of providing compensatory habitat elsewhere.

Some waterbird species are relatively mobile (those with low site-fidelity scores in Table 2) and these include the gulls and many of the generalist wetland wildfowl species including Shelduck, Gadwall, Bewick's Swan, Wigeon, Teal, Pintail, Pochard and Tufted Duck. Many of these species already exhibit variability in the numbers present on the Severn and in the UK as a whole between winters (Holt *et al*. 2009; Maclean & Austin 2008). It is thought that one of the reasons for variation in numbers is that birds may be "short-stopping" on their migrations from northern and eastern Eurasia. This means that birds winter further east in continental Europe due to the milder winters of recent years, or spend longer at sites further east in continental Europe before migrating onwards to the Severn

(Wernham *et al*. 2002). These species already show variability in their winter distributions, and a tendency to winter further east in milder winters, which are likely to become more frequent in response to climate change (UKCP09 2009). It therefore seems likely that providing compensatory habitat at sites further east in the UK may potentially be beneficial for these species, and could result in individual birds simply redistributing in response to reduced habitat availability on the Severn, and increased habitat availability at the newly created site(s). This is highly uncertain as such compensatory measures have never been attempted before, however it would be possible to analyse existing Wetland Bird Survey data to establish the extent to which birds are wintering further east and therefore give some indication of the likelihood of sites further east being colonised by birds that currently use the Severn. However, because of these issues it is uncertain whether such measures could entirely compensate for the reduction in the population size of the SPA waterbird species as a result of the implementation of one of the tidal power options, and there is a risk that birds from the Severn would not find newly created habitat at a distance from the Severn if they were displaced.

Species that are site-faithful (those with high site-fidelity scores in Table 2) include most intertidal invertebrate feeders and some intertidal bivalve specialists. The generalist wetland waders also largely fall into this category. Site-faithful species currently supported on the Severn include more than 1 % of the international populations of Ringed Plover, Dunlin and Redshank, and more than 1 % of the national populations of European White-fronted Goose, Grey Plover, Curlew and four other site-faithful species not listed in the SPA designation (Avocet, Golden Plover, Lapwing and Black-tailed Godwit). Two other site faithful species (Whimbrel and Spotted Redshank) are listed in the SPA designation but do not currently occur on the Severn in nationally or internationally important numbers.

All of these site-faithful species are likely to respond rather differently from the mobile species to habitat creation in other parts of the UK. It is thought that most site-faithful species colonise a site in their first winter based on a range of factors (e.g. food supply, winter temperature, and migration distance from the breeding grounds). There is some evidence from colour-ringing and resighting of Black-tailed Godwits that first-winter birds sample a range of sites before settling. Thereafter, most individuals will return to the site where they settled during their first winter in every subsequent year of life. If there were significant loss of habitat, and therefore a reduction in the carrying capacity, on the Severn as a result of implementation of a tidal power option, it is likely that adults of site-faithful species would continue to spend winters on the Severn. Reductions in food availability would most likely lead to increases in mortality rates of these individuals. The colonisation of any new habitat provided in other parts of the UK would most likely be driven by the recruitment of first-year birds. The first individuals to colonise such new sites may have relatively high survival rates due to high food abundance (assuming the site did not immediately reach carrying capacity). Because the redistribution of site-faithful species depends on demographic processes such as recruitment and survival, rather than simply individual birds moving to other sites, the colonisation rate of compensatory habitat provided at a distance from the Severn is likely to be much slower for these site-faithful species than for more mobile species. There is therefore less certainty in the likelihood of success of such measures for site-faithful species (including Dunlin, Redshank, European White-fronted Goose, Ringed Plover, Grey Plover, Spotted Redshank, Whimbrel and Curlew) and a higher risk associated with providing compensatory habitat for these species at a distance from the Severn.

One example of site-faithful species staying in the vicinity of a site rather than moving a great distance following habitat loss is Redshank in Cardiff Bay. Following the closure of the barrage Redshank were displaced to other nearby sites, but mortality rates increased for at least three years afterwards (Burton 2006; Burton *et al*. 2006; Burton & Armitage 2008).

Although most wader species are site-faithful, the distributions of several species have been shown to shift towards the north-east in response to climate change in recent decades (Austin & Rehfisch 2005; Maclean *et al*. 2008), and numbers of some species have been increasing in the Netherlands, perhaps indicating that some birds are moving there from this country (Hustings *et al*. 2008). It is likely that these redistributions occur as a result of demographic processes such as recruitment and survival, as described above, although it is possible that some individuals of slightly less site-faithful species are also "short-stopping" on their migrations. The provision of compensatory intertidal habitat creation at sites elsewhere in the UK, but to the east or north-east of the Severn Estuary, may therefore be beneficial for these species, although it may several years for such sites to be colonised and achieve stable population sizes. If populations of some species continue to move east and north in response to further predicted climate change (UKCP09 2009) then the potential benefit of newly created sites in these areas could increase in the future. However this is highly uncertain, not least because birds may continue to move east and north to sites outside the UK.

It is possible that the flyways of some species may not be supported by providing compensatory habitat at a distance from the Severn, for example on the east coast of the UK. This is most likely to be a problem for species that migrate to the north-west (Iceland and Greenland), as species that migrate to the east or northeast will pass the east coast on their migration routes, thus their migrations would in fact be shorter if a site on the east coast were colonised. Furthermore, all of these species already winter at a range of sites on the east coast of the UK.

Key species that migrate from Iceland and Greenland to the Severn include the passage populations of Dunlin, Ringed Plover and Whimbrel, a proportion of the wintering populations of Redshank, Golden Plover and Lesser Black-backed Gull, and the entire wintering populations of Knot and Black-tailed Godwit. There is an increased risk that these species (compared to species that migrate from breeding grounds to the east) may not be supported by sites at a distance from the Severn, however all of these species do occur at a range of sites including estuaries on the east coast of the UK. For wintering populations, there is some evidence from colour-ringing studies of Black-tailed Godwits that first-winter birds sample many sites before settling and so they are likely to find new habitats created at a distance from the Severn, for example on the east coast of the UK. However adult populations of most of these species are site-faithful and are therefore birds that winter on the Severn prior to the implementation of a tidal power option are unlikely to move to newly created sites (as described above). The situation for passage birds is less clear; Ringed Plover, Whimbrel and the *schinzii* race of Dunlin (the race that passes through the UK before onward migration) all occur primarily on the west coast in spring but return in autumn through both east and west coast sites. At present it is unclear whether there is flexibility in their migration routes. Substantial further studies using GPS tracking or colour-ringing and resighting of large numbers of birds of these species that pass through both west-coast and east-coast sites would be required to establish their flexibility to move between sites, especially in spring when they are under considerable time pressure to arrive on the breeding grounds at snow melt to enable them to breed in the short Arctic summer.

The Severn Estuary is historically considered as a refuge for waterbirds during severe winters because of its location in the south-west of the UK where winter weather tends to be milder than further east in the UK or in continental Europe. It is important to note that any habitat creation on the east coast would not support this function of providing a refuge in severe winter weather, even if waterbirds use it in winters without severe weather.

2.3.6 Compensation ratios

Habitats Directive guidance suggests that the area of compensatory habitat provided should be at least twice the area lost. However, the ratio of compensatory habitat compared to lost habitat that would need to be provided to compensate for waterbird losses (i.e. support the number of waterbirds predicted to be lost) on the Severn depends on a range of factors and is therefore uncertain. As on any estuary there are considerably different densities of waterbirds in different parts of the estuary, and further each species tends to use particular parts of the estuary. This means that there are substantial areas of the estuary with very few birds, and therefore compensation for the numbers of birds lost needs to provide habitat in an appropriate part of an estuary with the appropriate sediment type for the species in question. The density of birds on the area lost and the area created will determine the compensation ratio that is required. For example, the Welsh Grounds supports a significant number of Curlew but they occur at low density over a very large area. If this area were lost compensation could potentially be provided on a smaller area if the habitat created was a mud-sand mix with high densities of the large invertebrate species that curlew feed on. Conversely, Dunlin occur at very high densities in parts of Bridgwater Bay. If this area were lost a higher than 2:1 ratio of compensatory habitat may be required to provide sufficient feeding area for that number of birds, as the density of birds supported on created inter-tidal mudflat may be substantially lower than that on the area lost. Necessarily, defining the ratio of compensatory habitat requires an understanding of the number of each species that needs to be supported and the likely density that would be supported on the habitat that will be created. Furthermore, the most crucial factor is likely to be our ability to engineer and successfully retain the exact sorts of habitats the individual species require.

Understanding of how to achieve this is currently limited (see section 2.3.2 above) so the density of each bird species that would be supported on newly created habitat is highly uncertain. It is therefore realistic to anticipate that if a tidal power option were implemented any compensatory habitat requirements would involve creating new areas of inter-tidal that were larger than those lost to maximise the chance of suitable habitat developing to support the number of birds lost. This would also be likely to be a requirement in relation to compensation for intertidal habitat features of the SAC.

2.3.7 Gaps in knowledge

There are a number of areas of uncertainty in this work, including:

- The numbers of birds of each species likely to be lost from the Severn under each tidal power option.
- How to create optimal intertidal habitat for birds through managed realignment or topographic modification, and our ability to engineer the required types of intertidal habitat.
- The density of waterbirds of each species likely to be supported on created intertidal habitat, compared to natural intertidal habitat (and therefore the ratio of compensatory habitat that would need to be provided), and how long it would take to reach this density after creation.
- The density of waterbirds of each species likely to be supported on freshwater habitats, relative to intertidal habitats that would be lost under tidal power options (and therefore the ratio of compensatory habitat that would need to be provided).
- Through-the-tide movement distances of birds (for example from high-tide roosts to mid-tide feeding sites, to low-tide feeding sites). This limits our ability to define the distance within which all of these requirements need to be sited in any compensation packages.
- Within- and between-winter movements of birds between estuaries in the UK (and beyond). This is important in understanding the likelihood of new habitat created at a distance from the Severn being colonised by the same individual birds that currently use the Severn, and the rate at which this might happen.
- Colonisation rates of new sites by new birds, and demography of site-faithful species. This is important in understanding how long in might take for new populations of site-faithful species to build up on newly created habitat at a distance from the Severn.
- The rate at which the wintering distributions of some bird species might change in response to future climate change.
- Cold weather movements of birds. Better understanding of this would improve our certainty of the importance of the Severn as a cold weather refuge.

Many of these uncertainties could be addressed through further research. Suggested methods to achieve this are given in the following sections.

<u>Number of birds likely to be lost from the Severn Estuary under each tidal power option</u>

Some methods for reducing the uncertainty surrounding the number of birds likely to be lost from the Severn Estuary under each tidal power option are given in the waterbirds topic paper of the SEA (Severn Tidal Power 2010). Improving predictions regarding the type of sediments in the reduced-energy system following the implementation of a tidal power option, and predictions of the types and densities of invertebrates likely to occur in that sediment, would be extremely valuable in improving predictions for changes to waterbirds through individual-based modelling. A number of other measures could also improved predictions of the likely number of waterbirds that would be lost, and these are detailed in the waterbirds topic paper.

<u>How to create optimal intertidal mudflat habitat for waterbirds, and densities of waterbirds supported on created compared to natural intertidal habitat</u>

Our understanding of the best areas and methods to create new intertidal mudflats for birds could be greatly improved through a detailed investigation and review of all situations where intertidal mudflat has been created either inadvertently or by design. Such a study could compare the densities of different waterbird species supported on created mudflats and on natural mudflats in nearby estuaries. The long-term development of created mudflats and their bird populations (over decades) could be studied in situations where new mudflat has been created inadvertently. This includes many east-coast estuaries where sea walls were breached in the 1953 floods and not rebuilt in the same places. For example the Blythe and Alde estuaries have relatively new mudflats dating from this time. Studies of more recent managed realignment sites (where bird numbers have been monitored) could help to determine the time before a stable density of birds is achieved. Improving our understanding of the effects of changes to estuaries on birds would be very valuable in informing a wide range of future conservation management including managed realignment, not just in relation to Severn tidal power projects.

Developing the habitat association modelling used in the waterbirds topic paper of SEA to predict waterbird densities at a mudflat level (rather than the whole-estuary scale) would improve our understanding of the within-estuary distribution of birds and may enable predictions of the capacity of topographic modification areas at given locations in the estuary. The advantage of this approach over individual-based models is that where it is difficult to predict future invertebrate densities, using estuary morphology as a proxy means that realistic predictions of future waterbird densities can still be generated. Habitat association models can also be used to predict the likely future densities of a wider range of waterbird species than individual-based models.

<u>The density of waterbirds supported on freshwater wetlands compared to intertidal habitat</u>

The creation of freshwater wetlands is only likely to be effective as compensation for losses of the generalist wetland species and gulls (it is also likely to support freshwater species, although no significant effects are predicted to the species in this guild as a result of the tidal power options on the Severn, so compensation may not be necessary). As outlined above it could not compensate for the predicted losses of intertidal invertebrate feeders or intertidal bivalve specialists. However, if the creation of freshwater wetlands were considered as a compensatory measure for generalist wetland species after the SEA stage, it would be possible to conduct more detailed analyses of existing Wetland Bird Survey data to calculate the proportion of these species' populations that are recorded on freshwater sites, and estimates of the average density of each species supported at freshwater and intertidal sites. This would reduce the uncertainty regarding the habitat equivalency of freshwater wetlands compared to intertidal sites for this species guild and allow recommendations to be made regarding the ratio of the area of freshwater habitat creation compared to the area of intertidal habitat loss that would be required to support equivalent numbers of each species. Such a study would be relatively straightforward as the data required already exist.

<u>Through-the-tide movement distances of birds</u>

For intertidal feeding species (e.g. Shelduck, Dunlin, Redshank, Ringed Plover, Grey Plover) in particular, it is important that a range of ecologically-linked sites that support the needs of the species at different stages of the tidal cycle are provided close together (within the distance that the birds would normally move during a tidal cycle). Were any of the options to be taken forward it would be possible to provide more detailed information regarding through-the-tide movement distances of birds through detailed studies of waterbird movements. GPS tracking techniques using tags that record almost continuously would be the best method to use for such a study because very regular information on the location of birds would be required to establish movement patterns within a single tidal cycle. However other techniques such as colour-ringing and resighting or radio-tracking could also provide useful (although less detailed) information. Ideally, movement patterns should be studied on a range of estuaries, including the Severn, to establish the range of distances that birds will move between roosting sites and feeding sites at different stages of the tidal cycle.

<u>Within- and between-winter movements of waterbirds</u>

If the creation of new intertidal habitats at a distance from the Severn is to be considered, it would be valuable to investigate the within- and between-winter movements of the key waterbird species that the measure is targeted for. This analysis could be done using existing ringing data (although there may not be sufficient data for all species). This would help to determine the likelihood of birds of non-site-faithful species colonising compensatory habitat at a distance from the Severn if they were displaced from the Severn following the implementation of a tidal power option. It would also reduce the uncertainty as to which of the more site-faithful species are unlikely to move to sites at a distance from the Severn.

Colonisation rates of new sites and demography of site-faithful species

The colonisation rates of new sites and the demography of site-faithful species in relation to changing distributions is uncertain as it depends on a range of factors. These include the rate of change of distributions in response to climate change, settlement patterns of first-winter birds and the typical lifespan of the species in question. Reducing uncertainty around some of these issues has been described elsewhere, but further reducing uncertainty regarding colonisation rates of new sites could be undertaken through studies of changes in bird numbers on existing or planned (in the near future) habitat creation schemes such as managed realignment.

Rate of change of wintering distributions in response to climate change

The rate of change in the distribution of some wader species has already been quantified using data from the Wetland Bird Survey and other surveys across Europe (Maclean *et al*. 2008). It would be possible to conduct a similar analysis using the same existing data to determine the rate of change in the distributions of other waterbirds such as wildfowl (for example Bewick's Swan, European White-fronted Goose, Gadwall, Wigeon, Teal, Pintail, Shoveler, Pochard and Tufted Duck).

Cold weather movements of birds

Analyses of existing ringing data and data from the Wetland Bird Survey in relation to weather could potentially improve our understanding of the cold weather movements of birds, but there may not be sufficient data for all species to quantify the importance of the Severn as a cold weather refuge. Since these data already exist it would be relatively inexpensive to conduct an exploratory analysis to determine whether cold-weather movements can be quantified.

SECTION 3

CONCLUSIONS

3 CONCLUSIONS

The likely effectiveness of each mitigation or compensation measure for the designated SPA species in each species guild is summarised in Table 3.

Topographic modification to create intertidal habitat on the Severn Estuary is likely to be partially effective in mitigating the effects of intertidal habitat loss for intertidal invertebrate feeders, intertidal bivalve specialists, generalist wetland species and gulls. It is unlikely to have any significant benefits for piscivores and freshwater species. This measure has only been used at a relatively small scale in the past. Therefore, the likely success of this measure at the scale that would be required to compensate for predicted waterbird losses in the Severn is unknown.

The introduction of new refuges or roosting sites where saltmarsh roosting areas have been lost is an established method that has been used elsewhere for waterbirds with some success, for example in Cardiff Bay (Burton *et al.* 2003) and Teesmouth (Burton *et al.* 1996). Although this has not regularly been used as mitigation or compensation for SPAs, it is likely to be effective or partially effective in replacing roosting sites for all species.

Managed realignment at sites adjacent to the Severn Estuary has been studied as part of the SEA and is thought to be likely to largely create saltmarsh (as opposed to mudflat) habitats, and is unlikely to be possible at all if the B3 barrage were implemented. This measure is therefore likely to be effective or partially effective compensation only for generalist wetland species that feed on saltmarsh (for example Bewick's Swan, European White-fronted Goose, Wigeon), or for intertidal mudflat feeding species that require such areas as high-tide roost sites. Piscivores and freshwater species are unlikely to be affected by this measure. The same species guilds are likely to benefit from managed realignment at distance from the Severn Estuary, but creation of mudflat habitats at a distance from the Severn could also provide feeding opportunities for intertidal mudflat feeding species (e.g. Shelduck, Dunlin, Redshank, Ringed Plover, Grey Plover). However it is likely that this would only be partially effective (see below). Managed realignment is an established method that can create good quality habitat. However there are many examples where the habitat created has been of lower quality or diversity than natural intertidal habitat in the area, and thus supports lower densities of birds. It is therefore important to carefully design any areas of managed realignment to provide the best possible habitat quality. The web-based ABPmer managed realignment guide (http://www.abpmer.net/omreg/) provides useful information on techniques that can be used to achieve this. It is important to note that species in the intertidal bivalve specialist guild are likely to colonise newly created intertidal habitat several years later than other intertidal invertebrate feeders. This is because the bivalve prey on which such species depend take several years to colonise newly created habitats, and thus these habitats are not suitable for bivalve feeding waterbirds in the early years.

Creation of freshwater wetlands is an established practice for SPA compensation or mitigation and methods for creating high quality freshwater habitats are generally better established than those for creating intertidal areas. The creation of new freshwater wetland habitats adjacent to the Severn Estuary would be likely to be effective for freshwater species, and either completely or partially effective for generalist wetland species and gulls. It may also be partially effective for piscivores. However, there would only be likely to be very low-level benefits for intertidal invertebrate feeders and intertidal bivalve specialists, as freshwater habitats generally only support low densities of these species. As it is primarily the species in these guilds that are predicted to be most adversely affected by the proposed tidal power options, and for which compensation will be required, creation of freshwater wetlands would not fulfil the majority of the compensation requirements for waterbirds should a tidal power option be developed.

The creation of new intertidal habitats at distance from the Severn, either through managed realignment or topographic modification, is likely to be less effective than providing such habitats locally, although it could still be partially effective for several species guilds. Colonisation of sites to the east of the UK may be aided by eastward distribution changes of some species in response to climate change. However, many of the intertidal invertebrate feeders, intertidal bivalve specialists and generalist wetland species that would benefit from these measures are very site-faithful. Thus the re-distribution of these species to new sites could take many years and, for site-faithful species, is likely to be driven by high mortality rates on the Severn combined with recruitment of first-year birds to new sites elsewhere. Many of the intertidal invertebrate feeders and intertidal bivalve specialists also have high site dependence (50% or more of the Great Britain population is found on 10 or fewer sites). Populations of these species with high site dependence are likely to be affected more strongly by any negative effects on the Severn Estuary than populations of species with more widespread distributions. Thus, it is likely that the recovery species populations that are site dependent would take longer than other species, and may further reduce the rate of colonisation of any new intertidal habitat created at a distance from the Severn. Any sites created on the east coast of the UK would be unlikely to fulfil the role of the Severn as a refuge for waterbirds in severe weather, as it only fulfils this function because of its geographical location in the south-west. There is also uncertainty as to whether sites on the east coast would fulfil the role of the Severn as a stop over site for passage migrant birds, notably Ringed Plover, Whimbrel and the *schinzii* race of Dunlin, particularly during spring migration when these species primarily occur on the west coast. However, despite these limitations it is likely that intertidal habitat creation at sites elsewhere in the UK could be partially effective for a range of species, but this conclusion is based on expert judgement only as there is no precedent for such measures. Therefore there is considerable uncertainty surrounding this conclusion and a risk that compensatory habitat provided at a distance from the Severn may not be effective for waterbirds. The uncertainty and risk surrounding this measure could be reduced (but not eliminated) through the further studies described above, and we suggest that such studies would be essential before this measure could be recommended.

Table 3. Summary of the effectiveness of proposed compensation measures for each SPA waterbird guild. "Established methods" are those that have been proven to be successful elsewhere in compensating for the effects of developments on waterbirds. "Established practice" refers to whether the measure is an established SPA mitigation or compensation measure.

Measure	Guild	Effectiveness[1]	Established method?	Example(s)	Established practice?
Topographic modification (intertidal habitat creation) to prevent or reduce effects of intertidal loss.	Intertidal invertebrate feeders	2	Not at this scale (but some small scale projects)	Parkstone, Poole Harbour (see Topographic modification report)	NO
	Intertidal bivalve specialists	2			
	Freshwater species	N/A			
	Generalist wetland species	2			
	Gulls	2			
Introduction of new refuges and/or bird roost sites within the estuary where saltmarsh roosting areas have been lost.	Intertidal invertebrate feeders	3	YES Has been used elsewhere with some success	Cardiff Bay (Burton *et al.* 2003) Teesmouth (Burton *et al.* 1996)	NO (not regularly used)
	Intertidal bivalve specialists	3			
	Freshwater species	3			
	Generalist wetland species	3			
	Gulls	3			
Managed re-alignment adjoining the Severn Estuary to create intertidal habitat	Intertidal invertebrate feeders	2	YES	Freiston Shore on the Wash - 66 ha intertidal habitat created (Badley & Allcorn 2006)	YES
	Intertidal bivalve specialists	2			
	Freshwater species	N/A			
	Generalist wetland species	3			
	Gulls	2			
Managed re-alignment at distance from the Severn Estuary to create intertidal habitat	Intertidal invertebrate feeders	2	YES	Freiston Shore on the Wash - 66 ha intertidal habitat created (Badley & Allcorn 2006)	NO
	Intertidal bivalve specialists	2			
	Freshwater species	N/A			
	Generalist wetland species	2			
	Gulls	1			
Creation of freshwater wetland habitat close to the Severn Estuary	Intertidal invertebrate feeders	1	YES	Newport Wetlands Reserve (compensation for Cardiff Bay barrage)	YES
	Intertidal bivalve specialists	1			
	Freshwater species	4			
	Generalist wetland species	3			
	Gulls	3			

[1] Effectiveness is scored on a five-point scale where: 0 = ineffective
1 = effective at a very low level (e.g. new habitat that may support a low density of some SPA species)
2 = partially effective for some SPA species in the guild
3 = effective for some SPA species in the guild, partially effective for other SPA species in the guild
4 = completely effective for all SPA species in the guild

SECTION 4

GLOSSARY

4 GLOSSARY

Term	Definition
Barrage	A manmade obstruction across a watercourse to retain a head of water on the rising tide, and then run the water through turbines when the tide level drops.
Compensation	Measure which makes good for loss or damage to an SAC or SPA feature, without directly reducing that loss/damage.
Effect	Used to describe changes to the environment as a result of a tidal power option.
Far-field effects	Effects that are felt outside the Severn Estuary study area.
Hydrodynamics	The science of physical forces acting on the water.
Natura 2000	Natura 2000 is the European Union-wide network of protected areas, recognised as 'sites of Community importance' under the EC Habitats Directive (Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora). The Natura 2000 network includes two types of designated areas: Special Areas of Conservation (SAC) and Special Protection Areas (SPA).
Negative effects	Changes which are unfavourable for an SEA receptor.
Ramsar site	Ramsar sites are designated under the International Convention on Wetlands of International Importance 1971 especially as Waterfowl Habitat (the Ramsar Convention).
Receptor	An entity that may be affected by direct or indirect changes to an environmental variable.
Site of Special Scientific Interest (SSSI)	Designated under the Wildlife and Countryside Act 1981, any land considered by Natural England to be of special interest because of any of its flora, fauna, or geological and physiographical features.
Special Area of Conservation (SAC)	Strictly protected site designated under the EC Habitats Directive 92/43/EEC. Article 3 of the Habitats Directive requires the establishment of a European network of important high-quality conservation sites that will make a significant contribution to conserving the 189 habitat types and 788 species identified in Annexes I and II of the Directive (as amended). The listed habitat types and species are those considered to be most in need of conservation at a European level (excluding birds).
Special Protection Area (SPA)	Strictly protected site classified in accordance with Article 4 of the EC Directive on the Conservation of Wild Birds (79/409/EEC), also known as the Birds Directive. They are classified for rare and vulnerable birds, listed in Annex I to the Birds Directive, and for regularly occurring migratory species.

Term	Definition
Strategic Environmental Assessment (SEA)	Term used to describe environmental assessment as applied to policies, plans and programmes. 'SEA' is used to refer to the type of environmental assessment required under the SEA Directive.
Tidal Prism	The difference between the mean high-water volume and the mean low-water volume of an estuary

SECTION 5

REFERENCES

5 REFERENCES

Atkinson, P.W., Crooks, S., Grant, A. & Rehfisch, M.M. (2001) *The success of creation and restoration schemes in producing intertidal habitat suitable for waterbirds*. English Nature Research Report 425. English Nature, Peterborough.

Austin G.E. & Rehfisch, M.M. (2005) Shifting nonbreeding distributions of migratory fauna in relation to climate change. *Global Change Biology*, **11**, 31-38.

Badley, J. & Allcorn, R.I. (2006) Changes in bird use following managed realignment at Freiston Shore RSPB Reserve, Lincolnshire, England. *Conservation Evidence*, **3**, 102-105.

Burton, N.H.K. (2006) The impact of the Cardiff Bay barrage on wintering waterbirds. *Waterbirds around the world*. Eds. G.C. Boere, C.A. Galbraith & D.A. Stroud. The Stationery Office, Edinburgh, UK, p. 805.

Burton N.H.K. & Armitage M.J.S. (2008) Settlement of Redshank *Tringa totanus* following winter habitat loss: effects of prior knowledge and age. *Ardea*, **96**, 191-205.

Burton, N.H.K., Evans, P.R. & Robinson, M.A. (1996) Effects on shorebird numbers of disturbance, the loss of a roost site and its replacement by an artificial island at Hartlepool, Cleveland. *Biological Conservation*, **77**, 193-201.

Burton, N.H.K., Rehfisch, M.M. & Clark, N.A. (2003) *The effect of the Cardiff Bay barrage on waterbird populations. Final report*. BTO Research Report No. 343 to the Council of the City and County of Cardiff. BTO, Thetford.

Burton, N.H.K., Rehfisch, M.M., Clark, N.A. & Dodd, S.G. (2006) Impacts of sudden winter habitat loss on the body condition and survival of Redshank *Tringa totanus*. *Journal of Applied Ecology*, **43**, 464-473.

Castelijns, H., van Kerkhoven, W. & Maebe, J. (1997) *Vogels Van Het Sieperdaschor, Over Een Niet Voorziene Dijkdoorbraak En De Onverwacht Gunstige Gevolgen Die Dat Voor Vogels Had*. Natuur-beschermingsvereniging de Steltkluut in samenwerking met het RIKZ ed. Terneuzen en Middelburg.

Eertman, R.H.M., Kornman, B.A., Stikvoort, E. & Verbeek, H. (2002) Restoration of the Sieperda Tidal Marsh in the Scheldt Estuary, The Netherlands. *Restoration Ecology*, **10**, 438–449.

Esselink, P. (2000) *Nature management of coastal salt marshes. Interac-tions between anthropogenic influences and natural dynamics*. Koeman en Bijerk bv, Haren, The Netherlands.

Holt, C.A., Austin, G.E., Calbrade, N.A., Mellan, H. Thewlis, R.M., Hall, C., Stroud, D.A., Wotton, S.R. & Musgrove, A.J. (2009) *Waterbirds in the UK 2007/08: The Wetland Bird Survey*. BTO/WWT/RSPB/JNCC, Thetford.

Hustings, F., Koffijberg, K., van Winden, E., van Roomen, M., SOVON Ganzen- en Zwanenwerkgroep & Soldaat L. (2008) *Watervogels in Nederland in 2006/07*. SOVON-monitoringrapport 2008/04, Waterdienst-rapport 2008.061. SOVON Vogelonderzoek Nederland, Beek-Ubbergen.

Maclean, I.M.D. & Austin, G.E. (2008) *Wetland Bird Survey Alerts 2004/2005 (Release 2): Changes in numbers of wintering waterbirds in the Constituent Countries of the United Kingdom, Special Protection Areas (SPAs) and Sites of Special Scientific Interest (SSSIs)*. BTO Research Report 492. BTO, Thetford.

Maclean, I.M.D., Austin, G.E., Rehfisch, M.M., Blew, J., Crowe, O., Delany, S., Devos, K., Deceuninck, B., Gunther, K., Laursen, K., van Roomen, M. & Wahl, J. (2008) Climate change causes rapid changes in the distribution and site abundance of birds in winter. *Global Change Biology*, **14**, 2489-2500.

Mander, L., Cutts, N.D., Allen, J. & Mazik, K. (2007) Assessing the development of newly created habitat for wintering estuarine birds. *Estuarine Coastal and Shelf Science*, **75**, 163-174.

Robinson, R.A. (2005) BirdFacts: species profiles of birds occurring in Britain and Ireland. BTO Research Report 407, BTO, Thetford (http://www.bto.org/birdfacts).

Severn Tidal Power (2009) Severn Tidal Power SEA Topic Paper Annex A - Investigation into the feasibility of using topographic modification to prevent and reduce the effect of intertidal losses resulting from a tidal barrage scheme on the Severn Estuary. PB/BV Consortium Paper. Draft 3. Issued 5th November 2009. 77pp.

Severn Tidal Power (2010) Severn Tidal Power SEA Topic Paper. Waterbirds. BTO (PB/BV Consortium) Paper. Draft D1. Issued 12th January 2010.

UKCP09 (2009) UK Climate Projections, 2009. Website: http://ukclimateprojections-ui.defra.gov.uk/ui/admin/login.php published 18 June 2009, Crown Copyright 2008.

WAVE (2001a) *Guideline for the conservation and creation of ecosystems in relation to coastal development. Volume 1. Introduction*. Waterfront Vitalization and Environment Research Center, Tokyo.

WAVE (2001b) *Guideline for the conservation and creation of ecosystems in relation to coastal development. Volume 2. Technologies for the conservation and creation of tidal flats*. Waterfront Vitalization and Environment Research Center, Tokyo.

Wernham, C.V., Toms, M.P., Marchant, J.H., Clark, J.A., Siriwardena, G.M. & Baillie, S.R. (eds) (2002) *The Migration Atlas: movements of the birds of Britain and Ireland*. T. & A.D. Poyser, London.

APPENDIX 1

WATERBIRD OR SEABIRD SPECIES THAT REGULARLY OCCUR WITHIN THE SEVERN ESTUARY AND ARE LISTED AS RECEPTORS IN THE WATERBIRDS TOPIC PAPER OF THE SEVERN TIDAL POWER SEA

APPENDIX 1 WATERBIRD OR SEABIRD SPECIES THAT REGULARLY OCCUR WITHIN THE SEVERN ESTUARY AND ARE LISTED AS RECEPTORS IN THE WATERBIRDS TOPIC PAPER OF THE SEVERN TIDAL POWER SEA.

Receptor	**SPA feature (SPA review (Stroud *et al.* 2001) features in brackets)**	**Ramsar feature**	**SSSI feature**
Mute Swan *Cygnus olor*			
Bewick's Swan *Cygnus columbianus*	+	+	+
European White-fronted Goose *Anser albifrons albifrons*	+	+	+
Shelduck *Tadorna tadorna*	+	+	+
Wigeon *Anas penelope*	+	+	+
Gadwall *Anas strepera*	+	+	+
Teal *Anas crecca*	+	+	+
Mallard *Anas platyrhynchos*	(+)		
Pintail *Anas acuta*	+	+	+
Shoveler *Anas clypeata*	(+)	+	+
Pochard *Aythya ferina*	+	+	+
Tufted Duck *Aythya fuligula*	+		
Cormorant *Phalacrocorax carbo*			
Little Egret *Egretta garzetta*		+	
Water Rail *Rallus aquaticus*		+	
Oystercatcher *Haematopus ostralegus*			
Avocet *Recurvirostra avosetta*			
Ringed Plover *Charadrius hiaticula*	+	+	+
Golden Plover *Pluvialis apricaria*			+
Grey Plover *Pluvialis squatarola*	+		+
Lapwing *Vanellus vanellus*	(+)		
Knot *Calidris canutus*			
Dunlin *Calidris alpina*	+	+	+
Ruff *Philomachus pugnax*		+	
Snipe *Gallinago gallinago*			
Black-tailed Godwit *Limosa limosa*			+
Bar-tailed Godwit *Limosa lapponica*			
Whimbrel *Numenius phaeopus*	+	+	+
Curlew *Numenius arquata*	+	+	+
Spotted Redshank *Tringa erythropus*	+	+	
Greenshank *Tringa nebularia*		+	
Redshank *Tringa totanus*	+	+	+
Turnstone *Arenaria interpres*			
Black-headed Gull *Chroicocephalus ridibundus*			
Common Gull *Larus canus*			
Lesser Black-backed Gull *Larus fuscus*		+	+
Herring Gull *Larus argentatus*		+	

APPENDIX 2

SPECIES GUILDS, AND TRAITS OF SPECIES WITHIN EACH GUILD, FOR SEA RECEPTOR SPECIES NOT INCLUDED IN THE ASSESSMENT ABOVE

APPENDIX 2 SPECIES GUILDS, AND TRAITS OF SPECIES WITHIN EACH GUILD, FOR SEA RECEPTOR SPECIES NOT INCLUDED IN THE ASSESSMENT ABOVE.

Species	Population Status[1]	Habitat Dependence[3]	Site Dependence[4]	Site Fidelity[5]	Typical Lifespan (years)[6]	Migration Distance[7]	Migration Direction[7]
Primarily Intertidal Mudflat Invertebrate Feeders (except bivalve specialists)							
Bar-tailed Godwit	Declining[2]	High	High	High	5	Long	NE
Greenshank	Increasing[2]	High	Low	High[4]	No data	Long	NE
Turnstone	Stable[2]	High	Low	High	9	Long	NW
Primarily Intertidal Mudflat Bivalve Specialists							
Oystercatcher	Stable[2]	High	High	High	12	Short	NE
Piscivores							
Cormorant	Increasing[2]	Low	Low	High	11	Short	UK (some E)
Primarily Freshwater Species							
Water Rail	(Stable)[3]	High	Low	High[4]	No data	Long (short)	E
Generalist Wetland Species							
Little Egret	Increasing[2]	High	Low	Low[4]	5	No data	No data
Ruff	Declining[2]	High	High	High[4]	4	Long	NE
Snipe	Stable[2]	High	Low	High[4]	3	Long (short)	NE (some NW)
Gulls							
Black-headed Gull	Stable[2]	Low	Low	Low[4]	11	Long (short)	NE & UK
Common Gull	Stable[2]	Low	Low	Low[4]	10	Long (short)	NE & UK
Herring Gull	Stable[2]	Low	Low	Low[4]	12	Short	NE & UK

[1] Whether the species has undergone a >25% decline (or >33% increase) over a 5-, 10- or 25-year period either on the Severn Estuary or nationally (Maclean & Austin 2008).

[2] Species for which trends were only available at the national level.

[3] No trend available for the non-breeding seasons when the receptor is most prevalent on the Severn Estuary, so assumed to be stable.

[4] Qualitative assessment based on BTO expert judgement.

[5] Assessed using 2007/08 WeBS data: species for which 50% of the Great Britain population was found on 10 or fewer sites are classified as having High site dependence.

[6] Based on the 'WeBS Alerts Biological Filter' (Maclean & Austin 2008) in which a scoring system is used to assess the natural fluctuations in species' numbers between winters. Species with scores of five or below (for which a filter would be applied to 'High Alerts' in this system) are classified as typically exhibiting low site-fidelity, those with scores of 6-8 as typically exhibiting high site-fidelity. This method of defining site fidelity is a standard approach used in the WeBS Alerts system which monitors changes in the populations of designated waterbird species on SPAs and SSSIs (Maclean & Austin 2008).

[7] Longevity figures from "BirdFacts" (Robinson 2005).

[8] Migration distances and directions are taken from the Migration Atlas (Wernham *et al*. 2002) in conjunction with expert knowledge. Where two migration distances are stated, the first is the migration distance of the wintering population, with the second (in brackets) the breeding population. In most cases wintering populations are considerably larger than breeding populations, for example for many duck species. Migration direction is the direction the species moves from the Severn in the breeding season. Species that move NW mostly breed in Greenland or Iceland, those that move NE breed in Fennoscandia or Russia, those that move E breed in Eurasia, UK indicates the species breeds elsewhere in the UK and winters on the Severn.