Autumn **2011**

State of the Severn Estuary Report

www.severnestuary.net

An initial overview of the Estuary's use and features

INSIDE...

Acknowledgements

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Front cover:
The Severn Bridge at sunset © Roger Coleman
Mermaid Quay, Cardiff © Gwilym Owen
Chiloe wigeon © Dominic Heard
Loading of steel coils at Newport Docks © ABP South Wales

Foreword

Castle rock, Flat Holm. © Sam Whitfield 2010

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Miranda Krestovnikoff
Television Presenter

The Severn Estuary is one of the UK's most valuable resources. Not only does this truly dynamic and unique environment support thousands of migratory birds, important marine species and internationally important habitats, but it is also home to over a million people as well as industries, ports and associated transport networks. As such, the combined natural and cultural heritage of the Severn Estuary warrants special consideration on both a public and professional level, illustrated by the success of the tourist industry in the region. However, the rich living and working environment enjoyed by many people and organisations located in and around the Estuary's shores, is still not completely understood, with a general lack of awareness existing regarding the huge value and fragile nature of the environment.

As a TV presenter with a keen interest in the marine environment, I have been lucky enough to see many of these aspects first hand and experience just how important the Estuary is to all its users. This Estuary is my home - I've lived here for the last 20 years and its future is incredibly important to me. I have seen how the health of the environment underpins the socio-economics of the Estuary and appreciate the paramount importance of managing this resource in an integrated and sustainable way.

This report offers an opportunity for organisations and individuals alike, to learn of the current status and value of the Estuary. I hope that this interesting and attractive report will facilitate groups and individuals to work together for the future of the Severn Estuary, supporting the aims of the Severn Estuary Partnership which encourage the sharing of such information, knowledge, understanding and perspectives of estuary-wide issues.

Rhagair

Craig y Castell, Ynys Echni. © Sam Whitfield 2010

©John Widdup

Miranda Krestovnikoff
Cyflwynwraig Teledu

Aber Hafren yw un o adnoddau gwerthfawrocaf y DU. Mae'r amgylchedd gwirioneddol ddynamig ac unigryw hwn yn cynnal miloedd o adar ymfudol, rhywogaethau morol o bwys, a chynefinoedd sydd o bwys rhyngwladol. Mae hefyd yn gartref i ragor na miliwn o bobl, yn ogystal â diwydiannau, porthladdoedd, a'r rhwydweithiau trafnidiaeth cysylltiedig. Gan hynny, mae angen sylw neilltuol, ar raddfeydd cyhoeddus a phroffesiynol, i etifeddiaeth naturiol a diwylliannol gyfun Aber Hafren, fel a ddarlunnir gan lwyddiant y diwydiant twristiaeth yn yr ardal. Fodd bynnag, nid yw'r amgylchedd byw a gweithio a fwynheir gan lawer o bobl a chyrff glannau'r aber wedi'i lwyr ddeall eto, ac y mae diffyg ymwybyddiaeth cyffredinol ynghylch gwerth enfawr a natur fregus yr amgylchedd hwn.

A finnau'n gyflwynwraig teledu gyda diddordeb mawr yn yr amgylchedd morol, bûm yn ddigon ffodus i weld llawer o'r agweddau hyn fy hunan, a phrofi pa mor bwysig yw'r Aber i'w holl ddefnyddwyr. Yr aber hwn yw fy nghartref: bûm yn byw yma ers 20 mlynedd, bellach, ac y mae ei ddyfodol yn hynod bwysig imi. Gwelais sut mae iechyd yr amgylchedd yn cynnal economeg gymdeithasol yr aber, a gwerthfawrogaf bwysigrwydd hanfodol rheoli'r adnodd hwn mewn modd cyfun a chynaliadwy.

Cynigia'r adroddiad gyfle i gyrff ac unigolion, fel ei gilydd, ddysgu am statws a gwerth yr aber ar hyn o bryd. Gobeithiaf y bydd yr adroddiad diddorol a deniadol hwn yn hwyluso cydweithrediad grwpiau ac unigolion er budd dyfodol Aber Hafren, gan gefnogi amcanion Partneriaeth Aber Hafren, sy'n annog cydrannu'r fath wybodaeth, dealltwriaeth a golygon ar faterion sy'n ymwneud â'r aber cyfan.

Contents/Cynnwys

Introduction

This report has been produced by the Severn Estuary Partnership (SEP) in collaboration with the INTERREG IVB IMCORE Project, the Environment Agency and other organisations and individuals with an interest in the Severn Estuary.

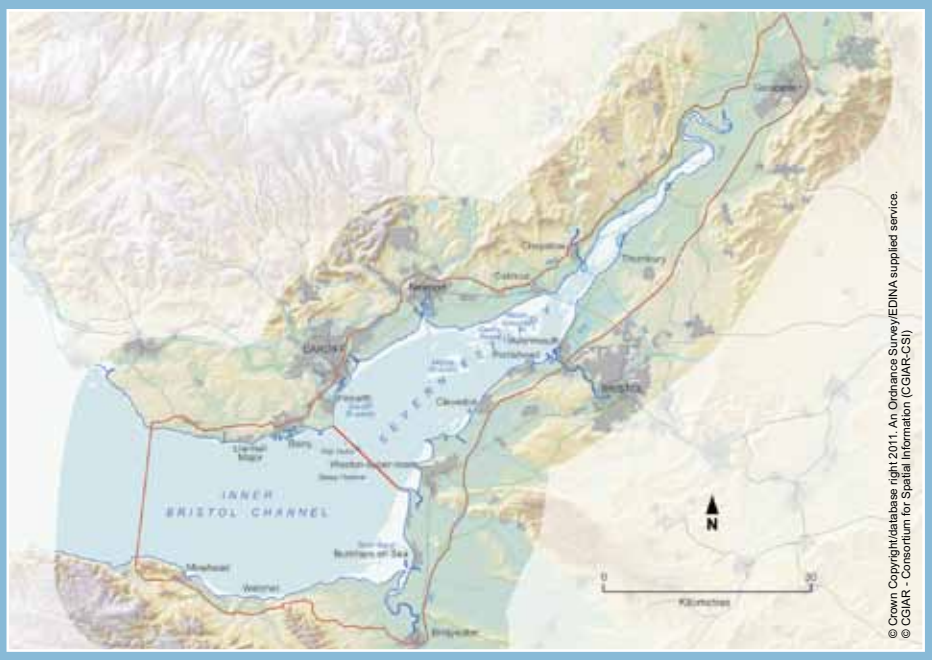


Fig 1: Map of the report study area, the Severn Estuary and Inner Bristol Channel. Source: SEP

Fig 2: Clevedon Pier. © Roger Coleman

Fig 3: View of the Second Severn Bridge at low tide. © Gwilym Owen

The aims of the report

This document provides an overview of the 'State of the Severn Estuary.' Written in a non-technical and easy to understand style, it aims to inform a wide ranging audience, including Estuary users and local people about why the Estuary is so unique.

A basis for future reporting

In providing a snap shot of the current state of the Estuary, it sets a baseline against which future changes on the Estuary may be identified, particularly those associated with climate change.

The State of the Severn Estuary report series

This document is the first in a series that reports on the state of and changes in the natural and human environment of the Severn Estuary. Whilst this particular report takes a broad perspective and considers links between uses and resources, subsequent reports will focus on particular topics and may outline specific indicators for more detailed monitoring.

Background information for the report

This report aims to provide an overview of the Estuary based on best available and up-to-date information, science and data. Wherever possible 2010 data is used and where appropriate, references are provided to additional sources of information. For some topics 2010 data is unavailable or inappropriate and in these circumstances the most suitable data has been used.

The topics covered within the report

Individual chapters outline key topics related to the natural environment, resources and uses of the Estuary.

The geographical area covered by the report

Although the Severn Estuary is commonly seen as the water body from the Second Severn Crossing to a line between Lavernock Point near Cardiff and Brean Down near Weston-super-Mare, the area covered by this report includes the Inner Bristol Channel and the upper Estuary as far north as Gloucester (See Fig. 1). This extends to the tidal limits of the river and incorporates the area covered by the Severn Estuary Partnership where there are close links between the Estuary and on and offshore activities and uses. For selected topics the report includes discussion of areas to the west of the area highlighted, as this region has a significant effect on the Estuary's economy and environment.

Your Estuary

Many people benefit from the Severn Estuary. The Estuary provides resources for communities around its shores through recreation, transport, trade and materials. It supports many activities ranging from sailing and fishing to dredging and offers opportunities for renewable energy generation. However, the Estuary is a fragile habitat and therefore needs to be sustainably managed and looked after for future generations.

The Severn Estuary Region

Fig 4: (A) Common Shelduck. © Dominic Heard (B) Mesolithic footprint at Goldcliff. © Matthew Reynolds (C) Saltmarsh on the Severn. © Natural England (D) Shad. © Paul Elsmere

The natural environment

The Severn Estuary is a huge, diverse area with many fascinating natural, cultural and geographical features. The Estuary is fed by the catchments of five major rivers; including the River Severn, the longest river in Great Britain. Not only is it Britain's second largest estuary, but it also boasts the highest tidal range in Europe with a tidal regime which causes strong tidal streams, mobile sediments and the famous Severn Bore (See Fig. 5). It contains a variety of landscapes and seascapes including salt marshes, cliffs, islands and tidal flats. It is a well known and important nature conservation site because of its internationally important habitats and species, including over-wintering birds and migratory fish.

The human environment

Along with over a million people who live close to the Estuary's shores in large low-lying urban areas, its waterfronts, coastal resorts and other recreation resources attract several million visitors a year. Significant industrial developments, ports and port-related activities are all supported by excellent land and sea communications, including links to Britain's major motorway network. Estuary industries include port-related installations, chemical processing plants, power stations and offshore aggregate extraction. Deep-water channels, cooling water and relatively cheap waste disposal are the Estuary's natural 'resources' for such activities.

Fig. 5 The River Severn's famous tidal bore (top). © SEP
Tourists and locals at Mermaid Quay, Cardiff. © Gwilym Owen

The past. . .

For centuries the region has been a focus for human activities, a location for settlement, a source of food, water and raw materials as well as being a gateway for trading and exploration. As a result the Estuary also holds a wealth of maritime archaeological and paleontological sites, as can be seen in Fig 4 (B), which shows the Mesolithic footprint of a child at Goldcliff.

The future. . .

Potentially competing and conflicting uses present challenges, particularly in the context of climate change. There are concerns associated with the maintenance of the Estuary's natural environment with regards to sea level rise alongside increasing demands for urban and industrial expansion. The large tidal range periodically results in frequent debate over the potential for offshore tidal energy generation. However, the Welsh and UK Governments have stated that it is not timely to develop any Severn tidal power scheme because of its associated costs and risks at present.

Key features of the Severn Estuary

Total area = 55,684 ha[1]
Intertidal area = 9,971 ha[2]
Subtidal area = 6,275 ha[2]
Non tidal area = 623 ha[2]
Length of coastline = 353 km[1]
Length of channel = 111.2km[1]
Tidal Range at Barry = 10m[3,4]
Tidal Range at Avonmouth = 14m[3,4]

Main sources of freshwater input = Rivers Wye, Usk, Severn, Avon.

Key habitats = Saltmarsh, Intertidal mudflats, Rocky intertidal habitats, Subtidal sandbanks (Seagrass beds & Biogenic reefs)

Designations = Special Protection Area, Ramsar, Special Area of Conservation, Site of Special Scientific Interest

Adjacent cities = Bristol, Cardiff, Gloucester, Newport.
Human population = ~1,039,000[1]
Major activities = Ports & shipping, energy generation, aggregate extraction, sailing and angling

The Severn Estuary Partnership

The Severn Estuary Partnership (SEP) is an independent, estuary-wide initiative providing support to many organisations who have responsibilities or interests in the Estuary.

SEP brings together local authorities and statutory agencies on a regular basis with a wide range of public and private organisations, local clubs and individuals, all with a common interest in the Severn Estuary.

The Partnership provides a unique neutral role linking people and organisations for the future of the Estuary.

The Severn Estuary Partnership Aims:

- To facilitate effective communication across and between organisations and individuals.
- To establish and embed a set of 'common principles' for sustainable Estuary use via Partners' strategies, policies and action plans.
- To act as a co-ordinating body to assist the effective and efficient delivery of agreed estuary-wide actions.
- To promote and publicise the Estuary at local, national and international level.
- To add value and fill gaps in effective Estuary management, providing extra capacity when required.

More information on the Partnerships aims & objectives can be found in the Strategic Business Plan 2011-2016 at: http://www.severnestuary.net

The Partnership also seeks to support joint working between Severn Estuary organisations and the public. In particular it is involved in, disseminates information and promotes stakeholder involvement through:

- monthly E-News bulletins with updates on consultations, plans and meetings.
- Severn Tidings Newsletters containing in-depth information about Estuary activities and people.
- organising an annual forum for Estuary updates, lively debate and "meet the neighbours" opportunities.
- the Severn Estuary Gateway, SEP and associated websites.
- biannual Joint Estuaries Days which bring together estuary-wide groups under a common platform.
- an estuary-wide contacts database of +2500 organisations and users.

Fig 6: The Waverley Paddle Steamer. © SEP

Fig 7: SEP Forum 2008 (above) and Forum Panel (below). © SEP

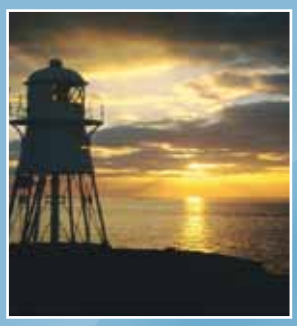


Fig 8: Sunset at Portishead. © SEP

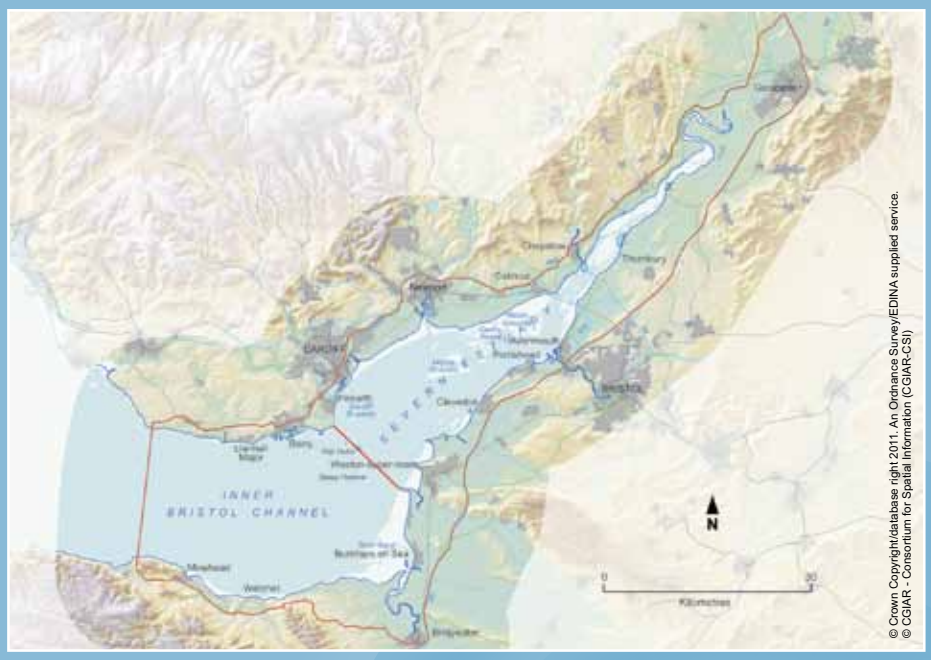
Fig 9: Flat Holm. © Gwilym Owen

The SEP provides a wide range of services, projects and events throughout the year and is open to industry professionals, user groups and individuals alike. Membership offers numerous benefits including an opportunity to improve your ability to make contact with people who share your interests and to meet others with useful information and experience, giving you over 15 years of knowledge and estuary-wide contacts at your fingertips.

Fig 10: Severn Estuary Mudflats. © Dominic Heard

Rhagarweiniad

Cynhyrchwyd yr adroddiad hwn gan Partneriaeth Môr Hafren (PMH) mewn cydweithrediad â'r Cynllun INTERREG IVB IMCORE, Asiantaeth yr Amgylchedd, a chyrff ac unigolion eraill sydd â budd iddynt yn Aber Hafren.



Ffigur 1: Map o ardal astudiaeth yr adroddiad, Aber Hafren a rhan fewnol Môr Hafren.

Ffigur 2: Pier Clevedon. © Craig Sulley

Ffigur 3: Golwg ar Ail Bont Hafren ar drai. © Gwilym Owen

Amcanion yr adroddiad

Rhydd y ddogfen hon arolwg o "Gyflwr Aber Hafren." Wedi'i hysgrifennu mewn dull annhechnegol, hawdd ei deall, amcana oleuo cynulleidfa eang, gan gynnwys defnyddwyr yr aber a phobl leol, ynghylch pam y mae'r aber mor unigryw.

Sail ar gyfer adroddiadau'r dyfodol

Trwy ddarparu cipolwg ar gyflwr presennol yr Aber, gesyd sail ar gyfer canfod newidiadau yn yr Aber yn y dyfodol, yn enwedig y rhai cysylltiedig â newid yn yr hinsawdd.

Cyfres Adroddiad Cyflwr yr Aber

Y ddogfen hon yw'r gyntaf mewn cyfres sy'n rhoi gwybod am gyflwr a newidiadau amgylchedd naturiol a dynol Aber Hafren. Er bod golygon yr adroddiad neilltuol hwn yn eang, ac yn ystyried cysylltiadau rhwng defnyddiau ac adnoddau, bydd adroddiadau dilynol yn canolbwyntio ar bynciau neilltuol, ac efallai'n amlinellu dangosyddion penodol ar gyfer arolygu manylach.

Gwybodaeth gefndirol yr adroddiad

Amcana'r adroddiad hwn ddarparu arolwg o'r Aber ar sail yr wybodaeth, yr wyddoniaeth a'r data diweddaraf un. Defnyddiwyd data 2010 lle bo modd, a darperir cyfeiriadaeth at ffynonellau gwybodaeth ychwanegol, lle bo hynny'n addas. Yn achos rhai pynciau nid yw data 2010 ar gael, neu nid yw'n addas. Os felly, defnyddiwyd y data addasaf.

Pynciau'r adroddiad

Mae penodau unigol yn amlinellu prif bynciau amgylchedd naturiol, adnoddau a defnyddiau'r Môr.

Ardal ddaearyddol yr adroddiad

Er y bernir yn gyffredin mai aber Hafren yw'r dŵr rhwng ail groesfan Hafren a llinell rhwng Trwyn Larnog ger Caerdydd a Brean Down ger Weston-super-Mare, mae bro'r adroddiad hwn yn cynnwys y Môr Hafren Mewnol a rhan uchaf yr aber cyn belled i'r gogledd â Chaerloyw. (Ffigur 1). Mae'n ymestyn hyd ffiniau llanwol yr afon, ac yn cynnwys ardal Partneriaeth Aber Hafren lle mae cysylltiadau agos rhwng yr aber a gweithgareddau a defnyddiau ar y lan ac ar y môr. Yn achos pynciau dethol, mae'r adroddiad yn cynnwys trafod ardaloedd i'r gorllewin o'r ardal ddynodedig, gan fod i'r rhanbarth effaith sylweddol ar economi ac amgylchedd yr aber.

Eich Aber Chi

Mae Aber Hafren o fudd i lawer o bobl. Darpara adnoddau ar gyfer cymunedau ei glannau trwy hamdden, trafnidiaeth, masnach a deunyddiau. Cynhalia lawer o weithgareddau, o hwylio a physgota i garthu, a chyfleoedd ar gyfer cynhyrchu ynni adnewyddadwy. Ond y mae'r aber yn gynefin bregus, ac y mae angen ei rheoli a gofalu amdani mewn modd cynaliadwy ar gyfer cenedlaethau'r dyfodol.

Rhanbarth Aber Hafren

Ffigur 4: (A) Halwyndir Hafren. © PMH (B) Gwangen. © Paul Elsmere (C) Hwyaden yr Eithin. © Dominic Heard (D) Ôl troed mesolithig yn Allteuryn. © Matthew Reynolds

Yr amgylchedd naturiol

Mae Aber Hafren yn ardal eang, amrywiol â llawer o nodweddion naturiol, diwylliannol a daearyddol cyfareddol. Mae'n ddalgylch pum afon fawr, gan gynnwys yr Hafren, afon hwyaf Prydain. Dyma aber ail fwyaf Prydain, sydd hefyd â'r amrywiaeth lanwol fwyaf yn Ewrop. Mae ei chylch llanwol yn achosi ffrydiau llanwol cryfion, gwaddodion symudol, a'r Eger Hafren enwog. Cynhwysa amryw dirweddau a morweddau, gan gynnwys halwyndiroedd, clogwyni, ynysoedd a thraethellau lanwol. Y mae'n safle cadwraeth natur adnabyddus a phwysig yn rhinwedd ei chynefinoedd a'i rhywogaethau o bwys rhyngwladol, gan gynnwys adar gaeafyddol a physgod ymfudol.

Yr amgylchedd dynol

Ynghyd â rhagor na miliwn o bobl sy'n byw'n agos at lannau'r aber mewn ardaloedd trefol mawrion, isel, mae ei glannau, ei threfi gwyliau glan môr, a'i hadnoddau hamdden eraill yn denu sawl miliwn o ymwelwyr pob blwyddyn. Ategir datblygu diwydiannol sylweddol, porthladdoedd a gweithgareddau porthladdol â chysylltiadau tir a môr rhagorol, gan gynnwys cysylltiadau â phrif rwydwaith traffyrdd Prydain. Mae diwydiannau'r aber yn cynnwys porthladdoedd, gweithfeydd prosesu cemegolion, gorsafoedd ynni a chloddio agregau'r môr. Sianelau dŵr dwfn, dŵr oeri, a gwaredu gwastraff cymharol rad yw 'adnoddau' naturiol yr aber ar gyfer y fath weithgareddau.

Ffigur 5: golwg ar Eger Hafren enwog. © PMH. Twristiaid a phobl leol ar Gei'r Morforwyn. © Gwilym Owen

Y gorffennol...

Am ganrifoedd, bu'r rhanbarth yn ganolbwynt gweithgareddau dynol, yn fan trigiannu, yn ffynhonnell bwyd, dŵr ac adnoddau crai, ac yn borth masnachu ac anturio. O ganlyniad, mae i'r aber fyrdd o safleoedd archeolegol a a phaleontolegol morol, fel a welir yn Ffigur 4 (B), sef ôl troed plentyn mesolithig yn Allteuryn.

Y dyfodol...

Dichon i wrthdrawiad defnyddiau cystadleuol osod her, yn enwedig yng nghyd-destun newid yn yr hinsawdd. Mae pryderon ynghylch cynnal amgylchedd naturiol yr aber yng nghyd-destun codiad lefel y môr, ynghyd â galw cynyddol am ehangu drefol a diwydiannol. O bryd i'w gilydd mae'r amrywiaeth llanwol mawr yn esgor ar drafod dichonoldeb cynhyrchiol ynni'r llanw: ond mae Llywodraethau Cymru a'r DU wedi datgan nad amserol datblygu unrhyw gynllun cynhyrchu pŵer ar Hafren, oherwydd y costau a'r peryglon cysylltiedig ar hyn o bryd.

Prif nodweddion Aber Hafren

Cyfanswm arwynebedd = 55,684 ha[1]
Arwynebedd rhynglanwol = 9,971 ha[2]
Arwynebedd islanwol = 6,275 ha[2]
Arwynebedd anlanwol = 623 ha[2]
Hyd y glannau = 353 clm[1]
Hyd y sianel = 111.2clm[1]
Amrywiaeth Lanwol y Barri = 10m[3],[4]
Amrywiaeth Lanwol Avonmouth = 14m[3],[4]
Prif ffynonellau dŵr croyw = Gwy, Wysg, Hafren, ac Avon.
Prif gynefinoedd = Halwyndiroedd, Traethellau mwd rhynglanwol, Cynefinoedd rhynglanwol carregog, Traethellau tywod islanwol (Caeau morwellt a Chreigresi biogenig)
Dynodiadau = Ardal Warchodaeth Arbennig, RAMSAR, Ardal Gadwraeth Arbennig, Safle o Ddiddordeb Gwyddonol Arbennig
Dinasoedd cyfagos = Bryste, Caerdydd, Caerloyw, Casnewydd.
Poblogaeth ddynol = ~1,039,000[1] Prif weithgareddau = Porthladdoedd a llongau, cynhyrchu ynni, cloddio agregau, hwylio a genweirio

Partneriaeth Môr Hafren

Mae Partneriaeth Môr Hafren (PMH) yn fenter annibynnol ar gyfer yr aber gyfan, sy'n cefnogi llawer o gyrff sydd â chyfrifoldebau neu fuddiannau parthed yr Môr.

Daw PMH ag awdurdodau lleol a chyrff statudol ynghyd ar adegau rheolaidd, ynghyd ag amrywiaeth eang o gyrff cyhoeddus a phreifat, clybiau lleol ac unigolion, oll â diddordeb yn Môr Hafren.

Swyddogaeth unigryw, ddiduedd y Bartneriaeth yw cyd rhwng pobl a chyrff er budd dyfodol yr aber.

Amcana Partneriaeth Môr Hafren:

- Hwyluso cyfathrebu effeithiol ar draws a chydrhwng cyrff ac unigolion
- Sefydlu a gwreiddio ystod o "egwyddorion cyffredin" ar gyfer defnyddio'r aber mewn modd cynaliadwy, trwy strategaethau, polisïau a chynlluniau gweithredu partneriaid
- Bod yn gorff hwyluso cyflawniad effeithiol ac effeithlon weithgareddau aber-gyfan y cytunwyd arnynt
- Hyrwyddo a rhoi cyhoeddusrwydd i'r aber ar raddfeydd lleol, cenedlaethol a rhyng-genedlaethol
- Ychwanegu gwerth a llenwi bylchau yn rheolaeth effeithiol ar yr aber, gan darparu rhagor o allu pan fo angen

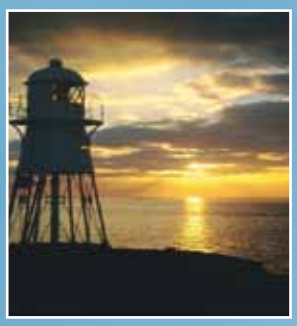
Am ragor o wybodaeth ynghylch amcanion a nodau'r Bartneriaeth, gweler Cynllun Busnes Strategol 2011-2016 yn: http://www.severnestuary.net

Mae'r Bartneriaeth hefyd yn ceisio cefnogi gweithio ar y cyd rhwng pobl a chyrff Môr Hafren a'r Cyhoedd. Yn neilltuol, mae â rhan yn y canlynol, ac yn rhannu gwybodaeth ac yn hyrwyddo ymwneud unigolion a chyrff trwy'r cyfryw :

- bwletinau e-newyddion misol ynghylch ymgynghoriadau, cynlluniau a chyfarfodydd
- newyddlenni Severn Tidings, sy'n gynnwys gwybodaeth ddofn ynghylch gweithgareddau a phobl yr aber
- trefnu fforwm blynyddol ar gyfer diweddariadau'r aber, trafod bywiog a chyfle i "gyfarfod â'r cymdogion"
- gwefannau Porth Môr Hafren, PMH ac eraill cysylltiedig
- Diwrnodau Môr ar y Cyd chwemisol, sy'n dwyn ynghyd grwpiau'r aber gyfan ar lwyfan cyffredin
- cronfa wybodaeth cysylltiadau aber-gyfan o +2500 o gyrff a defnyddwyr

Ffigur 6: Cwch Olwyn, y "Waverley". © PMH

Ffigur 7: Fforwm PMH 2008 a Phanel y Fforwm. © PMH



Ffigur 8: Machlud yn Portishead. © PMH

Ffigur 9: Ynys Echni. © Gwilym Owen

Mae PMH yn darparu amrywiaeth eang o wasanaethau, cynlluniau a digwyddiadau gydol y flwyddyn, ac ar agor i weithwyr diwydiannol proffesiynnol, grwpiau defnyddwyr ac unigolion fel ei gilydd. Mae budd aelodaeth yn cynnwys cyfle i wella'ch gallu chi i gysylltu â phobl sy'n cydrannu'ch diddordebau chi, ac i gyfarfod ag eraill sydd â gwybodaeth a phrofiad defnyddiol. Bydd rhagor na 15 mlynedd o wybodaeth, a chysylltiadau ledled yr aber, at eich galw chi.

Ffigur 10: Traethellau Llaid Aber Hafren. © Dominic Heard

Geology

Bedrock

The rocks which form the shoreline of the Severn Estuary range in age from about 400 million to about 200 million years old[1]. The oldest rocks - sandstones - deposited in the early and middle parts of the Devonian Period, occur along the Somerset and North Devon coast from Minehead westwards[2]. These are the rocks which form the uplands of Exmoor and the Quantock Hills. Rocks of a similar age underlie part of the upper Estuary near Lydney in Gloucestershire. Jurassic limestones and mudstones, about 200 million years old, form the spectacular cliff scenery of the Glamorgan Heritage Coast from Barry, westwards to Southerndown[3], and the cliffs at Lavernock Point and Penarth Head. These rocks also occur at Watchet in Somerset[4] and around Burnham-on Sea, but there they are mostly hidden by more recent deposits.

The bedrock of much of the shoreline of the Severn Estuary upstream of a line from Lavernock Point to Brean Down near Weston-super-Mare is formed of soft red mudstones of the late Triassic Period (about 220 million years old[5]). This is most often covered by the more recent deposits of the Wentloog, Caldicot and Somerset Levels; but in several places, such as at Penarth, Aust, Westbury on Severn and at Blue Anchor Bay in Somerset, it is capped by harder rocks, forming cliffs[6]. Between Barry and Sully on the Glamorgan coast, and at Sudbrook in Monmouthshire, the Triassic rocks are red or yellow sandstones and form low cliffs[3,7].

Fig. 1: Red and grey Triassic mudstone at Aust Cliff. © Tom Sharpe

Fig. 2: Carboniferous limestone at Flat Holm. © Tom Sharpe

Protruding through the cover of red Triassic mudstones in places along the coast are hard grey limestones deposited about 350 million years ago during the early part of the Carboniferous Period. These form the prominent headlands of Sand Point, Worlebury Hill and Brean Down at Weston-super-Mare[5], and extend inland as the Mendip Hills. The beds of limestone are usually tilted as a result of compression and folding of the rocks at the end of the Carboniferous Period about 300 million years ago[1]. To the west, these folded limestones form Steep Holm and Flat Holm as well as Barry Island and Sully Island on the Glamorgan coast[8]. The limestones are also present along the Welsh coast at Ogmore-by-Sea and Porthcawl and upstream at Chepstow[7]. On the English side, the Carboniferous limestones, along with some late Devonian sandstones, form the coast between Portishead and Clevedon. Some early Carboniferous volcanic rocks are present within the limestone sequence at Middle Hope at Weston-super-Mare[5].

Fig. 3: Faulted Jurassic limestone and mudstone at Lilstock, Somerset. © Tom Sharpe

Bedrock offshore

Offshore, the bedrock underlying the floor of the Severn Estuary is largely a continuation of the shoreline geology[9]. Upstream of the Lavernock Point-Brean Down line, the rock beneath the Estuary is mainly Triassic red mudstones. Around Flat Holm and Steep Holm, folded Carboniferous limestone forms the floor extending towards Sand Point and Brean Down (see Fig. 2).

Downstream, the rocks beneath the waters are mainly early Jurassic limestones and mudstones like those at Watchet or along the Glamorgan Heritage Coast, but in the western part, off Porlock and Foreland Point in Somerset, middle and late Jurassic rocks are present (see Fig. 3). These youngest rocks (about 160 million years old), are preserved in an east-west dip where the layers of rock have been bent and folded downwards. The Jurassic rocks beneath the Severn Estuary, west of Weston-super-Mare are cut by many east-west fractures or faults and bent into a series of roughly east-west folds[10]. These structures in the rocks have influenced the shape of the coastline westwards from near Burnham-on-Sea on the Somerset side, and between Lavernock point and Nash Point on the Glamorgan coast (see Fig. 4). Other faults, running southeast-northwest, perhaps extending across

Fig. 4: Jurassic limestone and mudstone formation at Nash Point. © Tom Sharpe

Fig. 5: Submerged forest tree stumps at Goldcliff near Newport.
© Tom Sharpe

the Severn Estuary from the western side of the Quantock Hills, intersect the Welsh coast at Nash Point and turn the coastline north-westwards. Upstream of Lavernock Point, the Severn Estuary runs north-eastwards. This is probably controlled by a much older fault system, extending back to early Carboniferous times, the Severn Estuary Fault Zone.

The Ice Age and after

At the height of the last ice age, about 20,000 years ago, much of northern and western Britain was covered by a thick ice sheet whose southern limit lay through South Wales. So much water was locked up in the great ice sheets of the northern hemisphere at this time that sea level fell by about 120 metres[1]. The Severn Estuary at this time would have been a wide, cold plain with a central river channel flowing to the sea which would have been situated far to the west, beyond Land's End. Rivers of meltwater from the ice sheet flowed south to join the Severn, transporting sands and gravels from the rock debris carried by the ice and cutting valleys deep below present sea level.

At the end of the last ice age, as the ice sheet melted and water returned to the world's oceans, sea level rose in stages, reaching its present height about 4500 years ago[1]. In the Severn Estuary, this rise in sea level inundated a wooded coastline. Beds of peat with trees were buried beneath fine grey clays. These 'submerged forests' are visible at low tide along the shoreline in a number of places along the Severn Estuary coast (see Fig. 5). The spread of clays form the Wentloog and Caldicot Levels on the north side of the Estuary and the Somerset Levels on the south where the clays can be up to 30 metres thick[6].

Fig. 6: Early Jurassic ammonite, Psiloceras planorbis at Aust Cliff.
© Tom Sharpe

Geologically important sites

The rocks along the Severn Estuary coast record changes of environment and climate through time, from the river-deposited sandstones of the Exmoor coast in the Devonian Period, the tropical seas of the Carboniferous, the desert plains and hills of the Triassic, and the spread of the Jurassic sea over the region[1]. The places which best display these rocks are protected as Sites of Special Scientific Interest (SSSI) which should be preserved for education and science. They include sites which are important for the fossils they contain, or for the occurrence of particular rocks, structures, or minerals[11] (see Fig. 6).

The Estuary today

The bedrock floor of the Severn Estuary upstream of a line from Lavernock Point to Brean Down is covered with areas of gravel, sand and mud. These also cover bedrock in the Bridgewater Bay area, but downstream of the Lavernock-Brean Down line, bedrock is exposed on the floor of the Estuary[9]. Movement of sediment within the Severn Estuary is complex due to the high tidal range and the strong tidal currents that prevail here. Not only are silt and mud carried seaward into the Estuary by the rivers, they are held in the Estuary, deposited and moved again over considerable periods of time. In addition, sand is carried up the Estuary and landward[9]. This sand is not derived from erosion of the shoreline rocks, but from the deposits of glacial rivers during the last ice age. The surface layers of the sandbanks are largely unconsolidated and may be moved and redeposited by the strong tides. Some of the near-shore sandbanks provide an element of protection against coastal erosion by reducing wave energy. The dredging of sand for the aggregates industry is therefore closely monitored.

The future

The Estuary is constrained at points by harder rocks such as along the Glamorgan and Somerset coasts, however much of the upstream shoreline is formed of softer rocks or river muds, such as the Wentloog, Caldicot and Somerset levels[8]. Where there are no defences or hard geology, the Estuary will continue to widen and retreat upstream under rising sea levels. However, there are very few stretches of coastline that are fronted by neither hard geology nor sea defences. It may therefore be necessary for certain stretches of sea defences to be moved landward in the future, thus allowing the Estuary to broaden in a managed way.

For more information see the following links:

- Severn Estuary Partnership, http://www.severnestuary.net/sep/estuary/landscape.html
- British Geological Survey, http://www.bgs.ac.uk/
- Geologists' Association South Wales Group, http://www.swga.org.uk/pubs.html
- Aust Cliff fossils and fossil collecting, http://www.austfossils.co.uk/
- Further references, pg 64.

The Water Environment

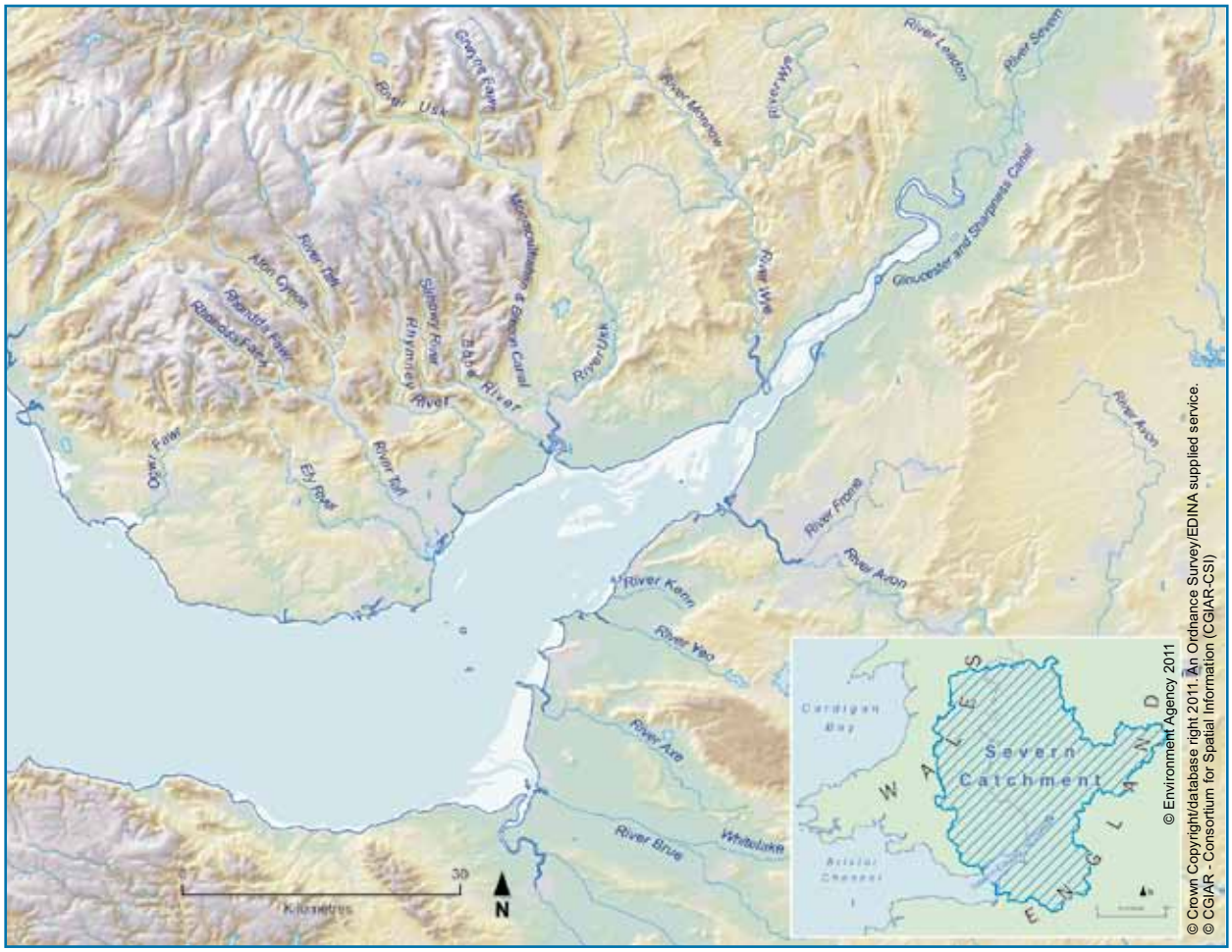


Fig. 1: The catchment and main tributaries of the Severn Estuary. Source: SEP

The Severn Estuary catchment area, that is, the land area draining into the Estuary, covers an area of 21,590 square kilometres[1]. There are over 600 natural watercourses[2]; with the main tributaries being the Ely and Taff impounded by the Cardiff Bay Barrage, the Rhymney, Ebbw, Usk, Wye, the Severn itself (the longest river in Great Britain at 354 km), the Avon and the Parrett (see Fig. 1).

Freshwater inputs to the Estuary

Freshwater inputs include both surface waters and groundwater[3]. The groundwater environment along the coast of the Severn Estuary is mainly comprised of low permeability soils overlying low permeability bedrock. Although water can be found within these rocks, in most cases it cannot infiltrate easily. As a result there is limited groundwater resource potential and the distribution of water on the coast is dominated by surface flow processes[4].

The main exception to this general pattern are the areas of Carboniferous Limestone which can store and transmit large quantities of water mainly through fractures and joints (see section on Geology). There are springs not only on the land surface, but also in the Estuary itself, including the Great Spring (intercepted by the Severn Railway Tunnel), which is partly used (10,910 m^3 per day[4]) by Dŵr Cymru: Welsh Water for public water supply[3].

The principal input of freshwater to the Estuary is surface water from rivers. In addition, there are also many man-made watercourses. A significant feature is the bordering low-lying land, the water levels of which are managed by an extensive system of drainage channels (termed rhynes in England and reens in Wales). These man-made channels drain to the Estuary, usually at outfalls through 'sea doors'- many of which experience some restriction of free flow during periods of high sea level at high spring tides[5].

Fig. 2: River Wye at Symonds Yat. © Environment Agency

Importance of freshwater flows to the Estuary

The quantity, quality and timing of freshwater inflows are essential to the living and non-living elements of the Estuary[6]. Freshwater inflows affect the physical, chemical, and biological nature of the Estuary, including salinity, nutrients and pollutants throughout the ecosystem. These inflows are also subject to seasonal variation and accommodating the needs of the many species that use the Estuary for at least one part of their life cycle[6]; such as migratory salmon and juveniles of marine fish such as whiting and sole (see section on Fish).

Flows of the main rivers directly feeding into the Severn Estuary

All flows in cubic metres per second (cumecs)
Source: Environment Agency, 2010

River	Typical summer low flow	Mean annual flood	Mean daily flow
Severn	11.2	1201	108.1
Wye	10.6	536	79.9
Usk	3.2	381	27.9
Taff	3.7	365	22.7
Avon	1.6	169	19.8
Parrett	2.5	187	13.4
Ebbw	1.2	103	7.5
Rhymney	0.7	99	5.9
Ely	0.66	56	4.7

Water Abstraction

Abstraction is the removal of water, permanently or temporarily, from rivers, lakes, canals, reservoirs, underground rocks (aquifers), an estuary or the sea on the open coast. Not only is water essential for human life (public and private water supplies); it is also an important economic driver and an essential requirement for industry, power generation, commerce and agriculture.

Fig. 3: Oldbury power station and in the foreground, the top of the tidal reservoir wall about to be revealed by the falling tide.
© Stephen Cullis

However abstraction needs to be managed responsibly to meet the reasonable needs of water users, while leaving enough water in the environment to conserve the water body habitats.

Freshwater is abstracted from all of the major rivers feeding the Severn Estuary in varying degrees. Some uses, such as in heavy industry have declined; but this has in many places been replaced by the needs of other sectors and there are increasing demands on some rivers such as the Wye and Severn to meet the needs of agriculture and the public water supply.

Most of the freshwater river abstraction points are situated well above the tidal limit. Those close to the tidal limit, such as the large abstraction from the Severn at Gloucester feeding the Gloucester – Sharpness Canal, have to be managed carefully to prevent the uptake of saline water – in this instance, made even more important as large quantities of the water from the canal are subsequently abstracted to provide drinking water for much of the Bristol area. There are also major abstractions direct from the Estuary for use as cooling water for the coastal power stations, including the tidal reservoir at Oldbury; used to retain water over periods of low tide (see Fig. 3). Energy providers are seeking to reduce the volumes of water they abstract; for example at Uskmouth power station, where 'make-up' water for the high-pressure boilers is piped from the nearby Nash wastewater treatment works as tertiary treated effluent.

River Severn Regulation

Fig. 4: Clywedog Dam near Llanidloes.
© iTravelUK

In the 1950s it was realised that predicted demands for water from the River Severn, particularly for public water supply, would be greater than the river could support, especially in dry years[7]. To increase the reliability of river flow, a dam was constructed in 1966, creating Llyn Clywedog (see Fig. 4), a 250 hectare lake in the headwaters of the catchment[8] near Llanidloes in Mid Wales. Further water is available from Lake Vyrnwy (35 minutes from Llyn Clywedog), a reservoir created in 1889 to supply water to Liverpool[8]. Water released from these reservoirs is then available for abstraction further down stream without flows falling too low. If low flows continue for a long period, there is not enough water in these reservoirs to maintain the required releases. At such times, additional water from the Shropshire Groundwater Scheme is made available to support the river via a series of large boreholes sunk into the sandstone aquifers from which groundwater is pumped into the river[8]. This highly complex management of flows is not only to assist continuation of abstraction, but also to protect wildlife and habitats, and to help preserve the natural balance of the river's ecosystem.

Tides and Flows

The Severn Estuary is commonly considered to have the second highest tidal range in the world after sites in the Bay of Fundy in Canada. This is a result of its shape and alignment. The alignment of the Bristol Channel is predominantly east-west, and that of the Estuary is north east –south west. This change in direction is enough to change the dynamics from wave-dominated in the wider Severn Sea to the west, to tidally-dominated in the upper Estuary. As a result of a combination of geology and human intervention through the draining of the Levels and coastal engineering works, the Estuary is funnel-shaped. This, together with the westward facing direction and the flattened Estuary floor magnifies the already 'macrotidal' (over 6m range) tidal range at the Bristol Channel which, (on a mean spring tide)

approaches 12.2m at Avonmouth and 12.3m at Beachley[6]. In the Estuary's swiftly narrowing funnel form, the tidal flow overcomes the resistance of the Estuary bed, producing a tidal bore[8].

The Severn Bore

A bore is unique to macrotidal estuaries, and occurs at spring tide when the incoming tide breaks against the outgoing river current, forming a wave that travels up the Estuary. The Severn Bore forms upstream of Sharpness and travels upriver at about 16 kilometres per hour. It can form a wave up to two metres in height (see Fig. 5). Although it is associated with spring tides, its height varies with tidal and meteorological conditions.

Fig. 5: Surfers riding the Severn Bore. © Gwilym Owen

Storm Surges

Storm surges pose a major risk, producing higher than normal sea level and flooding for land adjacent to the coastline. These are usually produced when low atmospheric pressure is associated with very strong winds and high tides. While rare in their extreme form, these can overtop or breach sea defences and cause flooding and erosion, depending on the exact weather conditions at the time[4]. If the wind direction is from the west or south west this results in a wind generated flow both constraining and pushing water up the Estuary, causing the water level to rise further (see Fig. 6). The storm of 1990 resulted in a rise of water level at Avonmouth of 1.6m at the time of high tide, causing damage to sea defences and properties along the Estuary.

Storm surge predictions are used when deciding upon coastal defence systems, but the difficulty is in knowing what will happen in the future. Some climate models predict that in the UK the number of storms over time will stay the same or reduce, but it is impossible to predict what will happen to the intensity of individual storms.

In addition to storm surges, the impacts of more localised winds increase coastal risk. An example is the impact of north-easterly winds on the coastline near Penarth Head in Wales. When the wind is from the north-east, this section of coastline is exposed to a large fetch in the same direction and significant erosion subsequently occurrs[5].

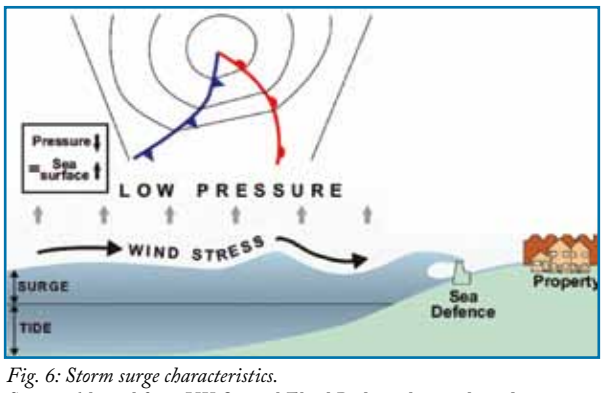


Fig. 6: Storm surge characteristics.
Source: Adapted from UK Coastal Flood Risk: understanding the uncertainty. Lewis, Horsburgh, Bates 2010.

The 1607 Flooding Event

There has been much discussion about the flood that took place on the Severn Estuary in the early seventeenth century. The event is marked on churches on the Gwent and Severn Levels and it has been suggested that up to 2000 people may have perished. Although modern day calendars place the flood in 1607, calendars in use at the time of the event would have documented the flood as occurring in 1606 (see Fig. 7).

Fig. 7: Markings of the Great Flood on Redwick Church. © SELRC

Whilst one theory suggests that a tsunami was responsible, it is known from contemporary accounts that the flood happened at about 9am local time and that the high tide for that day is estimated to have been at 08:35[5]. In addition, eight of the nine sources of data for the flood state that the weather was also stormy. Astronomical prediction software shows that the Moon and Sun were close at New Moon making these tides among the highest of the year. While a full explanation of this flood may never be known for certain, a storm surge is likely.

Climate change

Future changes in climate are anticipated to result in hotter mean annual temperatures; with wetter winters, drier summers and higher rainfall intensity overall. By 2050, winter surface water flows are predicted to increase by between 10-15% above current values, in comparison to decreases in summer flows; in the main by over 50% and as much as 80% in some places. It is estimated that these patterns could result in a reduction in total annual average river flow by up to 15%[8].
During this period mean sea level is predicted to rise from 0.097 – 0.63m above baseline[7]. With the predicted changes in river flow described above, this will result in modifications to the freshwater-seawater transition in the Estuary. A general seaward movement of the interface is anticipated in winter due to the slightly larger predicted winter flows, with a general and slightly greater movement inland in summer[4].

For more information see the following links:

- River flows, http://www.environment-agency.gov.uk/
- UK Hydrographic Office, http://www.ukho.gov.uk/Pages/Home.aspx
- The Severn Bore, http://www.severn-bore.co.uk/
- Further references, pg 64.

Habitats

Estuaries are complex systems that are comprised of subtidal, intertidal and terrestrial habitats, all interconnected and interdependent.

The Severn Estuary hosts some of the most important and protected habitats in the UK, with its vast tidal range playing a major role in creating the unusual physical conditions of the Estuary. The tidal characteristics not only influence the type and distribution of habitats but also affect the biological productivity of the Estuary. Whilst the Estuary is biologically poor compared with other UK estuaries, its unique set of physical characteristics still create a highly dynamic environment and support a wide range of communities.

The intertidal zone of mudflats, sandbanks, rocky platforms and saltmarsh is one of the largest in the UK and the Estuary's habitats support internationally important numbers of waterfowl, and large numbers of aquatic invertebrate populations. The Estuary also provides a valuable corridor for migratory fish and acts as a key nursery area for many species (see section on Fish).

Saltmarsh

Fig. 1: Andrew's Pant saltmarsh. © SEP

In the UK, the Severn Estuary contains the largest aggregation of saltmarsh habitat in the south and south-west. It covers about 1,400 ha, representing 4% of the total area of saltmarsh in the UK[1]. Saltmarsh environments fringe the coastline and can be found at locations such as Andrew's Pant, near East Aberthaw (Vale of Glamorgan pictured above), and Clevedon Pill. Saltmarshes develop where halophytes (plants which are more tolerant to saline conditions than conventional plants) colonise soft intertidal sediments, in areas protected from strong wave action. These halophytes provide important feeding areas for waterfowl.

Saltmarsh habitats are notable for their significance in supporting nationally and internationally important species and are frequently visited by numerous Species of European Conservation Concern (SPEC species), such as the Redshank, and Shelduck (see section on Birds). They also support an array of nationally important rare plant species, including the Bullbous foxtail, and the Slender hare's-ear (see Fig. 2).

Fig. 2: Slender Hare's Ear. © Ian Boyd

The upper saltmarsh in particular makes an ideal water roosting site, and provides a refuge from the tides that flood the mudflats twice a day. Saltmarshes also support extensive networks of freshwater and brackish drainage ditches, which in turn provide habitats sustaining a vast array of plant species, aquatic invertebrates, and small mammals such as water voles.

The Estuary's saltmarshes are of international importance, due to their dependence upon a narrow range of environmental conditions, and as such are designated as an **Annex 1 Habitat**[2] and a **Biodiversity Action Plan (BAP) Priority Habitat**[3] (see Box 1 and 2 respectively). In addition to their enormous conservation value, they provide some shoreline protection, acting as soft sea defences, absorbing energy and helping to reduce the risk of coastal erosion and flooding. They also play an important role in the recycling of nutrients through the Estuarine system.

Box 1: Annex 1 Habitats

Annex 1 Habitats are those listed under the Habitats Directive, and are considered to be under threat in the European Union either because they are in danger of declining, or because they already have relatively restricted ranges.

Box 2: Biodiversity Action Plan Priority Habitat

These are priority habitats that have been identified as being most threatened and require conservation under the UK's national Biodiversity Action Plan (UK BAP) – an action plan to ensure the development and enforcement of procedures to conserve, protect and enhance the UK's biodiversity.

Intertidal mudflats

Mudflats, which typically occur within the middle reaches of the Estuary, comprise a large proportion of the Severn Estuary's intertidal habitat, and can be found alongside intertidal sandflats. Combined, they cover around 20,300ha of the Severn Estuary intertidal area[4]. They are closely interlinked with saltmarshes and also provide refuge from wave energy and erosion. Mudflats, which become submerged with the high tide and fully exposed at low tide, display a range of specialist species adapted to live in this complex environment. However, as a result of the Estuary's unique physical characteristics and processes, there are significant differences between the fauna (and particularly the invertebrates) on the Severn Estuary and that of other UK estuaries.

The Severn Estuary mudflats provide important feeding grounds as well as an important roosting and resting area

for wading birds and waterfowl. Resident invertebrate communities supply a rich source of food for a wide range of migratory and resident bird populations and fish. However, despite the vast expanse of the Severn mudflats, their diversity (i.e. number of different species) is low; although a small number of specialist species are to be found in relatively high abundance.

These intertidal mudflats are of major conservation importance. They support the fish assemblage sub-feature of the Severn Estuary Special Area of Conservation (SAC) and Ramsar site, as well as the bird wintering and passage features of Special Protection Area (SPA) and Ramsar sites (see section on Nature Conservation Designations). They are an **Annex 1** qualifying feature of the Severn Estuary SAC and because of their importance, the Severn Estuary mudflats are also a **UK Biodiversity Action Plan (BAP)** priority habitat.

Rocky Intertidal Habitat

There are extensive rocky shores along much of the Estuary. These intertidal areas are typically comprised of hard substrate such as rocks, boulders, mussel/cobble scars, rocky pools and shingles (see Fig. 3). They represent an extreme environment where harsh conditions prevail due to exposure to tides, waves and wind. However, the variety of substrate coupled with exposure to conditions gives rise to a wide range of habitable conditions for an array of species.

Fig. 3: View from Sully Island rocky shore. © SEP

The rocky shores of the Severn support a large number of plants and animals, including brown and green algae, barnacles, limpets and winkles. They also provide an essential food source and resting place for a wide range of wintering and migratory waterfowl, such as Dunlin and Redshank. Rocky habitats also provide important roost sites at high tide for species such as Knot, Oystercatcher and Curlew (see section on Birds).

Rocky intertidal areas are a key 'supporting habitat' for the conservation of many important species. Due to the internationally important species they support (i.e. Dunlin, Redshank, Shelduck), the habitat is of European significance.

Seagrass Beds

Seagrass habitats of the Severn Estuary are made up of eel grasses. These occur extensively on the more sheltered mixed substrates around the Welsh side of the Second Severn Crossing.

On the Severn, seagrass beds are somewhat unique. They occur amongst mixed substrates of cobbles, sands, muds and large boulders; whereas elsewhere such beds are generally associated with mudflats. Two species of eel grass can be found around the Estuary, compared with most other sites where it is more normal for only one species to occur.

Fig. 4: Eurasian Wigeon. © Dominic Heard

The grasses provide a productive habitat for a wide range of species, including algae, invertebrates and fish. They also present an important habitat for overwintering birds such as geese and duck and a valuable food source to these important migratory species (see Fig. 4).

Both species of eel grass have restricted distribution in the UK.

Biogenic Reefs

Biogenic reefs are biological structures created by living species. Studies have revealed extensive biogenic reef systems in the intertidal and subtidal zones of the Severn Estuary, distinguishing the region from other estuaries in the south-west of the UK, where such reefs are largely absent. Intertidal reefs can be found at locations such as Redcliff Bay near Portishead, south of Severn Beach near Avonmouth; and at Goldcliff near Newport. Subtidal reefs occur in dense aggregations throughout the large parts of the mouth of the Estuary[5].

The reefs in the Severn are constructed by tube-dwelling polychaete worms, commonly known as Honeycomb worms (see Fig. 5).

Fig 5: Honeycomb Worm (Sabellaria alveolata). © Sion Roberts

These worms construct a network of tubes using sand particles and sediment to form 'honeycomb' like structures. The reef building worms live in both intertidal and subtidal

Table 1. Habitat losses and gains for the Severn Estuary.
N.B Estimated area in Hectares based on GIS data estimates
Source: Adapted from the Severn Estuary Coastal Habitat Management Plan (CHaMP), 2005

Total Estuary Change	Estimated area in 2005 (Ha)	20 years	50 years	100 years	Net gain/loss
(compared with 2005)		%	%	%	
Intertidal area	22,500	-7	-7	-11	Loss
Intertidal mudflats and sandflats	20,000	-6	-5	-9	Loss
Saltmarsh	1,600	-6	-41	-38	Loss
Transitional grassland	1,600	+13	+6	+6	Gain
Subtidal area	46,000	+3	+3	+5	Gain

areas, and are relatively abundant in the Severn Estuary compared with the rest of the UK.

The reef structures provide a habitat for many other species, often leading to higher species diversity within the reefs compared with surrounding substrates. Their cracks and crevices provide a home for many invertebrates which would otherwise be absent. Crabs, periwinkles, worms, barnacles and anemones inhabit reef structures. Subtidal reefs also support colonies of brittle stars and shrimp.

These biogenic reefs are protected as part of the Severn Estuary SAC 'Reefs' feature. Protection also serves to safeguard a number of reef dwelling species - protection by association.

Subtidal Sandbanks

Subtidal sandbanks are permanently submerged features of soft sandy sediments which exist in relatively shallow depths of less than 20 metres. Whilst they are often defined as elevations of the natural seabed, in the Severn Estuary they are highly changeable and mobile due to the extreme tidal conditions. Due to this mobility the sandbanks have somewhat restricted biodiversity.

The sandbanks of the Severn Estuary are not only distinct from those in other UK estuaries but they are considered to be some of the best. Despite the severely challenging conditions of the banks, they support very distinctive invertebrate communities, including notable species such as crustaceans, echinoderms (such as starfish) and polychaetes (such as lugworms). Despite only supporting small numbers of plants and animals, their mobility and dynamic nature provides considerable potential for the transport of invertebrate larvae to other habitats across the Estuary. This offers the possibility for species to extend their geographical range across a wider area.

Fig. 6: Sandbanks on the Severn.
© Environment Agency

Sandbanks are an Annex I qualifying feature of the Severn Estuary SAC under the Habitats Directive, and are also associated with other Annex 1 habitats . It is likely that the subtidal invertebrate communities associated with these sandbanks play a role in providing a food resource for certain fish species featured under the SAC and Ramsar site. Since the banks also occur in depths of less than 20 meters, they represent a depth zone which is easily accessible to feeding waterbirds, also serving as an important nursery ground for an array of fish species in the Estuary.

Climate Change

Studies have shown that there are some significant trends in habitat ecology associated with the region's changing shoreline and climate.

The Coastal Habitat Management Plan (CHaMP)[6] for the Severn Estuary, has predicted changes to the Estuary's habitats over the next 20, 50 and 100 years (as of 2005), arising from a range of natural and semi-natural factors, including climate change. Table 1 outlines net loss and gain for some of the Estuary's key habitats.

Of particular significance is the impact of potential sea level rise associated with climate change. This could lead to a loss of intertidal habitats, namely saltmarshes and mudflats, as habitats become 'squeezed' against existing sea defences.

Climate change could also affect reef habitats, especially in the long term. The Honeycomb worm in particular, lies at its northern most range in the UK, with a preference towards warmer waters. With increasing sea surface temperatures, these reef building species could benefit from a slight increase in water temperature, and possibly extend their range. However, with coastal squeeze resulting in smaller intertidal areas, the species might actually find its range reduced. More detailed effects of climate change on Severn Estuary habitats are referred to in the section on 'Weather & Climate Change'.

For more information see the following links:

- ASERA, Association of the Severn Estuary Relevant Authorities, http://www.severnestuary.net/asera/habitats.html
- The Habitats and species of the Severn Estuary. A basic introduction for developers and decision makers. Report by the Severn Estuary Partnership. www.severnestuary.net
- Further references, pg 64.

Birds

The importance of the Estuary

With its well renowned tidal range the Severn Estuary provides an extremely dynamic estuarine environment for many species. This high energy Estuary carries an immense volume of sediment (estimated at 30 million tonnes on the largest Spring tides)[1]. The deposition of this sediment creates and maintains the mudflats and saltmarshes around the Estuary which are important feeding grounds for large numbers of wintering wildfowl and waders migrating on the north Atlantic flyway[1].

During peak times, the Severn Estuary can be one of only 6 British estuaries to accommodate more than 100,000 waders[2].

With an overall assemblage of about 94,000 waterbirds (excluding gulls), the Severn Estuary Special Protection Area (SPA) supports populations of European importance of 6 species which over-winter and one passage species - as well as populations of a further 11 species which are of national importance. The designation as a Ramsar site (see section on Nature Conservation Designations) also denotes its importance for 4 waterbird species and breeding gulls[3].

Fig. 1: Curlew. © SEP

Whilst the majority of the species that forage intertidally are widely distributed across the Estuary, some species favour certain sites, attracted by specific sources of food. Special adaptations allow species to feed in different ways. Curlews, with their long bills, feed by touch; capturing lugworms buried deep in the mud (see Fig.1). Other species, such as the Dunlin are visual feeders, which simply run quickly across mudflats and saltmarshes to catch surface prey using their short bill[3]. The former take larger prey, and the latter smaller. This reduces competition between species and increases biodiversity. In the winter, Shelduck filter through surface mud to remove tiny snails, which can be found in their thousands in just one square metre[3].

Within the Severn Estuary and Bristol Channel a number of sites are designated nationally and internationally for their populations of waterfowl and seabirds. Such sites include the Bridgwater Bay National Nature Reserve and Peterstone Wentlooge Marshes.

Bridgwater Bay

The succession of extensive habitats found within Bridgwater Bay, is intersected by complex networks of freshwater and brackish ditches; and range from intertidal mudflats, saltmarsh, shingle beach and grazing marsh[4]. It is perhaps the varied invertebrate fauna (including 6 nationally rare species and 18 nationally scarce species) found in the Bay's ponds and ditches, which helps support the diverse bird assemblage of the Bay, therefore making the site highly important within the Severn Estuary as a whole. Populations include internationally important numbers of passage migrant and over-wintering species such as Black-tailed Godwit (see Fig. 2) and Dunlin respectively; in addition to nationally important numbers of waders and waterfowl like Oystercatcher and Knot[4].

Peterstone Wentlooge Marshes

Lying along the foreshore of the outer Severn Estuary, this coastal reserve acts as an excellent site for bird watching. The tidal mudflats and saltmarshes provide rich feeding grounds for a number of species. Many waders such as Curlew, Dunlin, Knot, Oystercatcher (see Fig.3) and Redshank can be found during winter, with elusive visitors such as Short eared owls and hunting Peregrines also having been spotted[5].

Fig. 2: Black-tailed Godwit. © Dominic Heard

Fig. 3: Oystercatcher. © Sam Whitfield, 2010

Internationally Important Species

The SPA is designated for sites which regularly support a significant proportion of important populations of Annex I species (see section on Nature Conservation Designations). For the Severn Estuary, these species are Curlew and Bewick's Swan (see Fig. 4). Curlew can be found in the intertidal mud and sandflats and saltmarshes as they are important for feeding and roosting; particularly those in the upper reaches of the Estuary. Bewick's Swan populations arrive at Slimbridge from their Siberian breeding grounds to the Severn Estuary in October and can be seen in here until March[6].

Fig. 4: Bewick's Swan. © Dominic Heard

Regularly Occurring Migratory Species

The Estuary also supports internationally important populations of regularly occurring migratory species such as the Dunlin, Redshank, Shelduck, Gadwall, and the European White-fronted goose[6]. Numerically, Dunlin are found to be the most important species on the Severn, feeding upon a variety of insects, snails and worms[2]. In 2010, Shelduck were most abundant in Bridgwater Bay, formerly the most important autumn moulting area for the species away from the Wadden Sea[2], in the south-eastern part of the North Sea.

The sheer size of the waterfowl assemblage (>20,000) is also an important part of the SPA designation. Although Ringed Plovers only occur in the Estuary in small numbers during the winter, due to the large passage of migrants through the Estuary in the spring and autumn, this species is still included as part of the Estuary's SPA[6].

Nationally Important Bird Populations

Fig. 5: Eurasian Wigeon. © Dominic Heard

These form part of the Ramsar and Site of Special Scientific Interest (SSSI), and include Wigeon (see Fig. 5), Pintail, Teal, Pochard, Tufted Duck, Whimbrel, Spotted Redshank, Ringed Plover, Grey Plover and Curlew. Dense populations of Grey Plover are, in the main, located between Peterstone and the Newport Wetlands reserve, whilst Curlews can be found in the inner Severn; with Bridgwater Bay supporting high concentrations of both species[2]. The national importance of the lesser Black-backed Gull and Herring Gull breeding populations are features of the Severn too (Ramsar designation[6]).

Where to See?

As well as being able to see the interesting and varied range of birdlife which appears naturally along the banks of the Severn Estuary, there are also places where the public can go to enjoy important species in specially protected areas and reserves; including Slimbridge Wildfowl and Wetlands Trust (WWT), Chew Valley Lake, the Severn Beach area, Newport Wetlands and Bridgewater Bay Nature Reserve.

Slimbridge - The 325ha[7] of land within the reserve at Slimbridge, play host to a variety of bird species; such as the Willow warbler, Siskin, Kingfisher and Ruff. In 1962, the Nene (Hawaiian goose), now the rarest goose in the world, was brought back from extinction through WWT's captive breeding programme and was successfully released into the wild as the first Slimbridge-reared Nene[7].

Table 1: Some seasonal species seen at Slimbridge Nature Reserve
Source: SEP, adapted from Slimbridge website.

When?	What?
Spring (March-May)	Sand martin, Common chiffchaff, Northern wheatear, Ringed plover, Dunlin, Curlew, Kingfisher.
Summer (June-July)	Sedge warbler, Blackcaps, Cetti's warblers, Hobby's, Common terns, Ruff, Green sandpiper.
Autumn (Aug-Sept)	Pectoral sandpiper, Willow warbler, Common chiffchaff, Lesser whitethroat, Eurasian teal, Marsh warbler.
Early Winter (Oct-Dec)	Redwing, Skylark, Bewick's swan, Jack snipe, Pintail (see Fig. 6), Pochard, Leach's petrel, Great skua.
Winter (Jan-March)	White-fronted geese, Bewick's swan, Water rail, Siskin, Gadwall, Pintail, Sparrowhawk, Spotted redshank, Little stint.

Fig. 6: Pintail. © Dominic Heard

Newport Wetlands - Cetti's warblers and bearded tits can be seen and heard in the reedbeds of Newport Wetlands, with ducks, geese and swans visiting the reserve in large numbers during the winter[8].

Avocet

Fig. 7: Avocet. © Dominic Heard

The Avocet, with its distinctive black and white markings and long up-curved beak (see Fig. 7), has been used as the emblem of the RSPB for years; as it represents the bird protection movement in the UK better than any other species. The species' return in the 1940s and its subsequent increase in numbers, signifies one of the most successful conservation and protection projects in the UK. Wales' only breeding population of Avocet can be found in the saline lagoons of Newport Wetlands[2]. Redshank, Lapwing, Oystercatcher, Ringed plover and Little ringed plover are the other five species of wader which also breed in the lagoons; which themselves play host to over 20 migratory wader species in spring and late summer[8].

Fig. 8: Shoveler duck. © Dominic Heard

Table 2: Some seasonal species seen at Newport Nature Reserve[8]

When?	What?
Spring	Bearded tit, Cuckoo, Lapwing, Swallow.
Summer	Oystercatcher, Redshank, Sedge warbler, Swift, Avocet.
Autumn	Dunlin, Goldfinch, Ringed plover, Shoveler (see Fig. 8).
Winter	Bittern, Black-tailed godwit, Dunlin, Starling.

Trends

2008/2009 saw the Severn Estuary producing the greatest diversity of species on low tide counts, with 64 species identified in total. Of those, Curlew, Mallard and Dunlin were found to be the most widespread species throughout the Estuary, with Dunlin reaching the highest ever peak count of 27,136 birds[3]. In contrast to the waterfowl distribution, wildfowl were generally more restricted in terms of area, with Teal favouring the Severn Beach and Weston-super-Mare areas; whilst Shoveler and Pintail preferred Slimbridge, Burnham-on-Sea and Newport areas[3].

Low Tide Counts on the Severn Estuary during 2008/2009 recorded a winter average of 6,231 birds - a significant increase since 2002/2003. The year also saw the highest ever counts for Redshank on the Severn Estuary, with a peak of 2,970. In general Redshanks are widespread on the Severn Estuary in winter; however they tend to favour river mouths such as those of the Rivers Parrett, Axe and Rhymney, as well as other sites with freshwater inputs into the Estuary[2].

In the last two decades, the overall number of waders wintering on the Estuary has declined. The most significant decreases seen were in the numbers of Grey Plovers; with numbers of European white-fronted geese and Bewick's Swans on the Severn Estuary SPA, showing a similar decrease. Whilst average winter Dunlin numbers have fallen from over 40,000 in the mid-1970's to around 15,000 in recent years, peak numbers are still of international importance[2]. Populations of wildfowl such as winter Shelduck have been steadily increasing over the past 30 years in conjunction with long term increases in the numbers of Pintails, Shoveler's, Teal (see Fig. 9), Lapwings and Tufted Ducks.

Fig. 9: Eurasion Teal (both) © Dominic Heard

Pressures

Among the various sites within the Severn Estuary, the status of seabirds and waterbirds has been affected by a number of issues. The impoundment of Cardiff Bay impacted upon large numbers of waterbirds on the Severn Estuary.

The success of schemes under European legislation, (e.g. Bathing Waters Directive and Urban Wastewater Directive) has significantly improved water quality within the Severn Estuary and UK in general (see section on Bathing Waters). Improvements have been so great, that the occurrence of coastal nutrient limitation has been increasing, therefore reducing the food supply for creatures in the food web which *feed* the birds of the Severn Estuary.

Bewick's Swan and White-fronted Geese numbers within the Estuary have also decreased significantly, as wintering sites further North and East in the UK are environmentally similar; acting as a more favourable location as they reduce the need for the species to migrate as far South as the Severn Estuary.

Climate Change

Climate change has more than likely led to declines in the numbers of waders in the Severn Estuary and southwest in general; with the potential loss of wetland and intertidal areas due to sea level rise, resulting in the change of sediment dynamics and loss of habitat for thousands of birds[3].

For more information see the following links:

- Severn Side birds, http://www.severnsidebirds.co.uk/
- Chew Valley Lake Birding, http://www.cvlbirding.co.uk/
- Newport Wetlands, http://www.rspb.org.uk/reserves/guide/n/newportwetlands/
- Slimbridge, http://www.wwt.org.uk/slimbridge
- Natural England, Bridgwater Bay National Nature Reserve, http://bit.ly.rwB8d
- Further references, pg 64.

Fish

The Severn Estuary and the waters further west in Bridgwater Bay have a very rich fish community with a combined total of 111 species[1]. Though some of these are probably accidental marine visitors and only rarely observed- such as the basking shark and sunfish, with others inadvertently swept downstream from rivers, it is considered that the fish assemblage in the Severn Estuary is one of the most diverse in the UK[2]. It is also one of the more important nursery areas in Britain[3].

Fig. 1: Small bass. © Andy Schofield

Fish species may be categorised according to their life-cycle (see Box 1). The most abundant in terms of both species and overall numbers are the marine estuarine-opportunists[3]. These rely on the Estuary for some aspect of their life-cycle (primarily juveniles that utilise the Estuary as a nursery) such as sprat, bass (see Fig. 1) and whiting. Other categories include predominantly marine and freshwater species that stray into estuarine waters, as well as small numbers that are truly estuarine and which are capable of completing their whole life-cycle within the Estuary (e.g. the common goby). The Estuary also acts as a migratory corridor for several important species (see Box 1), such as salmon, lamprey, shad and eel.

Box 1: Life-cycle characteristics[3]

Fish are highly mobile and move up and down the Estuary with the changing tides and seasons. Many species can tolerate high turbidity and a wide range of temperatures, salinity and oxygen concentrations.

Fish species in the Severn Estuary can be classified according to their life-cycle characteristics:

Marine: typically breeding offshore and generally intolerant of reduced salinity.

Marine Stragglers: abundant in marine environments but occurring infrequently in the Severn Estuary and other British estuaries.

Freshwater: typically occurring and breeding in fresh water.

Marine Estuarine-Opportunistic: marine species found in large numbers in the Severn Estuary and other British estuaries.

Estuarine: typically occurring and breeding in estuaries.

Anadromous: migrating from the sea into fresh water to breed, e.g. salmon.

Catadromous: migrating from fresh water into the sea to breed, e.g. eel.

Spawning within the Estuary is largely limited to the common goby and possibly also the sand smelt. Many of the abundant marine/estuarine species spawn in the Outer Bristol Channel with the resultant larvae drifting inshore to sheltered waters where suitable food is abundant and there are fewer predators[3]. It is usual then for the young of the year to migrate seaward in the winter months, in response to reducing salinity and or temperature[4]. In the case of a number of fish species, in particular gadoid (such as whiting and bass) the seaward migration is closely correlated with and in response to, abundance of the common shrimp[4]. This pattern of progressive colonisation followed by reduced abundance due to seaward migration can be seen for sand goby, sole, dab, pout, bass, poor cod, whiting and grey mullet. Such species will spend several years migrating between the Estuary and sea, before maturing and then living entirely offshore[4]. The saltmarsh channels found within the Estuary also provide an important means for certain fish species to travel further up the Estuary during high tides for feeding.

The use of conventional fish sampling techniques in the Estuary is extremely difficult because of the large expanse of inaccessible mudflats[3] and the extremely large tidal range. Consequently, most of the knowledge comes from data obtained from fish entrained on the cooling-water intake screens at certain coastal power stations[3]. Additional information, though limited, is provided by the small amount of commercial landings and the largely anecdotal reports from recreational anglers and clubs.

Power Station data

The nuclear power stations at Oldbury (inner Estuary) and Hinkley Point (Bridgwater Bay) have provided detailed accounts of seasonal changes in fish numbers and species composition over several decades[5]. In the case of Hinkley Point where sampling began in 1980 (and is still continuing) the information represents one of the largest time series for an entire animal community anywhere in the world[3]. Based on the sampling:

- The 10 most common fish species caught are (in order): sprat, whiting, sand goby, poor cod, dover sole, pout, sea snail, bass, flounder and dab. These make up 90% of all the samples, with sprat and whiting at an order of magnitude higher by number than the next most abundant species[6].
- The abundance of many species increased between the 1970s and 1990s and since 2002, the rate of increase has accelerated by a factor of two to four[6].
- The fish community is increasing by about one new species every two years[6].

The greater numbers of species are thought to be linked with changes in climate. Recent warming may explain the presence of greater numbers of species from the south without, as of yet, the loss of colder water species. In addition, the seasonal presence of some species has been extended because of milder winters[7]. The reason for the increase in abundance is thought to be largely due to the fact that sediment and water quality in the Estuary has improved, particularly with regard to heavy metal contamination; with increases in water temperatures also likely to be very significant[3].

Table 1: Periods of abundance in catch of popular species landed on the charter boat, Leah James in 2010.
NB: The darker the colour, the greater the species abundance.
Source: www.leahjames.co.uk

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Bass												
Blonde Ray												
Bull huss												
Cod												
Conger eel												
Dog fish												
Pouting												
Small eyed ray												
Smooth hound												
Spotted ray												
Spurdog												
Thornback ray												
Tope												
Turbot												
Whiting												

Commercial landings

In comparison to the rest of the UK inshore fisheries, a relatively small catch is landed commercially from the Severn Estuary. The landings have however increased over the last five years from approximately 50 to 90 tonnes in 2010[5]. The catch in 2010 was very mixed with rays (see Fig. 2) and bass being the principal species. This topic is covered in greater detail in the Fisheries section.

Fig. 2: Thornback ray.
© Cardiff University

Recreational fishing

Recreational angling accounts for the highest amount of fishing effort within the Severn Estuary and Inner Bristol Channel[8]. Anglers fish from the shores along much of the Estuary and from charter boats, targeting species such as cod in the winter and bass in the summer.

Fig. 3: Cod caught in the Bristol Channel.
© Robert Thomas, www.worldseafishing.com

In 2006, the Bristol Channel Federation of Sea Anglers began a database of 'specimen' catches caught by affiliated clubs[5]. A review of its database of recorded specimen catches over the last 5 years, shows an emphasis on elasmobranch species (species with cartilaginous, rather than bone, skeletons) such as ray (small eyed and thornback), spurdog, tope, lesser spotted dogfish and smooth hound[5]. In addition, catches of bass, cod (see Fig. 3), mullet, conger, whiting and sole were also recorded.

The absence of comprehensive catch records does not allow any detailed quantitative analysis, however interpretations of trends and relative species abundance may be possible[5]. For example, Table 1 shows periods of abundance in terms of catches of popular species landed on the charter boat Leah James (working out of Cardiff)[9].

Conservation

The Severn Estuary and the Rivers Usk and Wye are important conservation areas partly because of the presence of the migratory species: salmon, sea trout, sea and river lamprey, eels and twaite and allis shad (see Fig. 4). The Estuary is an important migratory route for these rare and protected species. As a result of such features, the Estuary is both a site of Special Scientific Interest (SSSI) and along with the Rivers Usk and Wye, also a Special Area of Conservation (SAC). It has also been given the international designation of Wetland of International Importance (Ramsar Site). The above species partly account for the citations (though not all of them for each designation). In addition to the individual species mentioned, both the Ramsar and SAC designations cite the 'Estuarine fish' population, in general, as a key feature.

Fig. 4: Shad. © Peter Clabburn

For more information see the following links:
- ASERA, http://www.severnEstuary.net/asera/fish
- Bristol Channel Federation of Sea Anglers, http://www.freewebs.com/bcfsa
- Further references, pg 64.

Marine Mammals

The Severn Estuary is not an important region for marine mammals[1] as there are no breeding sites in the Severn Estuary area for these species. Nevertheless, their presence is not uncommon. The following cetaceans all use the Estuary as a feeding area at different times of the year; Harbour Porpoise, Risso's Dolphin (see Fig. 2), Common Dolphin, Bottlenose Dolphin (see Fig. 3) and Grey Seal[2]; with the nearest breeding colony for Grey Seals being Lundy Island in the Outer Bristol Channel[3] (see Fig. 1).

Fig. 1: Grey Seal. © Nick Tyson

The Harbour Porpoise (see Fig. 4) is the most commonly recorded cetacean species occurring in the region, with frequent sightings in the Bristol Channel and occasionally in the Severn Estuary[1]. The mating season is in October, with births taking place between March and August. Interestingly, the harbour porpoise population in the Bristol Channel and Severn Estuary region is genetically different to the Irish sea population[4,5]. Whilst Harbour Porpoises are documented as being seasonally present in the Severn Estuary[6], it should be noted that sightings are still very rare.

Occasional sightings and strandings of larger marine mammals such as Humpback Whale, Minke Whale, False Killer Whale, Fin Whale and Killer Whale have been recorded in the Bristol Channel, though these remain uncommon[7,8].

Legislation protecting the seals, turtles and cetaceans in the Bristol Channel and Severn Estuary area;

- EU Habitats Directive & Species Directive 1992
- Bern Convention
- The Convention on the Protection of Migratory Species
- Ospar and Paris Convention 1992 (Annex V)
- Schedule 5 to the Countryside and Wildlife Act 1981 (as amended)

Fig 2: Risso's Dolphin © PGH. Evans and Sea Watch Foundation

Fig. 3: Bottlenose Dolphins © P. Anderwald and Sea Watch Foundation

Fig. 4: Harbour Porpoise © P. Anderwald and Sea Watch Foundation

For more information see the following links:

- Lundy Field Society, http://www.lundy.org.uk/island/seals.html
- Sea Watch Foundation, http://www.seawatchfoundation.org.uk/
- Further references, pg 64.

Non-Native Species

The Severn Estuary and the land and sea areas bordering it, like many other regions world-wide, are experiencing the arrival of new 'non-native' species of both animals and plants. Humans have introduced new (or alien) species to environments both inadvertently and deliberately for centuries, many of which have been benign or even contributed positively to Britain's natural heritage[1]. However, whilst deliberate introductions are generally well managed, the increased global movement of global movement of people and goods through trade and tourism[1,2], coupled with the effects of climate change, has resulted in increasing numbers of 'uninvited' non-native species now reaching our shores.

The routes by which non-native species may be introduced and/or expand the range of colonisation are many and varied. In the marine environment for example, species can be introduced as aquaculture escapees and by transportation in ship ballast and fouling on ship surfaces.

Invasive non-native species

The principal concern associated with the introduction and spread of non-native species is the potential for some to become invasive. Invasive non-native species are broadly defined as species that once introduced, have the ability to spread, causing damage to the environment, the economy or our health[3]. Invasive species upset the balance of the ecosystem as they may be bigger, faster growing or more aggressive than native species[4]. They may also have fewer or no natural predators to control their numbers. Native species are often unable to compete and fairly quickly the invasive species take over[5].

It is widely accepted that the harm associated with invasive non-native species is second only to habitat destruction, as the main cause of biodiversity loss worldwide. There may often also be a significant economic impact such as the fouling of structures as seen in Cardiff Bay with Zebra mussels[6] and obstruction of waterways as seen on parts of the Gwent Levels with Floating Pennywort (subject to an eradication programme in 2010)[7]. A recently published report has estimated the economic impacts of such species cost the UK economy, £1.7 billion per year[2].

Fig 1: Floating pennywort. © Crown Copyright - Great Britain Non-Native Species Secretariat

Fig 2: Zebra Mussels. © Paul Wash

Species recorded within or near the Severn Estuary

There are many examples of both terrestrial and freshwater non-native plants and animals immediately inland of the Severn Estuary. These range from the widespread species such as mink and Japanese knotweed, to those with currently less extensive distribution, such as the Zebra mussel (See Fig. 2) and killer shrimp in Cardiff Bay, the sunbleak fish in parts of Somerset and the highly invasive aquatic plant pennywort- found at a number of coastal freshwater bodies.

Killer shrimp

Known as *Dikerogammarus villosus*, it has been given the nickname 'killer' not only as a result of its voracious appetite for a range of native species, particularly native shrimps and young fish, but also as it is known to sometimes leave its killed prey uneaten. Originally from the region around the Black and Caspian Seas, the Killer shrimp has spread across Western Europe in the last ten years. Despite growing up to only 30mm long (larger than native freshwater shrimps), it has been identified as being the worst non-native invader by the Environment Agency.

Fig 3: Killer shrimp. © Environment Agency

There have been relatively few non-native marine species recorded colonising the extremely high energy environment and turbid waters of the Severn Estuary – although numbers increase to the west of the Estuary along the more open coast. Those that have been documented are shown in Table 1.

Table 1: Non-native marine species

Source: Non-Native Species Secretariat website

Species	Distribution	Risk
Australasian barnacle	Widespread	High impact - invasive
Slipper limpet	Widespread	High impact - invasive
Jenkins spire shell	Widespread	Low risk - not known to be damaging
Common cord grass	Widespread amongst suitable saltmarsh and mudflat habitats	High impact - invasive
Pacific oyster	Vale of Glamorgan coast	High impact - invasive
Sand gaper clam	Vale of Glamorgan coast	Low risk - not known to be invasive

Fig 4: Slipper limpets. © Keith Hiscock from www.marlin.co.uk

Whilst some of the non-native species detected in the Estuary are considered as being potentially invasive, any significant impact has yet to be identified. For instance, the Australasian barnacle will displace native barnacles in some habitats, but in some estuaries, such as the Severn, it has colonised new areas[6] (see Fig. 5).

Fig 5: Australasian Barnacle. © Pembrokeshire Coastal Photography

Unlike freshwater fish species that tend to have been introduced either illegally or unintentionally by human activities, the presence of new marine fish species is likely to be due to more 'natural' circumstances. In recent years it has been seen that certain fish species are extending their northern range, possibly as a response to climate change; particularly changes to water temperature patterns. A number of these such as the grey triggerfish, a Mediterranean species, are now fairly common in waters west of the Severn Estuary during certain times of the year[8]. But as with other 'off-course' individuals, sightings within the Estuary are still rare.

Fig. 6: Weed extraction boat, targeting Pennywort.
© Crown copyright 2009, Great Britain Non-Native Species Secretariat

Climate change

Climate change could have a substantial impact on biodiversity in the coming years – both by affecting the distribution of our native species, and by enabling some non-native species to become more common. Increasingly, there could be a rise in the currently benign non-native species that become invasive as the climate changes. Already we are seeing some evidence of animals occurring outside their usual or expected ranges. Recent research shows that the (generally northerly) expanding range of some species including marine molluscs, plants, migratory birds and fish are consistent with patterns of climate change seen in the UK over the past 30 years[1].

A distinction can be made between the spread of non-native species by human intervention and the inevitable changes to species composition that naturally occur in a dynamic environment such as natural colonisers, which may expand or shift their native ranges in response to climate change (though it can be argued that the migration of species due to climate change is a natural response to a man-made problem)[5].

For more information see the following link:

- Non-Native Species Secretariat, https://secure.fera.defra.gov.uk/nonnativespecies/home/index.cfm
- Further references, pg 65.

Nature Conservation Designations

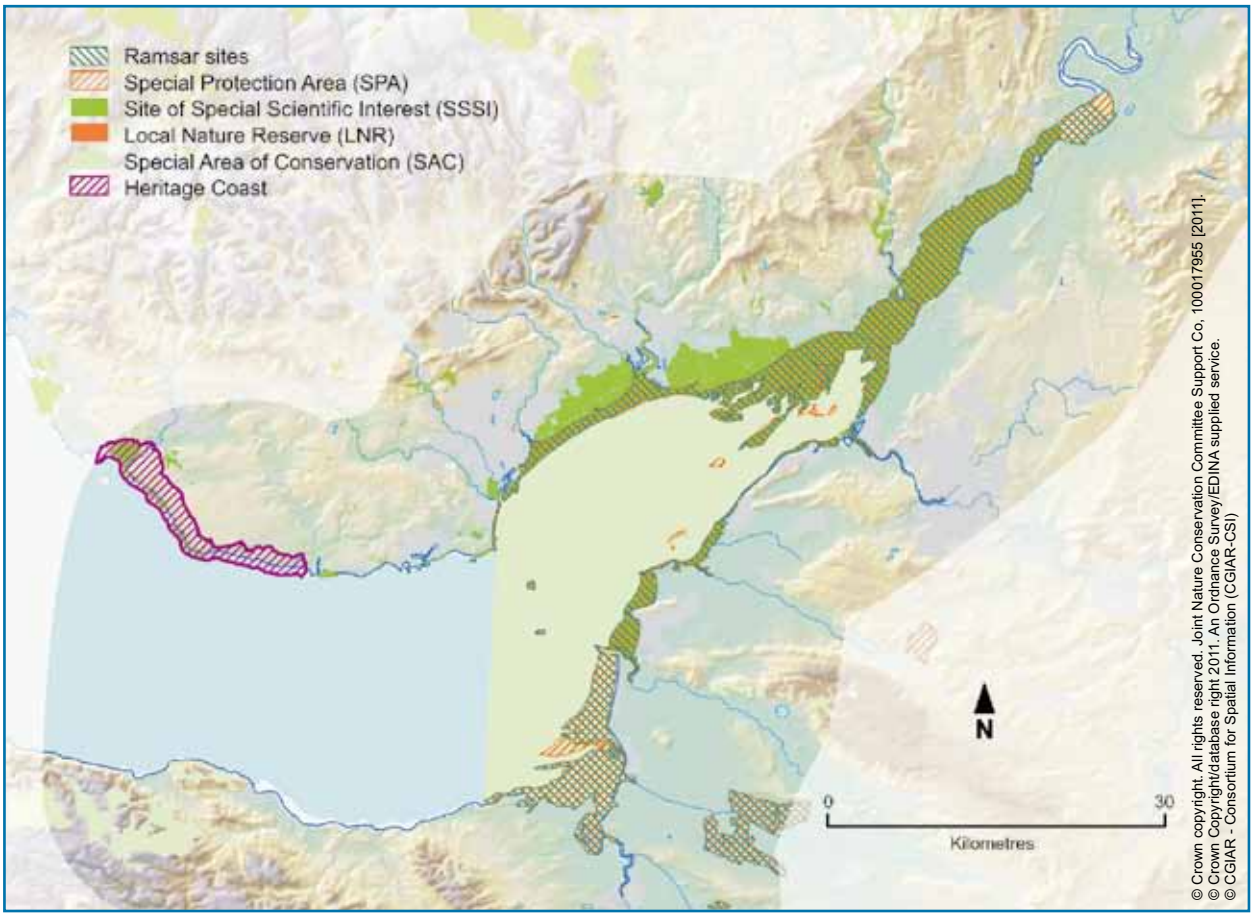


Fig.1: Map of the Conservation Designations currently in place in the Severn Estuary.
Source: SEP

Nature conservation is the active management of natural resources (plants, animals and the environment) to ensure that through protection they survive or are appropriately used. Nature conservation designations protect key resources in specific areas; generally having their own management, monitoring and reporting systems in place in order to ensure that deterioration does not occur. The Severn Estuary has numerous nature conservation designations (see Fig. 1) to reflect its important habitats, species and geology.

International

Ramsar

Ramsar sites are designated to stem the loss of wetlands now and in future. The Severn Estuary was designated as a Ramsar site on 13th July 1995, covering16,942 ha[1] of wetland. The qualifying interest features of the Severn Estuary Ramsar overlap with those of the Severn Estuary Special Protection Area (SPA) and Special Area of Conservation (SAC).

European

Special Area of Conservation (SAC)

SACs are designated under the Habitats Directive, for areas supporting rare, endangered or threatened species of plant or animal (other than birds) and important habitats.

Fig. 2: Sabellaria alveolata. © Sion Roberts

The Severn Estuary was designated as a SAC on 10th December 2009. Included in its 73,715.4 ha[2] is an overarching "estuaries" feature within which subtidal sandbanks, intertidal mudflats and sandflats, Atlantic salt meadows and reefs (of *Sabellaria alveolata*, see Fig. 2) exist. Furthermore, three species of migratory fish are defined both as features in their own right and as sub-features of the Estuary feature.

Special Protection Area (SPA)

SPAs are designated under the Birds Directive. Such sites are classified for their rare and vulnerable bird populations and for regularly occurring migratory species. SPA areas help guarantee the maintenance of appropriate resources and habitats required to ensure the survival or viability of wild bird species of European importance.

Fig. 3: Intertidal mudflats on the Severn Estuary. © SEP

On 13th July 1995, 24,662.98 ha[3] of the Severn Estuary were designated as a SPA due to the Estuary's national and international importance for the breeding, feeding, wintering and migration of rare and vulnerable species of birds. The intertidal mudflats (see Fig. 3) and sandflats, saltmarsh, shingle and rocky shore habitats bordering the Estuary are also protected within the SPA as they support the Estuary's large bird populations.

European Marine Site (EMS)

Fig. 4: SPA, SAC and Ramsar designated site at Sharpness. © Roger Morris (Bright Angel Coastal Consultants Ltd.)

The term 'European Marine Site' (EMS) is the collective term for intertidal SACs and SPAs (see Fig. 4). Competent and Relevant Authorities bordering the Estuary have a statutory duty to manage their activities within the Severn Estuary European marine site to minimise impacts and deterioration of the protected features of European importance. Natural England and the Countryside Council for Wales are responsible for providing conservation objectives and advice to the Relevant and Competent Authorities to assist them with their management of the site[4]. The Association of Severn Estuary Relevant Authorities (ASERA) facilitates these Authorities to discharge their statutory duties in the most efficient and cost effective way possible.

National

Marine Conservation Zones (MCZ)

The 2009 Marine and Coastal Access Act sets out tools for establishing Marine Protected Areas (MPAs), with the purpose of protecting and enhancing marine habitats and species. Marine Conservation Zones are a type of MPA and are designed to protect nationally important marine geology, geomorphology, wildlife and habitats in the UK's inshore and offshore waters[5]. For the Welsh side of the Severn Estuary this project is being undertaken by the Welsh Government via the Marine Conservation Zone Project Wales. For the English side of the Estuary, Finding Sanctuary is coordinating the process for the south-west of England area. At the time of writing, both projects are considering whether additional protection in the form of MCZs is necessary for the Severn Estuary.

Site of Special Scientific Interest (SSSI)[6]

Sites of Special Scientific Interest (SSSI) are the best examples of our natural heritage, of wildlife habitats, geological features and landforms. They are intended to form a national network of areas, representing in total the parts of Britain in which the natural features, especially those of greatest value to wildlife conservation, are most highly concentrated or of highest quality.

Fig. 5: Intertidal habitat on the Severn Estuary. © SEP

The study area has numerous coastal SSSIs (see Fig.1) that cover a very varied assemblage of designated features, from plants to geological formations. The most notable amongst these is the Severn Estuary SSSI that covers approximately 15,000 ha of foreshore and inter-tidal habitat and forms part of a larger area which includes the Upper Severn Estuary SSSI and Bridgwater Bay SSSI. Also within the Estuary, are the three island SSSI's of Sully (near Barry), Flat Holm and Steep Holm. Other coastal sites include Aust Cliffs, Brean Down, Portishead to Black Nore, the Gwent Levels and the 675 ha of coastline, from Blue Anchor to Lilstock (North Somerset). A significant new notification in 2010 was the Newport Wetlands SSSI. Its wide variety of habitats including inter-tidal foreshore (see Fig. 5) covering 865 ha, was created as part of the compensation for the loss of the Taff/Ely Estuary SSSI at Cardiff Bay following the completion of the barrage in 1999[4].

National Nature Reserve (NNR)[7]

Like SSSIs, National Nature Reserves represent the finest wildlife and geological sites in the country. They were initially established to preserve the natural features of the area whilst also enabling the public to learn about them. On the English side if the Estuary, the Somerset Levels and Bridgwater bay are designated National Nature Reserves; whilst on the Welsh side, it is the Newport Wetland Centre.

Area of Outstanding Natural Beauty (AONB)

AONBs are protected areas of high scenic quality which aim to enhance the natural beauty of the landscape. AONBs are designated solely for their landscape qualities (including landform and geology, plants and animals, landscape features and the rich history of human settlement over the centuries). There are two AONBs that extend to the shores of the study area[8] – the Quantock Hills AONB includes approximately three miles of the North Somerset coast near Watchet and the Wye Valley AONB surrounds 72 miles of the River Wye from just below Hereford, downstream to Chepstow. The Hills were designated in 1956[9] for their distinctive character, natural beauty and cultural heritage.

Heritage Coasts

Heritage Coasts are stretches of outstanding undeveloped coast. They are not protected by law, so are 'defined' rather than designated, but they are given special consideration by Local Authorities in planning decisions for example. There are two Heritage Coasts within the Estuary; the Exmoor Heritage Coast covering 34 miles between Minehead and Combe Martin and the 14 mile Vale of Glamorgan Heritage Coast between Aberthaw and Porthcawl[10].

Table 1: Principal reasons for the main Nature Conservation Designations[11]

Features	SSSI	RAMSAR	SPA	SAC
Estuary	■	■		■
Inter-tidal mud & sand flats	■			■
Saltmarsh	■			■
Rocky shores	■			
Reefs				■
Sub-tidal sandbanks				■
Migratory Fish	■	■		■
Birds	■	■	■	

Local

Site of Importance for Nature Conservation (SINC)[12]

Though not protected by law, SINCs are considered within the planning system. They are designated by local authorities to provide an important link to statutory designated sites and provide green corridors throughout urban areas.

Local Nature Reserve (LNR)

In the middle of the Estuary, the island of Flat Holm has been a designated LNR since 1975 (and SSSI since 1972). Flat Holm's natural history and geology is both interesting and important. Some of the notable features are; coastal limestone grassland; cliff ledge habitats, wild leek and a colony of breeding Lesser Black-backed gulls. The Cardiff Biological Database contains over 2,000 records for Flat Holm (see Fig. 6), mostly of plant and bird species[13].

Fig. 6 View from Flat Holm Island. © Sam Whitfield, 2010

CHaMP

Coastal Habitat Management Plans (CHaMP) provided advice to inform strategic flood risk and coastal management decisions to avoid damage to sites designated under the Ramsar convention, Habitats and Birds Directives, including modifications related to climate change and 'coastal squeeze' (see section on Weather and Climate Change).

In 2010, the Severn Estuary CHaMP guided the Severn Estuary Shoreline Management Plan II (SMP2) and the Flood Risk Management Strategy for the Estuary[14].

For more information see the following links:

- Countryside Council for Wales, http://www.ccw.gov.uk
- Natural England, http://www.naturalengland.org.uk
- Finding Sanctuary, http://www.finding-sanctuary.org/
- Flat Holm Island, http://www.flatholmisland.com/
- Flood Risk Management Strategy, http://www.severnestuary.net/frms
- Severn Estuary Coastal Group, http://www.severnestuary.net/secg/
- Further references, pg 65.

Population & Development

Human Population

The Severn Estuary has long been a focus of human activity. People have lived and worked around the Estuary for millennia. It provides attractive settlement prospects, including resources (food, water, raw materials) as well as significant opportunities for trade and leisure.

The Estuary is home to a relatively large human population of around 1 million people[1]. Other estuaries around the world, with comparable tidal ranges, have relatively much smaller populations and associated population pressures.

Around the Severn Estuary there are significant conurbations with populations in excess of 100,000 people. Large cities, including Cardiff, Newport and Bristol support a sizeable proportion of the Estuary's population, with smaller towns and remote rural settlements also contributing to the populace.

Summary population statistics for local authorities around the Estuary can be found in Table 1.

The Office for National Statistics (ONS) regularly release unit level estimates for resident populations in between major UK wide census surveys. The most recent data was published in 2010, showing slight increases in population figures across all Severn Estuary local authority areas (see Fig. 1).

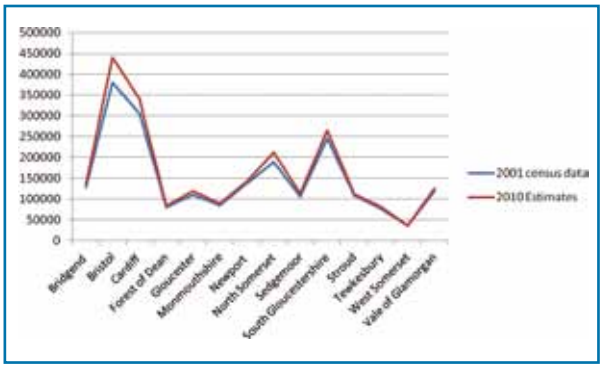


Fig. 1: Mid 2010 Population Estimates for local authority areas of the Severn Estuary, compared with 2001 UK Census data.
Produced by Cardiff University based on data from the Office for National Statistics (ONS) http://www.neighbourhood.statistics.gov.uk/dissemination/

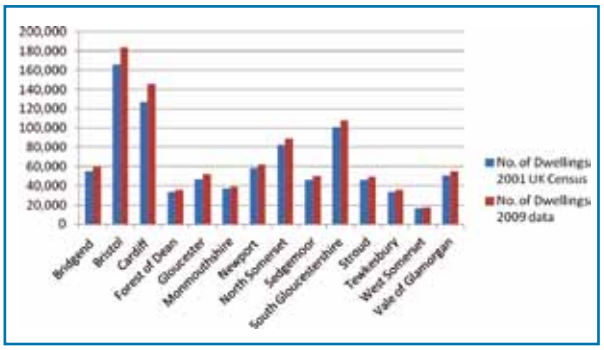


Fig. 2: Number of Individual dwellings in the Severn Estuary local authority areas in 2001 and 2009.
Produced by Cardiff University based on data from the Office for National Statistics (ONS) http://www.neighbourhood.statistics.gov.uk/dissemination/

Development around the Estuary

Given the Estuary's strategic location, with excellent land and sea communications and associated infrastructure, there have and continue to be significant development pressures in and around the Estuary. Whilst the restructuring of the economy and industry in the region over the last few decades has left a legacy of extensive areas of brownfield contaminated land, it has also presented a huge potential for urban renewal. The booming economy of the region in the 1990s and 2000s[2] led to considerable growth of the major conurbations (particularly around Cardiff and Bristol) and expansion of even some of the smallest settlements (such as Caldicot) alongside improvements to the commuter transport network. Indeed, most of the large residential development proposals referenced in the Severn Estuary Strategy document (2001) have been completed, representing an increased housing stock (see Fig. 2) of about 8% (average) for the Estuary region.

Table 1: Population statistics for local authority areas around the Severn Estuary (2001)
N.B All data is based on the 2001 UK Census (as the most up to date published data available at time of writing).

Local Authority	Total Population	Total Male Population	Total Female Population	Percentage Over 60 (%)
Bridgend	128,645	62,506	66,139	21.92
Bristol	380,615	185,660	194,955	19
Cardiff	305,353	145,761	159,592	18.67
Forest of Dean	79,982	39,010	40,972	22.96
Gloucester	109,885	54,003	55,882	19.37
Monmouthshire	84,885	41,448	43,437	23.58
Newport	137,011	65,764	71,247	21.05
North Somerset	188,564	91,632	96,932	24.82
Sedgemoor	105,881	51,589	54,292	24.71
South Gloucestershire	245,641	121,441	124,200	19.34
Stroud	107,898	52,908	54,990	22.88
Tewkesbury	76,405	37,150	39,255	23.33
West Somerset	35,075	16,637	18,438	33.38
Vale of Glamorgan	119,292	57,356	61,936	21.96

Increases in numbers of dwellings for each local authority area of the Severn show a relatively wide range, varying from around 2.6% in West Somerset, to 14.8% in Cardiff (see Table 2).

Table 2: Percentage Increase in Dwellings from 2001 to 2009 for each Local Authority Area

Produced by Cardiff University based on data from the Office for National Statistics (ONS http://www.neighbourhood.statistics.gov.uk/dissemination/)

Local Authority	% Increase
Bridgend	8.75
Bristol	10.5
Cardiff	14.75
Forest of Dean	6.21
Gloucester	11.3
Monmouthshire	6.91
Newport	5.95
North Somerset	8.09
Sedgemoor	8.88
South Gloucestershire	6.83
Stroud	7.11
Tewkesbury	7.21
West Somerset	2.68
Vale of Glamorgan	8.18

Urban and waterfront regeneration schemes have and continue to be a feature of the Estuary over the last decade; including the continued large scale development of the Cardiff Bay and Bristol Waterfronts to smaller schemes such as those at Lydney and Gloucester Docks (see Box 1). The Cardiff Bay scheme in particular has attracted a great deal of investment providing locals with jobs and a source of income. To date the regeneration of the Cardiff Bay area has generated over 17,000 new jobs and developed more than 5,000 new homes (with more planned for the future)[3].

Fig. 3: Cardiff Bay. © Gwilym Owen

The need to service the 'Severnside' conurbations and to meet regional development aspirations (within South East Wales and the Bristol/Gloucester area) results in continuous pressure for development around the Estuary. Alongside the urban and residential expansion noted above, there have been improvements and updating of the transport and energy infrastructure. A range of associated development proposals at a variety of scales have been discussed to help harness the region's potential. These have included the large-scale, controversial and now shelved M4 relief road and Severn Estuary tidal energy proposals[4] as well as a range of smaller schemes, such as those shown in Boxes 1 and 2. Economic strategies for south east Wales and the south west of England are set out in the '*South East Wales Development Strategy*'[5] and the '*Regional Economic Strategy for South West England 2006-2015*'[6], respectively. They set out regional plans for economic development in the key Severn Estuary regions.

In the context of all these development pressures, it is important to note the key role of planning authorities and other bodies around the region as they endeavour to fulfil their commitment to 'sustainable development.' These bodies attempt to balance development needs with the protection of the environment alongside the protection of property from flood risk and other potential hazards. (see section on Managing the Severn Estuary). In such a highly designated conservation area, achieving this balance is frequently complex and can be contentious. The 2009 Marine and Coastal Access Act's commitment to a coastal footpath around the entire UK coastline, for example, poses opportunities for improving public access to the shoreline and attracting recreational investments to the area, but also creates issues with respect to sensitive habitat and species disturbance.

The Welsh Government is committed to creating a continuous 850 mile 'All Wales Coast Path' by 2012. The Path's development has been funded, in part, by the Coastal Access Improvements Programme (CAIP), to the sum of £2 million per year since 2009 and is due to be launched on the 5th May 2012.

Box 1: Recent Developments

Recent and ongoing developments taking place across the Estuary include the Portbury Wharf residential development near Portishead, residential developments at Wentlooge and Newport and waterfront developments at Watchet, Bristol and Weston-super-Mare.

A recently completed development in the Severn Estuary region is the newly opened gas-fired Severn power station at Uskmouth near Newport. Opened in February 2011, it has the capacity to run 1.5 million homes and has generated mass employment during the construction phase. It will also provide 40 permanent jobs to the region (see section on Energy).

Box 2: Proposed Developments

- Plans for offshore renewable energy developments in the region are currently under way. In 2009, the RWE nPower renewables bid to the Crown Estate was successful, granting them development rights to the Bristol Channel Zone for the development of offshore wind.
- In March 2010 the Bristol Port Company received permission to build a Deep Sea Container Terminal at Avonmouth, which will serve large container vessels and the future planned Ultra Large Container Ships (ULCS).
- Regeneration of ports and waterfronts – such as Port Marine at Portishead; an ongoing development scheme creating a residential development of homes, retail space, community facilities and waterside amenities.
- Nuclear power - potential sites for development of nuclear power include a new third generation nuclear power station on EDF energy's site at Hinkley Point, and a new Horizon Nuclear Power venture at the site in Oldbury.
- Proposed Biofuel plant for Somerset under the European BEST (BioEthanol for Sustainable Transport) project[7].
- Severnside/Avon Industrial Site Development – proposals for the development of warehouse and distribution centres, waste recovery systems, and power generation[8].
- Plans for the proposed Avon Gas Power Station with an expected generating capacity of between 900-1,200MW of electricity, and could supply more than 1.5 million homes. Stage 2 of the consultation process is scheduled for Winter 2011/12[9].

Economic Activity and Employment

The Severn Estuary includes extensive sections of urban coastline with many key industries concentrated in the region. Most urban areas grew up around the main ports and harbours of the Estuary, associated with the rich industrial resources and economy of the Estuary's hinterland, including the heavy industrial base and resources of South East Wales. However, the last few decades have seen the restructuring of the Estuary's industrial base. This has included the closure of several key industrial sites, including the major integrated steel production plant near Newport, and the emergence of the service sector as a major employer. Petrochemical industrial complexes in the Barry and Avonmouth areas, ports and shipping power generation, waste disposal, aggregate dredging and leisure and recreation comprise some of the other predominant industries of the Estuary[10].

Recent employment statistics are made available on a regional basis (see Table 3), for example, Cardiff has seen a rise in unemployment since the 2001 UK Census, to around 4% of the population, with the most sought after jobs from the unemployed coming from the Sales and Customer Service sector and Elementary occupations. The economic outlook is worsened still with the proposed government and health care job losses, and the removal of hundreds of jobs due to cuts in government spending[11].

Employment is largely centred around the service sector, with a large proportion of jobs coming from the tourism, leisure and recreation sectors. In the past, farming and grazing was a key employer, however, this is now declining. Nevertheless grazing remains an important land use on the Somerset levels, which forms the largest lowland grazing marsh system in the UK. Within West Somerset 7.16% of the workforce is employed in the agricultural sector, a relatively high percentage compared with the rest of the Severn Estuary region[12].

Occupation types in the Severn Estuary region are represented in Fig. 4 overleaf.

Table 3: Employment statistics for local authority areas around the Severn Estuary (2001)

N.B Based on the 2001 UK Census (the most up to date published data available at time of writing).

Local Authority	% of active workforce employed	% of active workforce unemployed	% Retired
Bridgend	55.57	3.46	14.54
Bristol	60.1	3.08	11.14
Cardiff	55.55	3.09	11.66
Forest of Dean	63.06	2.97	14.92
Gloucester	65.32	3.39	12.53
Monmouthshire	61.29	2.63	15.61
Newport	56.76	3.94	14.32
North Somerset	63.91	2.12	16.07
Sedgemoor	65.13	2.72	16.19
South Gloucestershire	68.9	1.81	13.33
Stroud	66.2	2.4	14.62
Tewkesbury	67.17	2.02	15.3
West Somerset	56.41	2.94	22.2
Vale of Glamorgan	60.05	3.3	14.72

Fig. 4: Occupation types for the Severn Estuary (average percentage %) (2001)
N.B All data is based on the 2001 UK Census as the most up to date published data available at time of writing.

Cardiff

Financial and Business Service employment in Cardiff stood at around 35,000 in 2004; 18.4% of the city's workforce. Employment in this sector increased by 17.7% from 2000-2004 – higher than the rate of growth experienced in many of the UK Core Cities, including Bristol, Birmingham and Leeds and *above* the British and Welsh averages.

Cardiff's Leisure and Tourism sector generates significant economic and cultural benefits for the city through the staging of major international events at world-class venues such as the Millennium Stadium and Wales Millennium Centre. Cardiff's diverse leisure and tourism also embraces a proud heritage, boasting two castles, two national museums, two cathedrals, Roman remains and acres of parks and gardens. With around 18,200 workers employed in leisure and tourism industries, the sector accounted for around 9.5% of total employment in the city in 2004. Employment in this sector increased by 15.3% between 2000 and 2004 – higher than the British average but lower than the rate experienced in many of the UK Core Cities[13].

Bristol[14]

Bristol has nine key sectors; Aerospace and Defence, Creative and Media industries, Environmental Technology and services, Professional services, Information and Communications Technology, Retail, the Third Sector, Tourism and Leisure and the Public sector.

In September 2008, Bristol received a massive boost to its retail sector, with the opening of the new £500 million Cabot Circus retail and leisure development. Environmental improvements within this sector is of great focus, illustrated by the Bristol St. Nicholas Market receiving the 'Greenest Market in the UK' award in 2008, from the National Market Traders' Federation (NMTF) for the introduction of effective waste management systems.

With 59,000 employees within the financial sector, Bristol is regarded as the 'hub' of the professional services sector in the South West; as well as being the third largest of its kind outside London.

The 'Third Sector', otherwise known as the social economy, is a thriving and innovative movement in Bristol and an important part of the city's economy. The 'Social Economy in Bristol Audit 2004-05' found that this sector contributed £275 million to the local economy, growing at a rate that was 3% faster than the overall growth of the economy.

Infrastructure

The Severn Estuary region hosts around £14 billion worth of critical infrastructure[15], requiring constant maintenance and upgrading so that the region remains viable and competitive. This includes transport infrastructure, power and energy infrastructure and business infrastructure. Of particular note are the important motorway (M4 and M5) and rail networks which have been significantly enhanced over the last decade, with ongoing schemes providing improved connectivity between the region's conurbations.

There is also extensive coastal and sea defence along the Estuary's shoreline, providing protection to both urban and rural areas as well as critical infrastructure e.g. major roads, rail links and electricity generating sites. The Estuary is already significantly defended, particularly around the Wentlooge and Caldicot Levels on the Welsh side, and the Somerset Levels on the English, with additional small scale localised defences at several other locations[16]. These include hard defences designed to protect areas from marine/tidal flooding, such as the embankments along the Severn Beach, to structures designed to improve cliff toe stability such as at Penarth. As a result of these structures, flood risk varies from 1 in 1000 (low risk in urban areas), to 1 in 10 (high risk) in rural areas[17].

Climate Change (and Flood Risk)

The threat from climate change and flood risk in the Severn Estuary has the potential to be substantial, as many homes and businesses as well as crucial infrastructure exist on or near the shoreline across the region. With sea levels predicted to rise, the risk of flooding and damage to lives and property could increase without significant investment in the Estuary's coastal defence infrastructure. A recent study using tide gauge data from the Bristol Channel and Severn Estuary[18] found that there had been a rise in mean sea level over a 15 year period from 1993-2000 and that these trends were likely to continue[19].

The Severn Estuary Flood Risk Management Strategy – the Environment Agency's plan to manage tidal flood risk in the Severn Estuary – predicts that if no action is taken and current sea defences are not maintained, then much of the low lying land around the Estuary will flood several times a year[20].

For more information see the following links:

- South east Wales Development Strategy, http://www.capitalwales.com/contact/strategy.asp
- Regional Economic Strategy for South West England 2006-2015, http://bit.ly/sPMpea
- Flood Risk Management Strategy, http://www.severnestuary.net/frms
- Further references, pg 65.

Archaeology

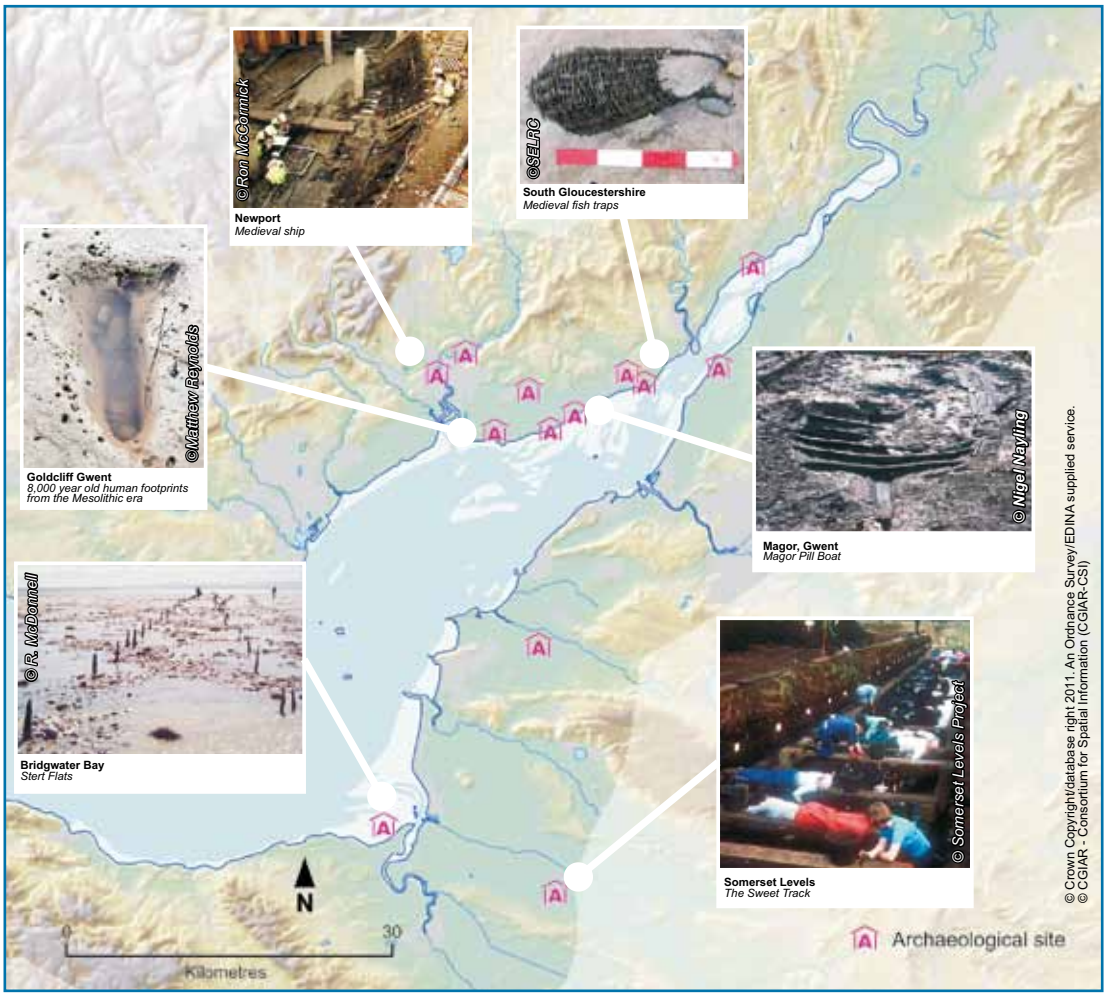


Fig. 1: A selection of archaeological sites around the Severn Estuary. Source: SEP

The Historic Environment

The Severn Estuary has one of the most rich and varied archaeological landscapes in Europe. The Estuary and its surrounding levels have been a focus of human settlement for many millennia and evidence can be found preserved in the archaeological record throughout the region. The Severn Estuary region demonstrates the greatest concentration of coastal archaeology in Britain and provides an irreplaceable record of historic importance[1].

The historic landscape of the Estuary is far better preserved than most sites around the UK, owing to the permanently waterlogged conditions, which assist the excellent preservation of remains[1]. These waterlogged conditions also preserve organic remnants of past environments, such as wood, which would otherwise degrade and eventually disappear.

Artefacts that have been found around the Estuary include Mesolithic foot prints, Bronze Age track ways, Iron Age villages, and fish traps from the Medieval period[2]. The Estuary also has a rich heritage of maritime archaeology, with remains of vessels found at Newport, Barland's Farm, and Caldicot[3].

A selection of Severn Estuary Artefacts

Mesolithic

Footprints, Gwent[4]
8,000 year old human footprints from the Mesolithic era can be found in the intertidal zone along the Welsh side of the Estuary, across the Gwent Levels. Preserved in estuarine clays, fragile traces of human history like these footprints are scarce.

Submerged forest, South Gloucestershire[5]
Many timbers of once large trees from the Mesolithic period can be found in the inter-tidal zone of both the English and Welsh sides of the Severn (see section on Geology).

Neolithic

The Sweet Track, Somerset[6]
The Sweet Track is one of over 40 prehistoric wooden track-ways known from Somerset. It takes its name from Ray Sweet, a local peat cutter who discovered the site. In the 1970s, the Somerset Levels Project excavated the track-way, which was built as a raised plank walkway through the 2km of reed bed that separated the Polden Hills from the 'island' of Westhay (see Fig.1).

Bronze Age

Caldicot Castle[7]
Founded by the Normans, the remains of the important masonry castle date from the early 13th and 14th centuries. The castle was developed as a stronghold in Medieval times and was later restored as a Victorian family home.

Redwick Settlement[8]
An intertidal prehistoric site was discovered by Derek Upton on a peat shelf close to the sea wall, 1.2km south east of the Medieval to modern village of Redwick in Gwent. Between 1999 and 2001, four rectangular buildings (measuring 11m by 4m) were fully excavated; having been preserved in the peat. Footprints from cattle were found surrounding the buildings, suggesting that the site was a seasonal settlement for cattle herders in the wetland.

Roman

The Aust Goddess, South Gloucestershire[5]
Recovered from the foot of a cliff near Aust one hundred years ago, this small bronze statuette is thought to date back to the late Iron Age or Roman times. It is widely believed that the statuette represents the Roman fertility goddess-Minerva and is of local origin. The find highlights the importance of the region in establishing historic trading links with Europe.

Barracks, Caerleon[5]
This site holds some of the best surviving barracks from the Roman world. Troops would have been supplied with wine and olive oil by boats from Europe travelling up the Severn, then following the River Usk. Pottery found at the site originated from Spain, Germany and France.

Amphitheatre, River Usk[5]
The amphitheatre lies on the River Usk, a tributary of the Severn and was used as a place for ceremonies and entertainment for the troops of the II Augusta Legion, stationed at Caerleon.

Pottery, South Gloucestershire[5]
Numerous Roman pottery finds have occurred from 'field-walking' in South Gloucestershire.

Barland's Farm, Gwent[5]
The vessel, made of oak timber planks held together by iron nails, was originally 11.1m in length and 2.6m wide with a mast step. It is likely that the Gwent example is representative of a group of boats that plied their trade across the Estuary, potentially also making longer, sea-going journeys.

Fish traps, Stert Flats, Bridgwater Bay, Somerset[9]
Tree-ring and radiocarbon dating suggest that construction of the numerous fish weirs on Stert Flats, was within the last four centuries. A millennium of fish traps is represented in the area, with the earliest 'V' shaped structures dating back to the 10th century AD (see Fig.1).

Medieval

Ship, Newport, Wales[10]
Discovered in 2002 during some development work for a new Arts Centre, this Medieval vessel is one of the most well preserved and intact examples of a fifteenth century ship existing in Northern Europe. The vessel was found containing some of its original cargo, including Portuguese pottery and coins. The discovery of this vessel is one of the most significant finds of international importance.

Fish Traps, South Gloucestershire[11]
Fish traps and baskets dating back to Medieval times were unearthed near Sudbrook during a survey prior to the construction of the Second Severn Crossing in 1991. Artefacts found include post settings, track-ways, and woven fish traps and baskets; illustrating the strong maritime history of the Estuary.

Magor Pill Boat, Gwent[12]
The vessel was found in 1994 by Derek Upton; the subsequent Glamorgan-Gwent Archaeological Trust excavation was funded by CADW. The vessel was found in an incomplete condition, of 7m by 3.4m (originally measuring 13.2-14.3m by 3.7m). Tree ring dating has shown the boat was built in 1240 AD.

Puxton, North Somerset[13]
Following extensive post-Roman flooding, Puxton was one of the first places on the North Somerset Levels to be recolonised; making the site a particularly fine example of a shrunken Medieval settlement.

Recent Finds[14]

During the summer of 2011, the well preserved remains of a 2000 year old Roman port were discovered outside the Roman fortress in Caerleon, South Wales, by a team from Cardiff University's School of History, Archaeology and Religion. The port is only the second known from Roman Britain and this is the first time the remains have been seen in almost two millennia.

The archaeological remains in the Estuary are not only fundamental to our understanding of the region's past, but also help us understand its present and future. This rich historical heritage forms an irreplaceable record and it is certain that there is much more to be discovered.

Threats and Climate Change

There are numerous threats to artefacts of historical importance within the Estuary- particularly from land-based development, although improved planning guidance and legislation is reducing this. With many sites remaining undiscovered, this threat is amplified. The potential damage to archaeological remains from climate change is also significant, with increasing erosion resulting from sea level rise posing a potential threat to features, both discovered and undiscovered.

For more information see the following links:
- SELRC, http://www.selrc.org.uk/
- Cardiff University News Centre, http://bit.ly/od54f9
- SEP, Archaeology Guidance notes, http://bit.ly/uM2dgt
- Further references, pg 65.

Tourism & Recreation

This section focuses on Severn specific tourism and recreation in the geographic area covered by all 14 bordering local authority districts (as identified in Table 1), with specific focus on the coastal zone.

Tourism is one of the largest industries in the UK; with a recent study confirming that (once direct and indirect impacts were taken into account), tourism was worth £115.4bn to the UK economy in 2009[1]. Tourism contributes £96.7bn to the economy in England (8.6% of GDP) and £6.2bn in Wales (13.3% of GDP)[1].

Coastal Tourism is continuing to grow in popularity throughout the UK. In 2008, spending associated with tourist visits totalled £3,108 million[2] in the Severn Estuary region. This was the result of over 37 million day visitors contributing to a total of 49.2 million visitors to the region in 2008[3]. Table 1 summarises the total expenditure by tourists within each local authority district in 2008.

Table 1: Total tourist spend in 2008[4]

Local Authority District	Total Expenditure (£'s million)
Bristol	£788.36
Cardiff	£646.64
South Gloucestershire	£277.06
North Somerset	£272.36
Sedgemoor	£214.15
Bridgend (2003)	£200
Monmouthshire	£146.47
Stroud	£123.47
Gloucester	£121.60
West Somerset	£110.02
Forest of Dean	£105.81
Tewkesbury	£102.35
Newport	No Available Data
Vale of Glamorgan	No Available data
Total	**£3,108.29**

Historical Tourism Development

Historically, certain settlements within the Severn Estuary study region have been extremely important for development of the tourism trade and coastal tourism industry; of particular importance have been the resorts of Barry Island on the Welsh side of the Estuary and Western-super-Mare on the English. Certain sections of the Estuary's shores are also popular locations for caravan and holiday parks, such as the stretch between Penarth and Barry on the Welsh side and Sand Bay north of Weston-super-Mare. Other historically important resorts include Penarth, Clevedon and Burnham-on-Sea.

Fig 1: Barry Island beach. © Peter Brabham

Barry Island[5]

Tourism began in Barry Island as early as 1876, when J.D. Treharne built a Pier on the island to enable passenger boats to land. In the first year the pier opened, over 15,000 visitors flocked to the island. However, it was the extension of the railway line to Barry Island itself in 1896, which really influenced the visitor numbers; with 100,000 people arriving throughout the 1890's. The railway, which is always open to the public, still provides access to the resort.

Tourism on the island soared over the following 100 years, with the introduction and development of many amenities and attractions. From 1966 to 1987, the Butlins holiday camp provided a range of activities for the people of South Wales as well as people from wider afield in the UK and abroad. Whilst many locals blamed the closure of Butlins for the demise of the local tourist trade, Barry Island's fate was not that dissimilar to many other coastal resorts, which have been struggling against a backdrop of overseas competition associated with cheaper and more attractive tourism products. In recent years, with the concerted actions of the local council, the Island's popularity has increased (see Fig. 1), with the re-opening of the Barry Island Pleasure Park and the filming of the Gavin and Stacey sitcom, Dr Who and Being Human.

Fig. 2: The new pier at Weston-super-Mare, rebuilt in 2010. © Rhoda Ballinger

Weston-super-Mare

The 19th century saw Weston grow from a tiny village of about 100 inhabitants, to a thriving Victorian seaside resort of nearly 20,000 people. A century later, the population had grown to nearly 70,000[6]. Today, Weston-super-Mare is still a popular tourist location, with attractions such as the SeaQuarium (which saw 8,400 visitors in February 2009[7]), Weston-super-Mare Museum, the Grand Pier (see Fig. 2), the Helicopter Museum and seasonal Wheel of Weston[6].

The Waverley paddle steamer, MV Balmoral and MW Marine cruise and ferry company, offer day-sea trips from Knightsone Island (see Fig. 3) to various destinations within the Bristol Channel and Severn Estuary at certain times of the year. After being burnt down, Weston's Grand Pier was rebuilt and officially opened in Autumn 2010. In addition, Weston Beach provides an expansive area for both wind and water sports[8].

2011 saw approval for the £50 million extreme sports attraction, which gained full support from district planners. Construction is expected to be completed in 2013, with the 'Leisuredome' company anticipating 550,000 visitors to the site and the generation of an additional £369 million for the tourism industry in the town[9].

Fig 3: Knightstone Causeway. © Roger Coleman

Impacts of Tourism[10]

Sustainability is the key to successful tourism in the Severn Estuary region. As such, since 2008, the South West Tourism Alliance has continued to work in close partnership with the independent charity Sustainability South West (SSW) on the English side of the Estuary to offer support to the tourism sector; through the provision of practical opportunities for businesses to become more sustainable. So far, particular focus has been given to supporting businesses (through advice, resources and training), engaging visitors (by using better communication), tackling transport (by examining the needs and influences of tourism related transport) and protecting assets (through the care of natural, historic and environmental aspects by all partners). Various positive and negative effects of tourism within the Severn Estuary are summarised in Table 2.

Some Severn Attractions

The Severn Bore[11]

The Severn Bore is one of Britain's spectacular natural phenomena, attracting thousands of visitors to Gloucester every year. It is a large surge wave that can be seen moving up the estuary of the River Severn, where the tidal range is the largest in Europe, (being as much as 12.3m at Beachley, see section on The Water Environment). As a spectacle, the bore is best viewed between Overton near Fretherne and Maisemore near Gloucester (see Fig. 4).

Fig 4: Surfers on the Severn Bore. © SEP

The Severn Way Walk[12]

The Severn Way is a walk linking Wales and England. The 337km (210 mile) trail marked 'Severn Way' is the longest river walk in Britain, tracing the route of the Severn from its source at Plynlimon to the sea and onto Bristol (see Fig. 5). There has been interest in the installation of 'counters' at various places along the Severn Way walk; in order to establish how many visitors a year use this popular route[13].

Fig 5: View of the Second Severn Bridge along the Severn Way Walk. © SEP

Table 2: Factors affected by tourism within the Severn Estuary region[10]

Factor	Effects
Economic	The profit tourism can bring to local and regional areas within the Severn Estuary is enormous; as shown by the amount of spend in the tourism sector each year. The economic importance of waterfront development sites and associated amenities around the Estuary cannot be underestimated, as noted in the section on Population and Development. Such schemes have not only transformed derelict and contaminated sites, but have also attracted significant investment and tourist numbers. The coastal resorts of the Estuary continue to face severe competition with overseas destinations; with many sites within these towns changing from tourism to residential use. However, major investment programmes in some of the resorts over the last decade have provided a boost to local economies as well as other benefits, including improved sea defences. The £29 million investment in Weston-super-Mare, for example, will help protect many seafront and town centre properties from future flooding.
Environmental	Tourism can provide new and renewed interest in environmental issues, wildlife and conservation. The tourism industry has been a key supporter of Blue Flag and other beach awards which, in turn, have promoted better beach and associated water quality around the Estuary. However, tourism and recreational activities have the potential to cause negative impacts, particularly disturbance of sensitive habitats and species. On the Severn Estuary the need to ensure that coastal access does not disturb over-wintering wildfowl has been a concern (see section on Nature Conservation Designations) particularly in the context of the development and promotion of the All-Wales Coastal Path
Social	Tourism can provide a profitable and alternative means of income for a community; both on a small and large scale (such as Barry Island and Weston super-Mare and Cardiff and Bristol respectively). There is however, the potential for more traditional forms of employment within a community, (such as salmon putcher fishing practised within the Severn; see section on Fisheries) to be disregarded by locals in favour of a cash income solely from tourism and its related trades.

Slimbridge Wildfowl and Wetlands Trust[14]

Slimbridge Wetland Centre is set within 325 ha against a spectacular Severn Estuary backdrop. 2010 saw 231,734 visitors and an income of £871,036 to the centre[15]. Land Rover rides and canoe safaris allow close encounters with a fantastic array of wetland life; including rare and endangered bird species as well as wild otters, dragonflies, grass snakes and wild Orchids (see section on 'Birds').

Newport Wetlands[16]

This nature reserve offers a haven for wildlife on the edge of the city and is a great place for tourists; with brilliant views of the Severn Estuary all year round. Newport Wetlands is a partnership between the Countryside Council for Wales, Newport City Council and the RSPB and welcomes more than 85,000 visitors a year[17].

Fig 6: Newport Wetlands. © SEP

Bristol

Fig 7: Panorama of Bristol. © Gwilym Owen

Bristol is the capital of the south-west of England with a population of 433, 100[7]. Its waterside location, lined with historic buildings, tourist attractions, boats and restaurants, makes a popular year round tourist destination for over 9 million visitors each year[18,19], with £788.36 million spent by tourists in 2008 alone[4].

Bristol Floating Harbour[20]

Bristol Harbour was the original Port of Bristol, but as ships and their cargo increased in size, commercial port operations moved to Avonmouth and Portbury (see section on Ports and Shipping). The harbour is now a tourist attraction with museums, galleries, exhibitions, bars and nightclubs (see Fig. 8).

Former workshops and warehouses have been converted or replaced by cultural venues, such as the Arnolfini art gallery, Watershed media and arts centre, the new Museum of Bristol, "M Shed", the At-Bristol science exhibition centre and the Bristol Aquarium as well as a number of fashionable apartment buildings- all of which attract both local residents and tourists alike. Museum boats are permanently berthed in the harbour. These include Isambard Kingdom Brunel's SS Great Britain (see text below) and a replica of the Matthew (see Fig. 9) in which John Cabot sailed to North America in 1497[20].

The Bristol Ferry Boat Company and Number Seven Boat Trips operate ferry services in the harbour, serving landing stages close to most of the harbour-side attractions. The Bristol Packet boats offer regular harbour tours with commentaries and river cruises up the River Avon to

Fig 8: Ferries on the floating harbour. © Gwilym Owen

Conham, Hanham and Bath and downstream to Avonmouth. In late July each year, the Bristol Harbour Festival is held, resulting in an influx of boats, including tall ships, Royal Navy vessels and lifeboats. The festival in 2010 saw nearly 250,000 people descend on Bristol[7] for the free three-day event; which is thought to bring nearly £10 million in to the local economy[21].

Fig 9: The replica of the Matthew. © Gwilym Owen

Brunel's SS Great Britain[22]

The SS Great Britain was built by Isambard Kingdom Brunel and launched in Bristol as a world leading vessel in 1843. The vessel led the way with a groundbreaking screw propeller, an iron hull and a massive 1000 horsepower steam engine. She sailed from 1843-1886 travelling 32 times around the world. She was finally abandoned in the Falkland Islands in 1937, leading to an ambitious salvage project to bring her home to Bristol in 1970. She has been restored and conserved in the dry dock where she was originally built; and receives between 150,000 and 175,000 visitors annually.

Banksy[20]

Born in 1974, and taking street art in Bristol by storm in the 80's, Banksy is now a world famous artist; with artwork found in London, LA, New York and of course, his home of Bristol. 2009 saw thousands of people queuing for hours to view a free Banksy exhibition, held at the city's Museum and Art gallery. Today, permanent pieces of his street art can be seen throughout the year all across the city; with a visit to each one making for an interesting tour for both tourists and local residents.

Cardiff

Cardiff has been named as one of the top 10 summer destinations to visit in 2011 in the National Geographic Traveller List[23]. The city has a population of over 336,200[24] and boasts 125 hotels, 73 restaurants and 149 pubs, bars and nightclubs (18 of which are on the waterfront), Cardiff castle, the 56 hectare Bute Park and the Millennium Stadium[24]. In the first six months of 2010 alone, more than 10 million people visited Cardiff; an increase of 3 million from the previous year[24].

Fig 10: Cardiff Castle. © Gwilym Owen

Cardiff Castle

A tourist survey conducted in 2009 highlighted the 2000 year old castle as one of Wales' top heritage attractions and a site of international significance; with 80% of oversees visitors stating that seeing Cardiff castle was their main sightseeing priority[25]. The history of Cardiff Castle (see Fig. 10) dates back to its use as a Roman Garrison and later as a Norman stronghold; even undergoing a gothic transformation in Victorian times[26].

Cardiff Bay[27]

Cardiff Docks, or Tiger Bay as it was once called, was the world's largest coal exporting port in the early 1900's. However from the mid 1920's onwards the docks area fell into decline. In 1987, to counter the effects of economic depression in this run down area, the Cardiff Bay Development Corporation was created. Today, the docks area (known as Cardiff Bay) has been totally transformed by the Cardiff Barrage that impounds the Rivers Taff & Ely, creating a vast fresh-water lake. This has resulted in Cardiff Bay becoming Europe's largest waterfront development with a wealth of leisure activities available both on and off the water.

Fig 11: Mermaid Quay. © Gwilym Owen

Fig 12: The Pierhead Buliding. © Gwilym Owen

A number of boat tours operate from Mermaid Quay (see Fig. 11), which allow tourists to gain an understanding of the history and fauna of this exciting area. Cardiff Bay is also home to a number of attractions such as Techniquest Science Discovery Centre, Craft in the Bay, The Welsh Government at the Pierhead (see Fig. 12), Butetown History and Arts Centre, Goleulong 2000 Lightship, the Norwegian Church Arts Centre and the Wales Millennium Centre, a stunning international arts centre (see Fig. 13).

Fig 13: Wales Millennium Centre. © Gwilym Owen

The Atlantic Wharf Leisure Village provides further options for family entertainment including an Olympic size swimming pool, ice skating rink and Cardiff International White Water Centre[24]. In 2009, Cardiff Bay attracted nearly 13 million day visitors; contributing significantly to the £703 million spent that year by tourists in Cardiff[24].

Fig. 14: Cliff collapse at Porthkerry caravan park. © Jen Reis

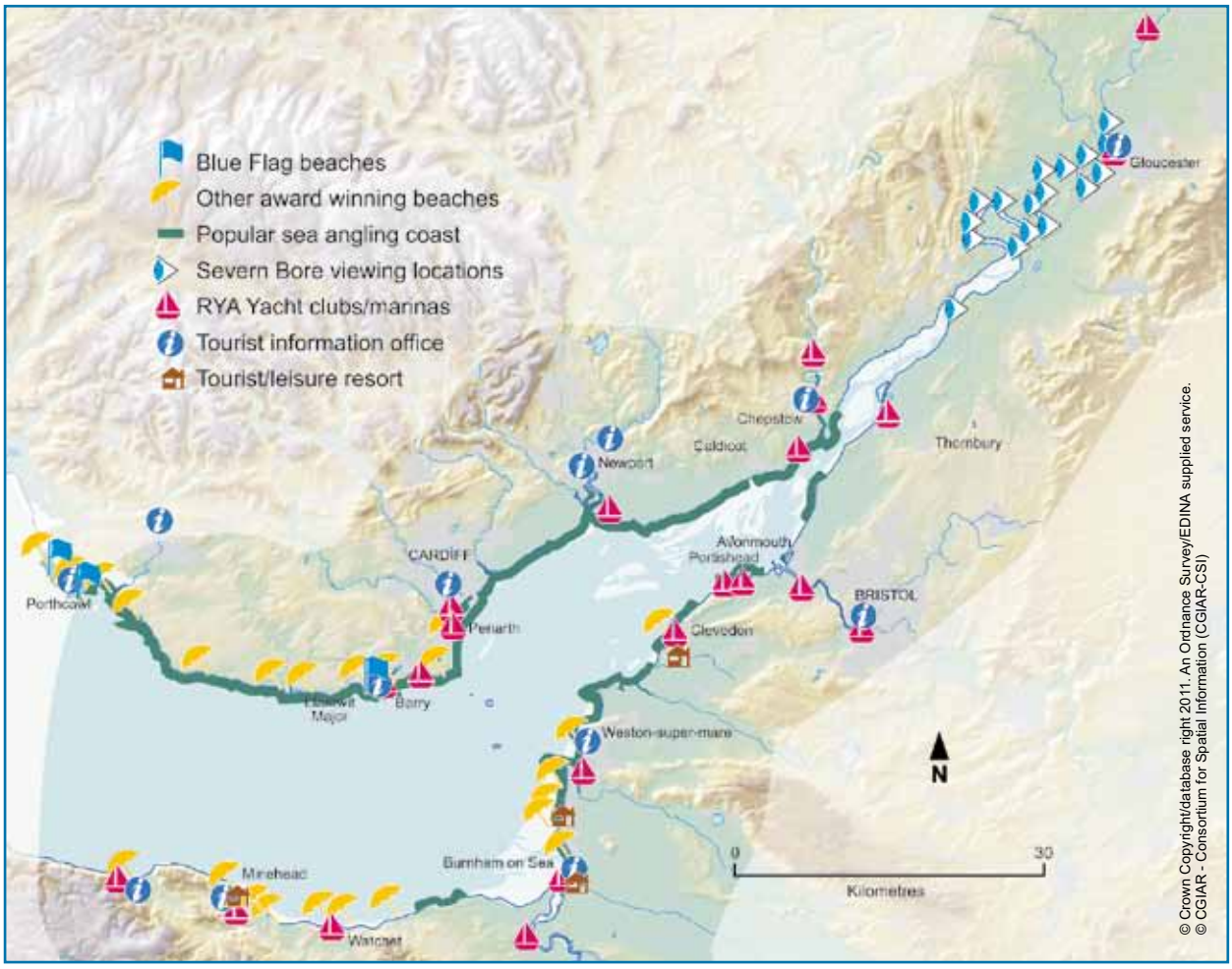


Fig. 15: Map illustrating the types and locations of various tourist activities within the Severn Estuary.
Source: SEP

Climate Change[10]

The effects of climate change within the Severn Estuary can offer opportunities for tourism as well as threats; as hotter summers and milder winters are likely to attract more overseas and domestic visitors to the South of England in general. However, whilst this increase in visitor numbers may result in more jobs within the Severn tourism sector, additional strain may be seen on infrastructure, sewage capacity, traffic congestion and health facilities.

In towns and cities, such as Cardiff and Bristol (which are already highly popular with tourists) greater visitor numbers will also bring a greater demand for accommodation and improved infrastructure.

Storm surges and rises in sea level, (factors which are associated with climate change) could damage land, buildings and infrastructure along the shores of the Estuary, threatening the less well maintained defences. For example, whilst the defences near Stolford and Combwich along the Steart Peninsula provide a high level of protection, flood risk is determined by the defences at Steart; which are themselves, far weaker[28]. The vulnerability of some low-lying coastal settlements which rely heavily on tourism (e.g. near Sand Point) will increase, as the potential for the loss of certain beaches through sea level rise and loss of access due to tide cut-off occurs. Whilst not attributed directly to climate change, the cliff failure at PorthKerry leisure park near Barry in October 2011, illustrated the potential of natural coastal processes to cause significant damage to important tourist infrastructure (see Fig. 14). There is also the potential for the loss of certain beaches through sea level rise and loss of access due to tide cut-off.

For more information see the following links:

- Visit Cardiff, http://www.visitcardiff.com/
- Visit Bristol, http://visitbristol.co.uk/
- The Waverley, http://www.waverleyexcursions.co.uk/
- The Severn Way Walk, http://bit.ly/vmiKOt
- Cardiff Castle, http://www.cardiffcastle.com/content.asp
- Further references, pg 65-66.

Energy Generation

From coal to tidal power, the energy-producing possibilities of the Severn Estuary area have long been a focus of interest. Many of the conditions which contributed to this interest in the past are still present whilst other factors have emerged and evolved to keep pace with technological developments. These have occurred both within the more traditional energy generating industry and with the introduction of new fuel types. As a result of the Estuary area having a wealth of favourable conditions, it continues to play a major role in the provision of UK energy generation, not only in terms of output, but also in the variety of generating plants and fuel types.

Various contributory factors relevant to site selection in the Severn Estuary area:

- Supply of cooling water – major consideration for fossil fuel and nuclear power stations.
- Availability of disused industrial land (brown-field sites) – important for new developments.
- Connections to the National Grid system.
- Natural processes - large tidal range and wind resource.
- Large population – high demand for power.
- Transport infrastructure including sea access.
- Gas networks.
- Skilled labour.

Electricity can be generated either specifically for the National Grid, (usually by large power stations), or to provide on-site power within industrial installations. Whilst most of the latter only generate sufficient energy for on-site needs, a few also supply the National Grid with any surplus. Where industrial processes require both electrical and thermal energy in the form of steam or hot water, this need is often met by a combined heat and power plant (CHP) such as Dow Corning.

Nuclear

Atomic energy provides approximately 18% of the electricity consumed in the UK[1]. The Severn Estuary area has been one of the principal areas of nuclear power generation within the UK since the first generation of nuclear power stations in the 1950s.

Fig 1: Magnox Reactor at Oldbury power station. © Science & Society picture library

Hinkley Point B on the Somerset coast has two Advanced Gas-cooled Reactors. It began generating electricity in 1976 and is anticipated to cease generating in 2016[2]. It is currently operating at a reduced maximum electrical output of 840 megawatts (MW), approximately 70% of its full output[2].

Table 1: Electricity generating installations

Fuel type	Site location	Generating capacity (MW)
Coal	Aberthaw B, near Barry	1500[7]
	Uskmouth B, Newport	393[5]
Gas	Severn Power, Newport	850[11]
	Centrica, Barry	235[12]
	Dow Corning, Barry	27[11]
	Seabank, Avonmouth	1140[10]
Nuclear	Oldbury	435[4]
	Hinkley Point B	840[2]
Wind power	Solutia UK, Newport	5[14]
	The Bristol Port Co. Avonmouth Docks	9[13]
Recovered biogas (methane)	Wessex Water, Avonmouth	3[16]
	Dwr Cymru Welsh Water, Cardiff East Treatment works	4.5[17]

The older Hinkley Point A, built between 1957 and 1965, ceased operations in 2000[3]. All fuel has been removed and the plant is being decommissioned.

Oldbury, on the upper Estuary, is another nuclear power station approaching the end of its generating life. It began producing electricity in 1967 and was originally due to cease generating in 2008, but it continues to operate, though at a reduced capacity of 435 MW. It is anticipated that output will reduce further with the closure of one of the two Magnox reactors in 2011[4].

The Magnox station at Berkeley, near Sharpness, has long ceased generating. Completed in 1962, it was the third nuclear power station to open in the UK. It closed in 1989 and was the first to be decommissioned in the UK. Defueling ended in 1992 and it is now in a 'care and maintenance' phase, which is due to last until 2074.

Fossil Fuel (coal, gas and oil)

In recent years, gas-fired power stations have provided an increasing share of the energy mix, though coal-fired power stations continue to play a significant role. Whilst there are no dedicated oil-fired power stations in the area, oil is used for combustion support in some coal-fired plants.

Fig 2: Severn Power gas-fired power station at Newport. © Severn Power Ltd

Fig 3: Aberthaw coal-fired power station.
© RWE npower

The coal-fired Uskmouth Power Station (originally known as Uskmouth B) at Newport was first operated in the early 1960s. Refurbishment in 1998 extended the plant's life by around 25 years and included the installation of flue gas desulphurisation equipment. Its generating capacity was also increased to 393MW. Currently, a small amount of biomass (under 3%) is added to the coal[5] however the operator, Scottish and Southern Energy, is seeking to convert the plant to use 100% biomass[6]. The adjacent Uskmouth A coal-fired power station was demolished in 2002 and is now the site of the new Severn Power gas-fired power station.

Aberthaw B (near Barry) is a coal-fired power station with a generating capacity of 1500 MW; this is enough power to meet the needs of some 1.5 million people – equivalent to the total populations of five cities the size of Cardiff[7].

The plant also uses a variety of biomass products as a secondary fuel that is 'co-fired' together with the pulverised coal. Since it began full operation in 1971 it has undergone major refurbishments including a seawater flue gas desulphurisation process that removes up to 35,000 tonnes of sulphur dioxide per annum[8] and in 2007, new steam turbines were installed. Aberthaw A power station closed in 1995 and has since been demolished. A joint project between Cansolv Technologies Incorporated (CTI) and RWE npower will see further development taking place at Aberthaw; with the construction of pilot technology, designed to capture 50 tonnes of CO_2/day in order to adhere to new air pollution policies

In a combined cycle gas turbine (CCGT) power station, a gas turbine generator generates electricity; heat in the exhaust (waste heat) is used to make steam, which in turn drives a steam turbine to generate additional electricity. This last step enhances the efficiency of electricity generation[9].

Seabank Power Station is a 1,140MW gas-fired CCGT power station at Hallen Marsh, near Avonmouth. Operated by Seabank Power Ltd, it was built in 2 parts, with Seabank 1 (760MW) completed in March 2000 and Seabank 2 (380MW) in January 2001[10].

The gas-fired Severn Power Station, built on the site of the old Uskmouth A Power Station, became operational in November 2010 (officially opened in February 2011). The CCGT plant has a design capacity of 850 MW and has a high generating efficiency of 57%[11]. Though built next to the River Usk, cooling is not achieved by using river water, but through an air cooled condenser[11].

The Centrica power station at Sully near Barry is a gas-fired CCGT plant. The combined output capacity of both the gas and steam turbines is 235 MW[12].

Another power plant at Barry is the Barry Cogeneration Plant operated by Npower Cogen Ltd within the Dow Corning Ltd chemical complex. This is a combined heat and power plant (CHP) that produces 27 MW electrical output and overall around 155 MW thermal output, as it provides both electrical power and steam for the Dow Corning site – though it can export electricity to the National Grid if required[11].

Wind Power

There were two sites with large wind turbines operating in 2010 within the Severn Estuary. At Avonmouth Docks, there are three turbines each with a 3 MW capacity rating, that provide up to 50-75% of the port's electricity demand[13]. At Solutia UK Ltd in Newport, two 2.5 MW[14] rated turbines became operational in early 2010. They are expected to generate a third of the site's annual average usage and there is the facility to export surplus electricity to the National Grid[15].

Fig 4: Wind turbines at Avonmouth Docks.
© The Bristol Port Company

Bio-gas (methane)

Methane from sewage sludge at the Bristol Sewage Treatment Works in Avonmouth is used to generate up to 3 MW of electricity mainly to power the site but it also provides surplus energy to the National Grid[16]. A similar scheme was in commissioning phase at Cardiff East Sewage Treatment Works at the end of 2010[17].

Marine renewable energy

Whilst there were no marine renewable energy schemes operating within the study area in 2010, energy generation in and around the Severn Estuary cannot be discussed without mention of the latest assessments of the Severn tidal energy schemes.

Power Station	Fuel	M-Watts
Aberthaw B	Coal	1560
Seabank	Gas	1140
Hinkley Point B	Nuclear	860
Severn Power	Gas	850
Oldbury	Nuclear	435
Uskmouth B	Coal	393
Centrica	Gas	230
Dow Corning	Gas	27
The Bristol Port Co.	Wind power	9
Solutia UK	Wind power	5
Wessex Water	Recovered biogas (methane)	3

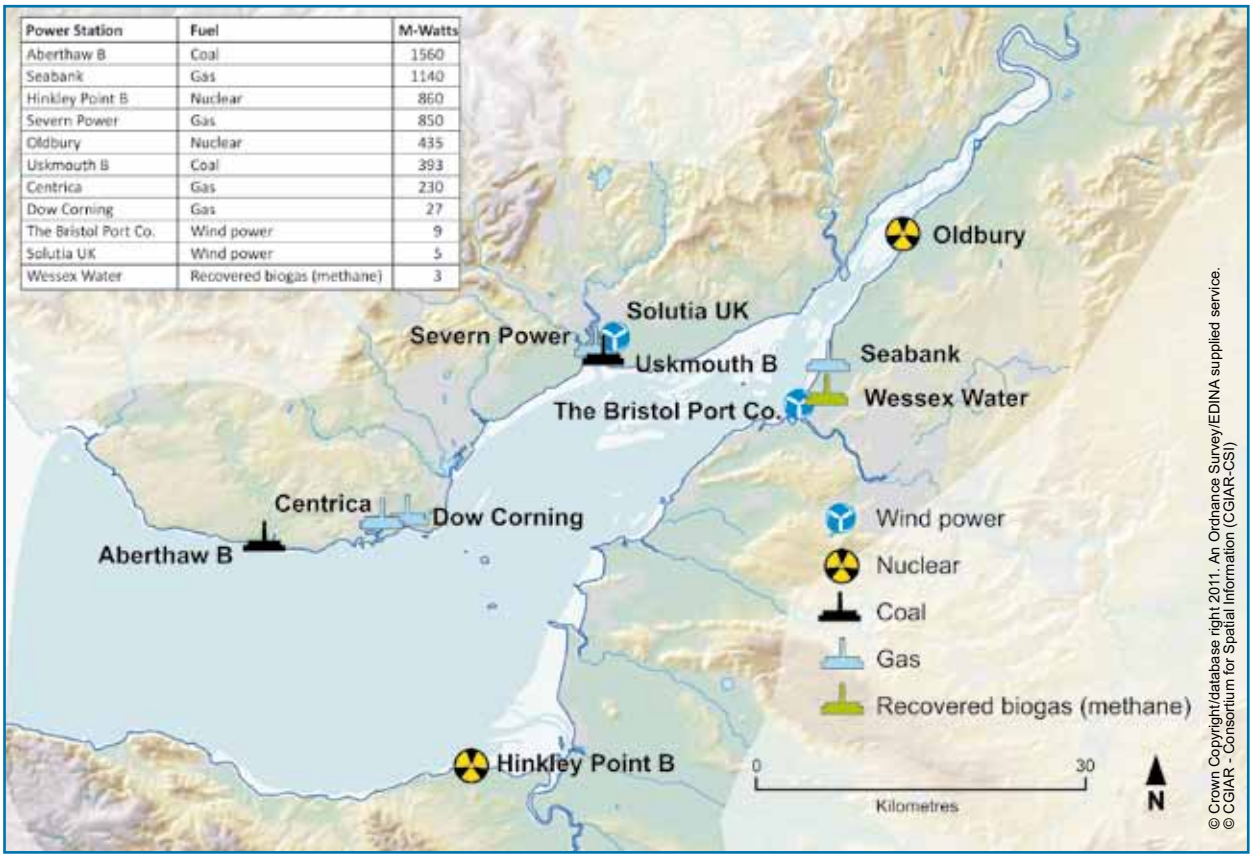


Fig. 5: Locations and types of power stations within the Severn Estuary. Source: SEP

Interest in harnessing the vast tidal energy resource of the Severn Estuary has existed since the 1920's, however 2008 saw attention focused again on the Severn Estuary, largely as a result of European Union statutory obligations to increase the percentage of energy generation from renewable sources coupled with concerns about energy security. Following an earlier report by the Sustainable Development Commission that had identified the Estuary as having the UK's largest single tidal range energy resource, a comprehensive two year Severn Tidal Power feasibility study was commissioned. Overseen by a cross-Government team, the aim of the study was to investigate whether the Government could support a tidal power scheme, by considering five alternative options; three barrages and two lagoons – all large structures housing multiple turbines and which were shortlisted and identified in Phase 1 of the feasibility study.

The study found that the cost of a tidal power scheme in the Severn Estuary could be as much as £34 billion (Cardiff to Weston barrage option), and was 'high cost and high risk' in comparison to other ways of generating low-carbon electricity. As such a scheme was unlikely to attract the necessary private investment given the current economic climate, which would require the public sector to own much of the cost and risk.

In light of these findings the Government announced in October 2010 that it did not see a strategic case to bring forward a Severn tidal power scheme in the immediate term. This outcome does not however, prevent a privately financed scheme coming forward and there continues to be considerable interest amongst private sector consortia and individual companies such as the Corlan Hafren Consortium, which is still pursuing and promoting the Severn's tidal energy proposal.

The Future

Interest in establishing energy generating plants within the Severn Estuary area looks set to continue as there are numerous proposals to develop sites. Both Hinkley and Oldbury have been identified as possible sites for new-build nuclear power stations. There are proposals for a large gas-fired plant at Severnside and plans for biomass fired generation plants at Newport, Avonmouth and Royal Portbury Docks (Avonmouth). Planning permission has been granted for 10,560 solar photovoltaic energy panels (solar panels) to be built at a coastal site near Newport. There are also proposals for the development of more wind turbines and several 'energy from waste' plants on both the English and Welsh sides of the Estuary.

For more information see the following links:

- DECC, www.decc.gov.uk
- British Energy, www.british-energy.com
- Nuclear Decommissioning Authority, www.nda.gov.uk
- STP feasibility study, http://bit.ly/izR1kr
- Corlan Hafren, http://www.corlanhafren.co.uk/
- Further references, pg 66.

Fisheries

With such a vast tidal range, high turbidity, strong tidal currents and extensive mud banks, fishing for one's livelihood on the Severn Estuary has always been demanding. The Estuary's many fisheries evolved to meet these demands, by adopting a variety of fishing methods; some of which are unique to the Estuary. Historically, most of the fisheries in the area have targeted migratory species, but there has also been a long tradition of catching marine fish and shrimp.

> The term fishery (or fisheries) is taken here to be the industry or occupation devoted to the catching and/or selling of fish or other aquatic animals (such as shrimp) and also to the place where they are caught - on a commercial basis.

Marine fisheries

Fig 1: Small trawler towing gear. © Devon & Severn IFCA

The level of commercial fishing activity in the Severn Estuary and Inner Bristol Channel is generally much lower than on fishing grounds to the west[1] and in comparison to the rest of the UK inshore fisheries, a relatively small amount of catch is landed commercially from the Severn Estuary area[2]. This is principally as a result of the strong tides, together with the low density of fish above the minimum landing size[1]. The Estuary acts as an important nursery ground for many commercially valuable species including sole and bass and as a result, the majority of the fish found within the Estuary are juveniles[1].

All licensed commercial fishermen must submit sales notes of fish sold[2]. This is the only source of catch data for vessels less than 10m; however greater statistical data is collected from vessels over 10m in the form of landing declarations and log books. All the data is recorded against the location of catches within pre-defined 'catch areas' known as statistical rectangles. The study area is covered by three such 'statistical rectangles' with the western-most area stretching from Cardiff to a line between Swansea and the North Devon coast. It is within this area, (which covers only a small part of the Severn Estuary), that 100% (90 tonnes) of the recorded catch was taken in 2010 with an approximate value of £200,000[2].

Whelks dominate the recent landings in terms of total weight, making up over a third of landings (over 30 tonnes) in 2010[2]. This is followed by skates and rays, where thornback ray and small eyed ray form the majority of this species type in terms of both volume and value[2]. Combined values of skate and rays indicate that they are the most valuable marine fishery in the study area (approximately 32% of the total value in 2010). This is followed by lobsters, bass and sole[2].

For the declared catches from 2007 to 2010 the overwhelming majority (approximately 84%) was landed by Welsh registered vessels[2] mostly at Swansea and Porthcawl – both just outside the study area. It is possible that some vessels landed catches taken from the Severn Estuary, but no data exists and if they had, it is likely to have been very small in terms of both weight and value. Of the few commercial fishing vessels operating within the Severn Estuary area, all are less than 10m in length and most, if not all, operate on a part-time basis, with many supplementing income through charter angling trips. There are three vessels working part time from Newport, using small beam trawls for flatfish and brown shrimps[3]. There are two boats operating out of Minehead setting pots and several others also setting pots and nets close inshore, between Highbridge and Burnham-on-Sea in Bridgwater Bay[3].

A small number of shore-based fisheries also exist, such as that in Bridgwater Bay where fishermen (again, part time) use stake-nets; catching skate, sea bass and ling in the summer, cod and whiting in the winter and shrimps usually between August and October. It is in Bridgwater Bay where the only remaining mud-horse fisherman operates, using a wooden sledge (the mud-horse) to safely navigate across the mud flats exposed at low tide to access the stake nets[4].

Migratory fisheries

Fig 2: Putcher rank in the upper Severn Estuary. © Environment Agency

Fig 3: Lave net fishermen in the Severn. © National Museum of Wales

Of the migratory fish using the Estuary, commercial fishermen target only eels and salmon. Sea trout are also caught by the salmon fisheries, but in very low numbers and are generally regarded as by-catch. Though shad are still present in the Estuary, the fishery that once rivalled that of salmon in terms of value, ceased decades ago due to declining numbers. Lamprey also use the Estuary on their way upstream to spawn in the rivers, but are not the target species of any fishery.

Eels

Eels are found in all European countries bordering or connected to the North Atlantic[1]. They are caught as juveniles (elvers or glass eels) returning from the sea primarily in tidal waters, or as adults (yellow and silver eels) in a variety of fisheries; the vast majority of which are at sites on inland water bodies.

Elver fishing in England and Wales is concentrated mainly in the Severn Estuary area- and principally on the tidal reaches of the Rivers Severn, Wye, Parrett and Usk[5], though some estuarine coastal sites are also fished. Only hand-held dip nets are permitted for the capture of elvers[1] and the fishing season is short, coinciding with the elvers entering rivers in spring[6].

Over the past two decades, catch data from across Europe shows elver populations declining rapidly from the high levels of the 1970s; a situation generally reflected in the Severn Estuary. From the catch returns submitted for the 423

licensed nets that operated within the study area (including tidal reaches) during 2010, a total of 1127 kg of elvers were caught[7] - though a reduction on previous years, this still represents a significant seasonal fishery. Although the numbers of elvers have declined in recent years, the number of licensed nets remains high, reflecting the continued high demand- principally from eel farms in Asia and the Netherlands.

Commercial yellow and silver eel (adult stages) fisheries within the Severn Estuary area have had a long history, but the greater number of fisheries has always been above the tidal reaches in freshwater habitats. The decline of eel numbers has lead to a significant reduction in netting – with no licensed nets operating in the Estuary area in 2010.

Salmon

Over the past centuries there have been salmon fisheries around much of the Estuary area, including the lower Estuary such as at Cardiff and the River Parrett in Bridgwater Bay. However, the majority of effort has historically been from Newport upstream. Largely due to declining abundance, many fisheries have ceased to operate and with the closure of both the major drift net fishery upstream of Newport and the Goldcliff putcher ranks (near Newport) since 2000, (with the exception of the lave net fishery at Black Rock Portskewett), all the remaining fisheries lie upstream of Lydney[8].

Fig.4: Salmon caught in a Putcher.
© Environment Agency

Though fishing by nets and putchers continues, the fishing effort and catches have greatly reduced over the past few decades[8]. The low abundance of salmon has brought about the cessation of most of the putcher fisheries that typically caught relatively few salmon, whilst a combination of private interests and Environment Agency action has paid others not to fish[8] as a measure to conserve stocks. A small number of fishermen continue to operate the few remaining active putcher ranks, up to 5 of which have been licensed in recent years[8].

The lave net and draft net fisheries have similarly declined over the past few decades and since the introduction of Net Limitation Orders in 2009, no more than 25 and 3 respectively may be licensed[8].

Table 1: Declared salmon catches in 2010
Source: Environment Agency

Method	No. fished	No. of fish caught	Fishing season
Putcher ranks	2	128	1st June – 15th August
Lave nets	25	110	1st June – 31st August
Draft nets	1	0	1st June – 31st August

The three remaining traditional fishing methods for catching salmon:

Putchers (see Fig.4) are traditionally, conical baskets about 2m long, made from natural materials (such as willow), but more recently from steel and are fished in ranks (sometimes referred to as fishing weirs[6]), often containing many hundreds of baskets. Ranks consisting of up to 3 or 4 tiers of baskets are positioned within the inter-tidal zone across the tidal flow. They are usually arranged to fish on the ebb tide; with fish becoming caught as they fall back on the tide and being trapped within the baskets, to then be retrieved by a fishermen once the ranks is exposed at low tide[8].

Lave nets (see Fig.3) are large triangular nets, loosely hung between the forks of large hand-held 'Y' shaped wooden frames. The fishing takes place on the ebb tide. The fishermen stand in the water up to their waists, lower the net into the water – and wait. They may fish in two ways, either standing in a low water channel waiting for the fish to swim into the net (a practice called cowering) or by watching for a splash or wake of a fish and then running to intercept the fish before it reaches deep water.

Draft nets (sometimes referred to as long-nets[9]) are similar to conventional seine nets set to encircle and catch salmon[8]. One end of the net is held at the water's edge whilst the rest of the net is fed out from a boat as it moves across the river. The far end of the net is secure on the boat and both boat and net drift downstream in an arc to the area licensed to be fished – the draft. The boat then returns to the bank below the starting point. The net is then closed and slowly hauled ashore.

Heritage fisheries

For some of the salmon fisheries, the commercial rewards have become secondary to maintaining the history and heritage of salmon fishing in the Estuary, whilst catching a few fish. For the Lave nets in particular, the cultural significance has been recognised by the Government, whilst aspects of both the putcher and draft net fisheries also provide cases for their preservation as efforts are made to increase stocks. The Black Rock Lave net fishery has taken major steps in recent years to both preserve and promote the cultural heritage of its unique fishing method with the opening of a new net hut (visitor centre) in 2006, in addition to members giving public demonstrations of the fishing equipment.

For more information see the following links:

- Devon and Severn Inshore Fisheries and Conservation Authority, www.devonandsevernifca.gov.uk
- Severn and Wye Smokery, www.severnandwye.co.uk or visit the smokery at Chaxhill between Minsterworth and Westbury-on-Severn
- The Black Rock Lave net fishery, www.blackrocklavenets.co.uk
- Further references, pg 66.

Marine Aggregates

Marine aggregate is sand or gravel, used principally as a raw material by the construction industry. In the UK, the majority of aggregate (including crushed rock) comes from land-based sources, but since the 1960s developers have been increasingly reliant on marine sources to supplement demand and meet construction needs[1].

The Severn Estuary contains extensive areas of sandbanks. It is estimated that the Middle Grounds between Newport and Chepstow contain quantities in excess of 1700 million cubic metres[2] alone. These sandbanks were not formed by modern processes, but are derived from periods of glaciation and major changes in sea level that ended approximately 4,500 years ago[2]. Though there appears to be no major modern source of sand[3], it is considered likely that limited inputs from the Bristol Channel occur under certain conditions.

The pattern of supply of sand for construction purposes around the Severn Estuary, particularly in South East Wales, is unique in the UK because of its current and historic dependence on marine dredged resources[4] (around 80 to 90% of the demand for natural sand in South Wales is met by marine sources[5] compared to about 21% for the whole of England and Wales[1]). These resources are of significant commercial interest as the sand dredged is of high quality, with well sorted grain-sizes and virtually no wastage. There are also significant manufacturing and production benfits[5]; further supplemented by the industry's ability to land large tonnages by sea, close to urban areas[6].

In 2010, out of a combined total of 937,908 tonnes[7] of sand which was extracted from a permitted licensed tonnage of 3.05 million, most of the production was landed at Cardiff, Newport and Avonmouth[5].

Fig. 1: An aggregate dredger in operation. © ABP South Wales Ports

Severn Estuary

The dredged areas at Bedwyn Sands, Denny Shoal, West Middle Ground and North Bristol Deep (see Fig. 4 overleaf) consist of well sorted fine to medium grained sand mainly used as building sand. They are generally thick deposits but they mainly exist in shallow water or inter-tidal settings that present tidal restrictions on access and thus on extraction[5]. In 2010, an application to dredge 150,000 tonnes a year at North Middle Grounds was under consideration (with permission granted in April 2011).

Fig. 2: Aggregate dredger discharging cargo at a sand wharf. © Tarmac Marine Dredging Ltd

Fig. 3: Loaded dredger returning to port. © Tarmac Marine Dredging Ltd

Table 1: Licensed dredge areas[7]

Dredge site	Approximate location	Maximum annual extraction (tonnes)	Total volume landed in 2010
Bedwyn Sands	Welsh waters. 2km off Caldicot foreshore, 3km downstream of Second Severn Crossing	250,000	937,908 tonnes
Culver Sands	English waters. 12km north off Minehead	1,000,000	
Denny Shoal	English waters. 3km NW of Avonmouth	150,000	
Holm Sands	Straddles median line, but mostly in Welsh waters. From between the Holm Islands to 8km west.	1,150,000	
North Bristol Deep	Welsh waters. 9km south of Newport	250,000	
West Middle Grounds	Welsh waters. 7km south of Newport	250,000	

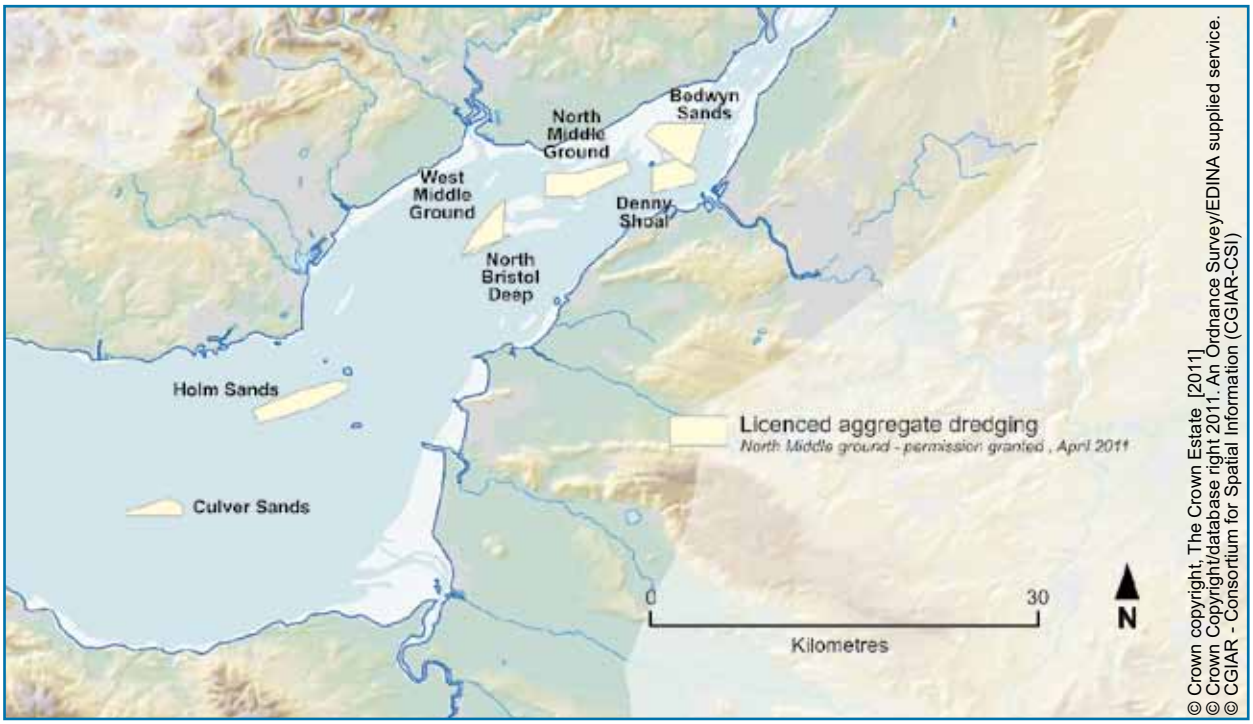


Fig. 4: Map showing licensed dredge areas (and North Middle Ground application areas).
Source: The Crown Estate © Crown Copyright (2011) and Environment Agency

Inner Bristol Channel

The largest licence in the Severn Estuary area applies to Holm Sands (see Fig. 4), at least in terms of the annual upper tonnage limit. However, although the maximum annual extraction rate from Holm Sands is 1,150,000 tonnes (reduced from 2,975,000), the tonnage actually dredged has been well below the limit in recent years, at around 100,000 to 200,000 tonnes per year[8]. This reflects the decline in the sand resource. Culver Sands is an isolated sandbank of well-sorted medium grained sands suitable for both building and concreting uses.

Fig 5: Aggregate dredger loading cargo. © Tarmac Marine Dredging Ltd

Regulation

The Crown Estate owns the mineral rights to much of the UK seabed and issues commercial licences for both prospecting and the extraction of aggregates[1]. However, the planning and consenting process is the responsibility of the regulator (Marine Management Organisation in England and Welsh Government in Wales), who, through a consultation process, determines whether an area can be used for aggregate extraction[1]. The exception in the Severn Estuary is the Bedwyn Sand reserve. This area of sand bank is owned by the Swangrove Estate and permission to dredge has been granted by the Mineral Planning Authority, Monmouthshire County Council.

For more information see the following websites:

- MMO, http://www.marinemanagement.org.uk/works/minerals/index.htm
- The Crown Estate, http://www.thecrownestate.co.uk/marine_aggregate
- Welsh Government, http://bit.ly/t0Amio
- Further references, pg 66.

Transport

The Severn Estuary has an important intermodal transport network bordering its shores. This network has been influenced by the geography and topography of the region and it reflects both the historic and economic developments and requirements of the Estuary over the years.

One of Wales' main national road and rail network routes runs parallel to the south coast acting as a corridor; joining Wales with Ireland, England and the rest of Europe. The network of roads, railways and ports was initially developed to serve the industrial needs of the South Wales Valleys in the 18th and 19th centuries. Today the road and rail transport networks around the Severn Estuary link the Welsh valleys to the city centres and port areas of Newport, Cardiff and Swansea, whilst in England they follow the main tourism, industry and conurbation districts of Weston-super-Mare, Avonmouth and Bristol.

Road

Significant volumes of road (and rail) traffic move through the Estuary, both in and around Wales and South West England; including traffic originating in both countries, as well as elsewhere. Roads are the most extensive and comprehensive of transport networks in Wales and South West England, and hence are currently the most flexible mode of transport for freight.

The M4 and M5 motorways are key parts of the trunk road networks and are an important link for the Severn Estuary from South Wales and South West England to London, the Midlands and numerous international destinations[1].

Rail

There have been significant increases in the use of the rail network on both sides of the Estuary for both freight and commuting equally. The Cheltenham to Cardiff route has experienced extra passenger numbers and figures show that the increase in station usage from 2004/5 to 2008/9 from stations at Lydney, Chepstow, Caldicot and the Severn Tunnel Junction is 55.9%[2]. Extra services and stops have been introduced on this route, particularly at the Severn Tunnel Junction which provides a connecting service for those commuting to Bristol from Chepstow and Lydney. Existing rail terminals generally have good road connections for freight movements, although the addition of more terminals could reduce the potential problems caused by the 'final mile' of a multi-modal transit (the first or last leg of a journey at the origin or final destination). Apart from some bulk commodities, origin and destination locations of freight within Wales are often not directly connected by rail. The electrification of the Great Western Railway from London - Bristol - Cardiff will improve services to South Wales and require significant engineering works through the Severn Tunnel[2]. This will result in London to South Wales services being diverted via Gloucester down the Severn Estuary line whilst the work in the tunnel is carried out.

Shipping and Ports

The Severn Estuary ports are well-served by road and have generally adequate rail connections, although there is scope for development. Connections between modes of transport are important when planning the development of new port terminals. Cardiff, Newport, Bristol and Sharpness are the main ports within the Severn Estuary, responsible for handling a substantial proportion of UK trade whilst also acting as important players in the local and regional economy[3]. During the consultation and debate on the Severn Estuary barrage proposal and the related alternative schemes, attention was given to the detrimental effects that ports within the Severn Estuary may suffer both during the construction and operation of any proposal. In general, shipping in the UK is likely to expand as a low-carbon, economical method of both national and international trade[3]. For more detailed information, see the Ports & Shipping section of this report.

Bridges

The view of the Upper Severn Estuary is characterised by the two iconic Severn Bridges. The Severn Bridge and Second Severn Crossing are landmarks of the Estuary as well as major transport routes linking South Wales with South West England. The original Severn Bridge supports the M48 and joins Wales with Aust on the English side of the Estuary at the mouth of the River Wye and Chapel Island. The bridge was opened in 1966 to replace the old ferry service crossing from Aust to Beachley[4].

Fig. 1: The Second Severn Crossing.
© Gwilym Owen

In 1996 the Second Severn Crossing (see Fig. 1) was opened to relieve congestion on the local road network, and M5 motorway. New link motorways on the Avon and Gwent sides of the Estuary were constructed to divert the M4 motorway over the new crossing, whilst the existing route over the first bridge between Awkley in England and Rogiet in Wales was re-designated as the M48. The new bridge provides a direct link for the M4 motorway into Wales[5].

Pipeline

There are a number of pipelines straddling the Severn which transport oil and gas products. On the Welsh shores, a gas pipeline links Milford Haven to Gloucestershire before joining the wider UK pipeline networks in the Midlands. Across the water, at The Bristol Port Company, fuel tankers discharge aviation fuel from ships into the Bristol Aviation Fuel Terminal which feeds directly into the UK's fuel pipeline and storage network[4].

Tunnel

Fig. 2: Train leaving the Severn Tunnel. © Brett Palfrey

The Severn Tunnel was built by the Great Western Railway (GWR) between 1873 and 1886[2]. It is 4 miles 624 yd (approximately 7 km) long, although only 2¼ miles (3.62 km) of the tunnel is under the River Severn itself. The Severn Tunnel links South Gloucestershire in England to Monmouthshire in South Wales and is part of the main (passenger and freight) railway line between London and South West England, and South Wales.

Canal

Fig. 3: Gloucester Docks. © Gwilym Owen

The Severn Estuary is linked to two canals; the Monmouthshire and Brecon and the Gloucester and Sharpness canals. The Monmouthshire and Brecon canal was used during the industrial revolution to transport coal from the mines in Brecon to the docks at Newport. Today the canal is landlocked, navigable and used only for recreational activities between Cwmbran and Brecon. On the English side of the Estuary, the 16 miles of the Gloucester and Sharpness waterway (once the broadest and deepest canal in the world) bypasses the meandering upper stretches of the Severn Estuary to link the commercial port of Sharpness with Gloucester's historic docks[6] (see Fig. 3).

Despite its distance from the sea, the build specifications of the Gloucester and Sharpness canal enabled ocean going vessels to safely reach Gloucester; this allowed the county to compete with coastal docks, resulting in substantial effects on the overall development of the commercial characteristics of the town in the 19th century.

Today vessels of all sizes can navigate safely up the Estuary, through the enormous ship lock at Sharpness, continuing up the canal to Gloucester into a calmer part of the River Severn. Nowadays, many commercial ships end their journey at Sharpness, offloading their cargo for onward transport by water or road[6]. A variety of specialist freight and cruise ships can be seen using the canal with tall ships, Royal Navy vessels and large gravel barges being just some of the more interesting sights.

Airports

The Severn Estuary is serviced by regional airports on both its Welsh and English sides. Cardiff and Bristol airports operate international and domestic, chartered and scheduled flights.

Cardiff[7]

- No. of passengers in 2010: 1,404,613[7]
- 1000 employees[7]
- 206 ha[7]

With more than 50 direct destinations and over 800 one-stop destinations around the world; in excess of one million passengers per year utilise the scheduled airlines and chartered tour operators flying out of Cardiff airport. On average, up to 25 aircraft can take off and land every hour along the airports' 2,392m long and 46m wide runway; doing so over either the sea or agricultural land to minimise the impact of noise on the neighbouring communities. It is estimated that over 1,000 jobs are provided by Cardiff airport alone, facilitating numerous aspects of the Welsh economy. Furthermore, the Welsh Government has defined an area (in which the airport lies) as a 'centre for aviation excellence'; with various high-profile companies being located within a small radius. Public transport links include regular bus services and trains via Rhoose Cardiff Airport Station.

Since the start of 2003, Cardiff has twice been voted one of the Top 10 Best UK Airports in the Telegraph Travel Awards, with 2006 witnessing the establishment of a £7 million enhancement programme.

Bristol[8]

- No. of passengers in 2010: 5,747,604[8]
- 2,900 employees[8]
- 176 ha[8]

In 1927, following the provision of £6,000 by a group of local businessmen, (achieved through public subscriptions to inaugurate a flying club at Filton Aerodrome), initial plans for an airport at Bristol begun. 1929 saw the decision to develop a 'fully-fledged' airport at Bristol being practicably applied through the purchase of farmland at Whitchurch, which would act as the location for the new build. The following year, the airport was officially opened by HRH Prince George, making Bristol only the third civil airport in the whole country. Today, Bristol airport covers 176 hectares of land, providing direct flights to over 112 destinations across 29 countries. Over 2,900 employees work in 50 different businesses for Bristol Airport; with proposed expansion set to see job opportunities, passenger numbers, airport capacity and renewable energy utilisation (in the form of wind power and biomass heat generation), all increase.

For more information see the following links:

- South West Observatory, http://www.swo.org.uk/state-of-the-south-west-2011/transport/mode-of-travel/
- Further references, pg 66.

Ports & Shipping

Fig. 1: Loading of steel coils at Newport docks. © ABP South Wales

All the major towns and cities around the Severn Estuary were developed largely as a result of sea trade which brought prosperity and employment to the region[1]. In the 19th and 20th centuries earlier in-river and coastal wharves were replaced with impounded docks more suited to deal with the expansion of trade, larger vessels and the high tidal range. At some, such as Lydney, Gloucester, Bristol City, Portishead and Penarth Docks, trade has long ceased and they now mainly operate as marinas. Others however, still provide a vital conduit for sea trade. These ports and the services they support continue to have an important role in the local, regional and national economy as they are responsible for handling a substantial proportion of UK trade[2]. The major ports are Bristol (Royal Portbury and Avonmouth), Cardiff, Newport and Barry, with smaller ports at Sharpness and Bridgwater[1]. Table 1 shows the volume of cargo handled by each of the ports in 2010.

Table 1: Cargo volumes handled by each port in 2010
Source: Department for Transport Port (provisional) Freight Statistics 2010[3]

Port	Operator	Cargo tonnage (in 000's tonnes)		
		Inbound	Outbound	Total
Barry	Associated British Ports (ABP) South Wales	188	93	281
Newport		1391	677	2068
Cardiff		1746	486	2232
Gloucester and Sharpness	Victoria Group	373	39	412
Bristol (Avonmouth / Portbury)	The Bristol Port Company	6043	1229	7272
Bridgwater	Sedgemoor District Council	40	nil	40

The ports have generally held their own in recent years through investment and adaptation to change[1]. The attraction of all these ports is that there is very good access to both rail and motorway networks on both sides of the Estuary, that place the ports within relatively easy reach of a vast market; with well over 40 million people within 250 km of Bristol[1] for example.

Table 2: Principle cargoes

Barry[4]	Containers, dry bulks, timber, general cargo, liquid bulks (mainly chemicals), steel and metals.
Newport[4]	Containers, timber, dry bulks (grain, aggregates, coal, agribulks), general cargo, steel and metals.
Cardiff[4]	Containers, dry bulks (aggregates, minerals), timber, fresh produce, general cargo, steel and metals.
Sharpness[5]	Dry bulks, grains and foodstuffs, timber, minerals and general cargo
Port of Bristol[6]	Containers, motor vehicles, aviation fuel, dry bulks (coal, animal feeds, grain), liquid bulk (jet fuel, petroleum products, molasses, fertiliser, orange juice), forest products, chilled foods (especially fruit and vegetables), steel and metals.
Bridgwater[7]	Aggregates, passengers (passenger ship Balmoral).

Fig 2: A container vessel entering Queen Alexandra lock, Cardiff. © ABP South Wales

Tidal constraints

The extreme tidal range within the Severn Estuary (over 14m at Avonmouth, and 10m at Barry on the largest Spring tides) is an ever present restriction to both navigation and port operations. Navigation to the ports is often only possible during the incoming high tides and access to the ports through lock systems (apart from Bridgwater which consists of a number of river wharfs) may only be possible for a few hours either side of the high tide[2, 8].

A further potential constraint to each port's operations is the maximum size of vessel which can be received in its locks. Apart from Royal Portbury Dock, which was completed

Fig 3: Large bulk carrier entering Royal Portbury Dock, Avonmouth. © The Bristol Port Company

in 1977 (with the largest entrance lock in the UK[8]), all the impounded docks and their locks were built over one hundred years ago, when vessel sizes were far smaller. This restriction is likely to have a significant bearing in the type of business a port can attract and how it may adapt to future changes in maritime trade.

Table 3: Lock sizes

Port	Length (m)	Beam (m)	Draught (m)	Dead-weight tonnage
Bristol (Portbury)[8]	300	41	14.5	130,000
Bristol (Avonmouth)[8]	210	30	11	35,000
Cardiff[8]	198	27	10.4	35,000
Newport[8]	244	30.1	10.5	40,000
Barry[1]	178	23.8	9.2	23,000
Sharpness[8]	140	16.5	6.5	10,000

Fig 4: Bulk carrier approaching Newport Docks. © ABP South Wales

To remain competitive, ports need to constantly adapt to changing markets and developments in both transportation practices and cargo handling technology. Many of the Severn Estuary ports have invested heavily in new dockside facilities in the last decade[9], but the biggest port development in the Estuary for a century may occur at Avonmouth. In March 2010, the Bristol Port Company was granted a Harbour Revision Order to allow the construction of a new Deep Sea Container Terminal[2] along its foreshore. The development is being designed for future generations of ultra-large container ships carrying up to 18,000 containers[10] (TEU's / 20ft equivalent units)[9]. With a planned 1.2km of quay and 100 acre storage and handling area, the terminal is expected to have a capacity of 1.5 million TEU's per year[9].

Maintenance Dredging

Many areas of the Severn Estuary are subject to large sediment deposition and require dredging in order to maintain safe navigable depths[2]. Most ports have to regularly dredge their approach channels and occasionally also their dock basins and locks. At Royal Portbury and Avonmouth Docks, in the region of 1.5 to 2 million m^3 of dredged material is removed each year and at Cardiff and Newport, approximately 600,000 and 100,000 m^3 is removed per year respectively[2]. Maintenance dredging is a highly regulated activity with volumes capped by licences and materials deposited at licensed disposal sites within the Estuary. The main navigation channel in the Severn Estuary does not require dredging as it is deep and naturally scoured by the tidal currents.

Harbour Authorities

Statutory Harbour Authorities administer ports and often have responsibility within their harbour limits for moorings, controlling traffic, maintaining navigation aids and channel depth[1]. Thus a port operator may differ to the relevant Harbour Authority. The Bristol Port Company is the Harbour Authority for the eastern side of the Estuary downstream of Avonmouth to the island of Steep Holm and up the Avon to Bristol[1]. At Newport, on the Welsh coast, Newport Harbour Commissioners and Associated British Ports (ABP) are the authorities for both the area seaward of the mouth of the River Usk and the river through the city. At Cardiff the area enclosed by the barrage is the responsibility of Cardiff Harbour Authority whilst ABP have responsibility seawards of the barrage[1] out almost out as far as the island of Flat Holm.

Gloucester Harbour Trustees are the Authority for the tidal reaches of the Rivers Severn and Wye downstream to Goldcliff near Newport. British Waterways is the port authority for Sharpness Docks and Navigation Authority for the Gloucester-Sharpness Canal. Sedgmoor District Council is the Harbour Authority for the Port of Bridgwater which includes an area of Bridgwater Bay extending into the River Parrett Estuary to Bridgwater, the tidal River Brue and a small southern part of the Axe Estuary[1] (see section on Managing the Severn Estuary).

Shipping

Information on the number of vessels calling at the Estuary's ports in 2010 is currently unavailable. However, the figure is likely to have been approximately 2,000; with just over 1,300[10] vessels calling at the Port of Bristol. Cargo vessels come in greatly varying sizes and designs and though general cargo vessels are still important, many are now built to carry a specific cargo type. The wide variety of facilities offered at the Severn Estuary ports means that many vessel types can be seen on the Estuary; dry-bulk carriers transporting grain, coal, ore and other similar products in loose form, tankers carrying chemicals and petroleum products, container ships, car carriers, sand dredgers and both general cargo and multi-purpose vessels. The Bristol Bulk Terminal can receive very large ships, now typically reaching a tonnage of up to 130,000 deadweight; with the largest vessel docked to date being the St. John at 128,000 tonnes deadweight.

For more information see the following links:

- The Bristol Port Company, http://www.bristolport.co.uk/
- Associated British Ports, http://www.abports.co.uk/custinfo/ports/cardiff.htm
- Newport Harbour Commissioners, http://www.newportharbourcommissioners.org.uk/
- Further references, pg 66.

Water Quality

The water quality of the Severn Estuary is an important indicator of the overall health of the Estuary's ecosystem and also an important factor in influencing tourism, recreational activities and the commercial/industrial sectors. Water quality in the Estuary, as with other estuaries, is complex; with a large variety of inputs from numerous different sources and complex interactions between contaminants and 'master variables' such as salinity and dissolved oxygen. Due to the high levels of suspended sediment and the tendency of many contaminants to associate with particulate matter due to their low solubility, sediment quality is also an important issue in the Estuary.

The levels of most contaminant inputs to the Estuary are much lower than they were 25 years ago, following the closure of major industries and the introduction of stricter pollution control[1]. This has resulted in improvements to both overall water and sediment quality; though discharges of contaminants continue, along with the legacy of past pollutants still present in sediments in certain areas.

For many years, the Estuary and the rivers feeding it have been widely used for the disposal of many forms of treated and untreated waste products. Until quite recently, the Estuary received sewage and industrial effluents amounting to 800,000m^3 a day and 200,000m^3 a day, respectively[2]. The major industries discharging into the Estuary include (or have included until recently) the smelters, incinerators, fertiliser and numerous other chemical plants in the Avonmouth area; coal and steel industry, paper mills, chemical and pharmaceutical manufacturers in south Wales; and nuclear power plants at Hinkley, Berkeley and Oldbury. Sewage from the urban centres of Bristol, Gloucester, Newport and Cardiff adds directly to the pollutant load, as do domestic and agricultural sources to the large numbers of tributaries entering the Estuary[3].

Contaminants from these activities enter the Severn Estuary either from point sources (as discharges, such as from wastewater treatment works and industries), or from non-point sources (diffuse pollution) such as atmospheric deposition (power stations and vehicle emissions), shipping (hull coatings) and storm water runoff from urban and agricultural areas.

Fig. 1: Trade effluent discharge outfalls at Tata Steel, Newport.
© Environment Agency

Water Quality standards, Regulation and Monitoring

Water quality within the Estuary has to conform with legislation. European Directives set out standards for water quality and impose monitoring requirements[3]. The Environment Agency is responsible for achieving the water quality objectives in the Estuary and undertakes extensive monitoring to assess compliance with Directives (and other obligations and to inform consenting decisions). In particular, the Water Framework Directive provides a major focus for much of the biological and chemical monitoring currently undertaken[4]. Some of the key directives are briefly discussed below:

Water Framework Directive

This Directive was transposed into UK legislation in 2003 and is the most substantial piece of water legislation to date. It requires the protection of the ecological status of all inland and coastal water bodies from deterioration and, where necessary and practicable, the restoration of water bodies to "Good Environmental Status" by 2015. In doing so, it promotes the sustainable use of water as a natural resource; the conservation of habitats and species which directly depend upon water; the progressive reduction or phasing out of the release of pollutants that present a significant threat to the aquatic environment and the management of the effects of floods and droughts. The Directive is being implemented using Management Plans that operate at the River Basin scale. These River Basin Management Plans (RBMPs) contain the main issues for the water environment and the actions required to achieve the objectives of the Directive.

The area covered by the Severn Estuary and Bridgwater Bay is situated within the Severn River Basin Management Plan. The River Basin is subdivided into management catchments and then into 'water bodies'. The aim of achieving at least 'Good Environmental Status' applies to each water body.

The status of water bodies is judged by a number of measures, including chemical and biological quality. The Severn Estuary is currently classified as a heavily modified water body (due to the extensive flood defences that constrain its natural development) with moderate ecological status/ potential, though it has been assessed as achieving good chemical status.

Dangerous Substances Directive

The aim of this Directive is to improve water quality through the elimination and/or reduction of discharges of dangerous substances. The Directive established two lists of substances; List 1 substances are particularly dangerous because of their toxicity, persistence and bioaccumulation. Pollution by these substances must be *eliminated*. List II substances are less dangerous but have a deleterious effect on the aquatic environment. Input of these substances must be *reduced*. Environmental quality standards (EQSs) that identify limits have been established for all substances[3].

Data collected by the Environment Agency generally indicate universal compliance with Environmental Quality

Standards for all parameters monitored at the majority of sites. An exception is for the monitoring points for certain substances, particularly metals located in the Avonmouth area. However, when averaged across the year as required by the EQS, compliance for all parameters is achieved[3].

Urban Wastewater Treatment Directive
The objective of this Directive is to protect the environment from the adverse effects of sewage discharges and, therefore, it sets treatment levels on the basis of size of sewage discharges and the sensitivity of waters receiving the discharges[3]. The ongoing improvement programme of the water utility companies has resulted in major improvements to the quality of sewage discharges to the Severn Estuary.

Bathing Waters Directive
This Directive is concerned with the quality of bathing waters for the purpose of protecting public health and requires the monitoring of principally microbiological parameters (see section on Bathing Waters).

Estuarine master variables

Dissolved Oxygen (DO)
DO in the water is one of the most basic and important measures of a water body's health, affecting a wide array of aquatic plants and animals. Low DO has immediate and long-term effects, ranging from shifts in biological communities, disruption of fish migration, and (under the worst conditions) fish kills[5]. The level of DO in the Estuary decreases when concentrations of oxygen-demanding organic materials are too high.

Dissolved oxygen levels in the Estuary are generally high, with levels above 8 mg/l throughout the whole Estuary and concentrations above 95% at the seaward end[4]. During 2004 and 2005, monitoring of DO saturation found that saturations were greater than 90% at most sites, including bottom waters. The lowest surface value, 72.4% was just downstream of Lower Parting, Gloucester (in August 2005). Overall, DO saturation values suggest no widespread severe oxygen depletion, either at the surface or at depth in the Estuary[2].

Salinity
The Severn Estuary is a vertically well mixed estuary. A characteristic feature is a persistent north-south salinity gradient, with the lowest salinities occurring along the Welsh Coast[6,7], due to greater input of freshwater. Salinities within the Estuary vary considerably over the tidal cycle and in response to changes in river flow. At high water on mean spring tides (with a typically low river flow) the freshwater-saline interface is located approximately 8km downstream of Lower Parting, Gloucester. From here there is a steep salinity gradient until 50km, beyond which the salinity increases more gradually[2] until west of the Holm Islands, with a maximum salinity (30‰).

Suspended particulate matter (sediments)
The Estuary's 'brown', turbid waters are due to the vast volume of fine sediment held in suspension as a result of the extremely high energy environment. This suspended particulate matter is not directly related to any form of pollution but can influence other aspects of water quality such as levels of dissolved oxygen and the adsorption of metals.

It has been estimated that on spring tides over 30 million tonnes of sediment are in suspension and around 4 million tonnes on smaller Neap tides[8]. Concentrations vary considerably – vertically, laterally and longitudinally. Median values along the length of the Estuary range from 81-336mg/l, with the highest values occurring in the mid-Severn Estuary region (between Sharpness and Avonmouth[8,9]) and with extremely high suspended sediment concentrations near the Estuary bed, often exceeding 20,000mg/l[8].

Fig. 2: The turbid waters of the Estuary off Cardiff Docks.
© Environment Agency

Nutrients
The most significant input contributors of nutrients to the Estuary are rivers, largely through agricultural run-off and urban wastewater discharge outfalls. Nutrients such as nitrogen and phosphorous, are critical to supporting aquatic life. However, an overabundance of nutrients can lead to excessive plant and algal growth, which causes dissolved oxygen to drop when plant and algal matter decay[5]. This phenomenon known as 'eutrophication', can impair aquatic life and lead to fish kills[5].

The Severn Estuary and Bristol Channel provide one of the highest UK inputs of nitrogen and phosphorus to the marine environment, reflecting the Estuary's size, the location of human settlements and the intensity of agricultural land use. Concentrations of dissolved inorganic nitrogen are reported to have doubled over the past 20 to 25 years[4]. Due to the highly turbid waters that permit little light penetration, algal productivity is generally low and eutrophication is not considered a major issue within the Estuary.

pH
The pH of water in the Estuary increases from around neutral at its freshwater end to approximately slightly alkaline in the outer Estuary. Recent surveys by the Environment Agency showed that all pH results were within the EQS range of 6.0 - 8.5 (annual average) to protect fish and the EQS range of 7.0 -8.5 (75 percentile) to protect shellfish[4]. There are however, a number of outfalls such as from some sewage treatment works and from Aberthaw Power Station, which have consented pH levels that are outside the normal

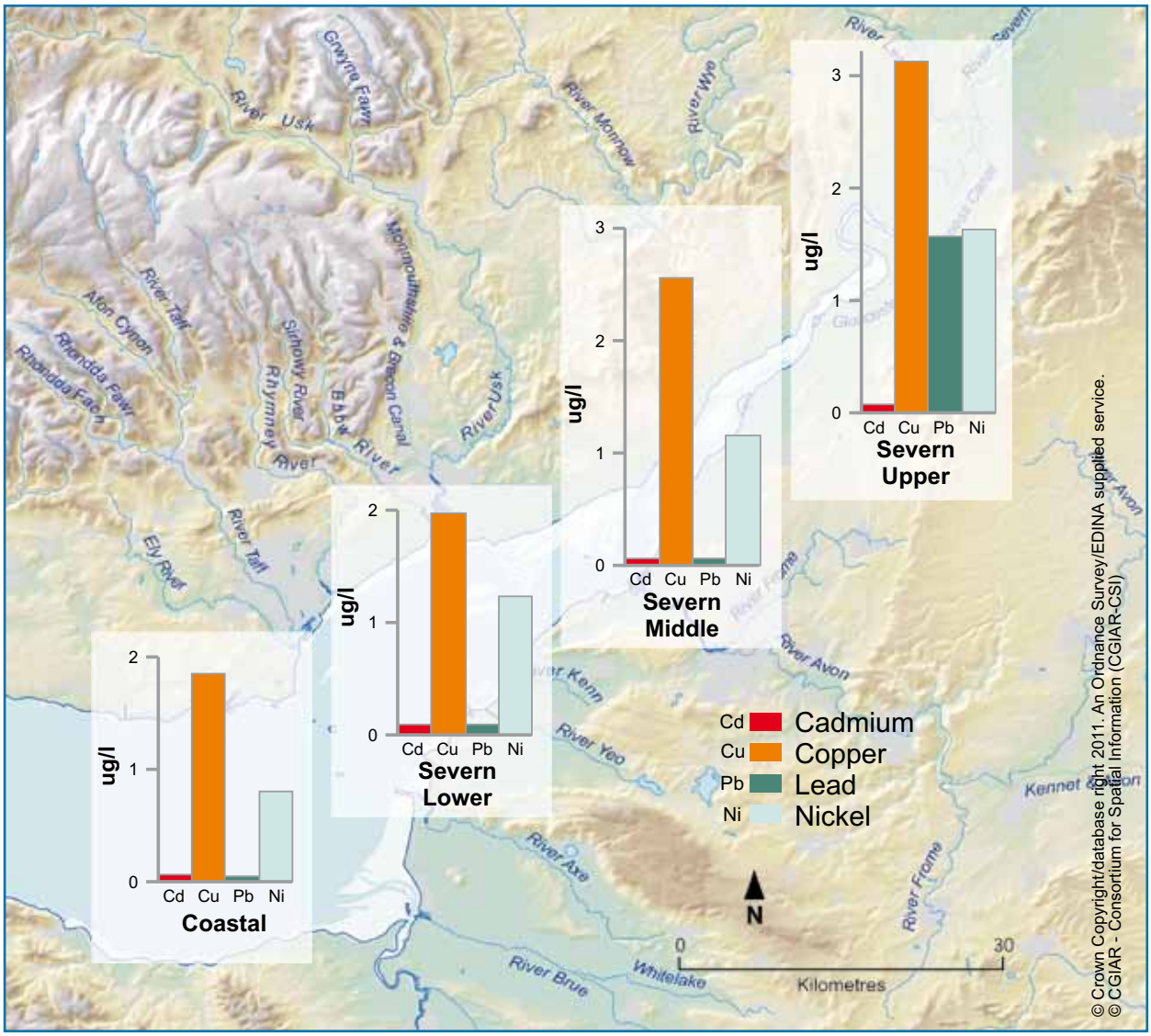


Fig. 3: Average concentrations of selected dissolved metals.
Source: SEP and EA

consented values of pH 5.5 to 9[4]. Such discharges result in very localised modifications to pH and the high buffering capacity of seawater and the available dilution ensures that pH quickly returns to the normal range.

Contaminants

The list of potential chemical pressures on water quality is substantial and includes metals, organometals, hydrocarbons, nutrients, solvents, mineral acids, biocides, fungicides, flame retardants, polychlorinated biphelnyls (PCBs), pesticides and radionucleides[3]. The decline in heavy industry and introduction of pollution control in the later part of the 20th century has seen a general downward trend in contaminant inputs. However a number of water quality issues continue – some of these are described below.

Metals

The main sources of trace metals to the Severn Estuary are from rivers and wastewater treatment works (WWTW). Trace metals are transported through the water body either in solution (dissolved metals) or adsorbed onto suspended sediments[4]. There has been a marked overall decline in both dissolved and adsorbed metal sediment concentrations over the past 30 years. This has been attributed to a combination of reduced industrial activity and improvements in emission controls.

Based on the review of consented discharges by the Environment Agency[10], the average concentrations of dissolved metals such as cadmium, copper, nickel, lead and zinc (see Fig. 3) are all below Environmental Quality Standards (EQS) thresholds. However, at near-shore locations in the vicinity of outfalls and rivers, elevated concentrations of contaminants have been observed with isolated (i.e. one-off) exceedences of EQS for various metals. However these did not result in EQS exceedence when expressed as an annual average[4].

The concentration of trace metals in the sediments of the Estuary is relatively uniform[9], largely due to the strong tidal mixing which disperses contaminants from their source. Despite this dilution, contamination levels tend to be highest in fine sediments (primarily located between Avonmouth and Severn Beach; Caldicot flats; River Parrett and outer

Bridgwater Bay; and between the mouths of the Rivers Usk and Taff). Enhancement in these fine sediments is still observed for a number of metals[3].

There are currently no formal sediment quality standards applying to the UK, although certain Directives contain standstill provisions (i.e. concentrations in sediments should not increase). A study has shown that sediments at a number of sites in the Estuary contained levels of metals likely to exert pressures on organisms, though such effects were probably chronic and not acute[4, 9].

Trace organics

A wide range of organic substances have been detected in water, sediment and organisms in the Estuary including organotins, hydrocarbons, polyaromatic hydrocarbons (PAHs), pesticides, herbicides and polychlorinated biphelnyls (PCBs).

The vast majority of data for toxic organic compounds in the Severn Estuary have been found to be below the limit of detection. An exception to this is tributyltin (TBT) (a contaminant associated with antifouling paint). Maximum levels of TBT of 0.003µg/l have been recorded in the Severn Estuary. Concentrations of TBT in the sediments have been found to be in the higher ranges in the vicinity of the ports of Newport and Cardiff. The global ban on the use of TBT should result in reductions in the concentrations of organotins in such sediments over time, although in some, degradation can take many years[4].

Surveys in the 90's recorded concentrations of individual PAHs that were generally below the Water Framework Directive Priority Substances standards (annual average EQS of 50ng/l)[11]. However, more recent studies have shown that the maximum allowable concentration of 10ng/l for all PAHs was frequently exceeded[12]. The highest concentrations occur at certain sites located close to the coast where the past export of coal is considered to have made a significant contributing to the PAH contamination of the sediments.

Synthetic compounds have historically been an issue and monitoring has indicated several EQS exceedences for pesticides and herbicides in the upper Estuary. Recent data however, indicates that exceedences of EQS' now rarely occur. Evidence therefore suggests continuing improvements in water quality. Concentrations of PCBs generally fall below the detection limits - this is thought to be due to their affinity for and persistence in sediments[3].

Radiological Contaminants

Inputs of radiological contaminants into the Estuary are very low. The Environment Agency reported in 2007[13] that none of the key establishments discharging radioactive discharges into the Estuary resulted in exposure radiation that was more than 5% of the total exposure limit of 1mSv/year. In recent years, a major Estuary hotspot has been in the waters off Cardiff due to the discharges from the GE Healthcare's facility in Cardiff; though in 2006, the total dose from this site was approximately 1% of the dose limit[13]. The total dose is likely to have reduced further due to reductions in discharges of tritium in liquid wastes[4].

Within the Severn Estuary and its tributaries, contaminant levels (trace metals, trace organics and radiological contaminants) all currently comply with Water Framework Directive standards for Priority and Priority Hazardous Substances and Annex VIII pollutants (substances for which the UK Government has set EQS at national level)[4]. Each of the three water bodies (upper Estuary, lower Estuary and Bridgwater Bay) achieve Good Chemical Status and the concentrations of Annex VIII pollutants do not compromise achievement of Good Ecological Status[4].

Fig. 4: View of the upper Estuary. © Environment Agency

Fig. 5: The River Parrett, one of the Estuary's main tributaries. © Titan Environmental Services Ltd

For more information see the following links:

- Severn River Basin Management Plan, http://www.environment-agency.gov.uk/research/planning/124941.aspx
- Severn Estuary pSAC, http://bit.ly/scPG8l
- Further references, pg 66.

Bathing Waters

The objective of the 2006 Bathing Waters Directive (BWD) is to protect public health and the environment from faecal pollution at bathing waters, both coastal and inland. European Community Member States are obliged to identify all bathing sites where bathing is explicitly authorised or where it occurs by large numbers of bathers[1].

The Environment Agency is responsible for the collection of water samples at the designated beaches during the bathing water season, which in the UK is taken to be from 15th May to 30th September (though sampling commences two weeks before the start of the season)[2]. Weekly samples are taken from predetermined points where the average density of bathers is usually at its highest. Samples are analysed for a range of parameters including the presence of different types of indicator bacteria[3].

Fig. 1: Summer bathers on Weston-super-Mare beach. © The Metro

Bathing Water Standards

The BWD sets standards for the maximum level of bacteria that indicate faecal pollution either from humans or animals. The standards specified in the Directive fall into two categories; Mandatory and Guideline[2]. To comply with the Directive, bathing waters must achieve the Mandatory Standard. Member States are also obliged to strive to achieve the Guideline Standard that is about twenty times stricter. The Directive does not require the reporting of faecal streptococci, but such data is collected in the UK as a requirement of the Blue Flag Award scheme[3].

The maximum levels of bacteria permitted per 100ml sample are shown below.

Table 1: Maximum levels of bacteria permitted per 100ml
Source: Environment Agency

Bacteria	Mandatory	Guideline
Total coliforms (TC)	10,000	500
Faecal coliforms (FC)	2,000	100
Faecal Streptococci (FS)	n/a	100

Fig. 2: Whitmore beach © Environment Agency

Bathing Water Classification[1,3]

- Each bathing water site receives an annual water quality classification for every season. This classification is calculated from 20 samples taken during the season (see Fig. 5).
- The Environment Agency counts the number of certain types of bacteria which may indicate the presence of pollution, mainly from sewage or livestock waste. Total coliforms (TC), faecal coliforms (FC) and faecal streptococci (FS) (see Fig. 3) are bacteria that are not directly harmful but indicate the presence of pollution. An increase in the concentrations of bacteria indicates a decrease in water quality.
- Higher quality means the bathing water meets the criteria for the stricter UK Guideline Standards of the Directive.
- Minimum quality means that at least 95% of the samples meet the Mandatory Standards of the Directive.
- Fail means that fewer than 95% of the samples meet the required Mandatory Standards.
- Not sampled indicates that the bathing water was closed during the bathing season.

Fig. 3: Water sampling. © Environment Agency
Miscroscopic view of a faecal coliform, E. coli. © Sharedwaters.net

Bathing water standards compliance 2010

There has been a significant improvement in the water quality at bathing waters over the last two decades, as a result of the Bathing Waters Directive and the Urban Waste Water Directive; which have resulted in higher levels of sewage treatment around the Estuary[2]. In 2000, none of the beaches within the Severn Estuary study region achieved the Mandatory Standard, some were a considerable way from the more stringent Guideline Standard. The latest results (see Table 2) show that all 14 beaches achieved at least the Minimum Standard, with 9 achieving the Higher Guideline Standard[3].

Table 2: Bathing Waters Standards, 2010

Source: Environment Agency

Beach	Classification	
	2000	2010
Cold Knap	Minimum	Higher
Whitmore	Minimum	Higher
Jackson's Bay	Minimum	Minimum
Clevedon	Minimum	Higher
Weston south beach	Fail	Higher
Weston (main)	Minimum	Minimum
Weston Uphill	Minimum	Minimum
Brean	Minimum	Minimum
Berrow	Minimum	Higher
Burnham Jetty	Minimum	Higher
Blue Anchor	Minimum	Higher
Dunster	Fail	Minimum
Minehead	Minimum	Higher
Porlock Wier	No data	Higher

Fig. 4: Jacksons Bay © Environment Agency

The recent revision of the Bathing Water Directive is resulting in major changes. Through phased implementation, the new legislation now places a strong emphasis on providing information to the public via improved reporting and will set more rigorous standards and a new classification scheme for bathing water quality.

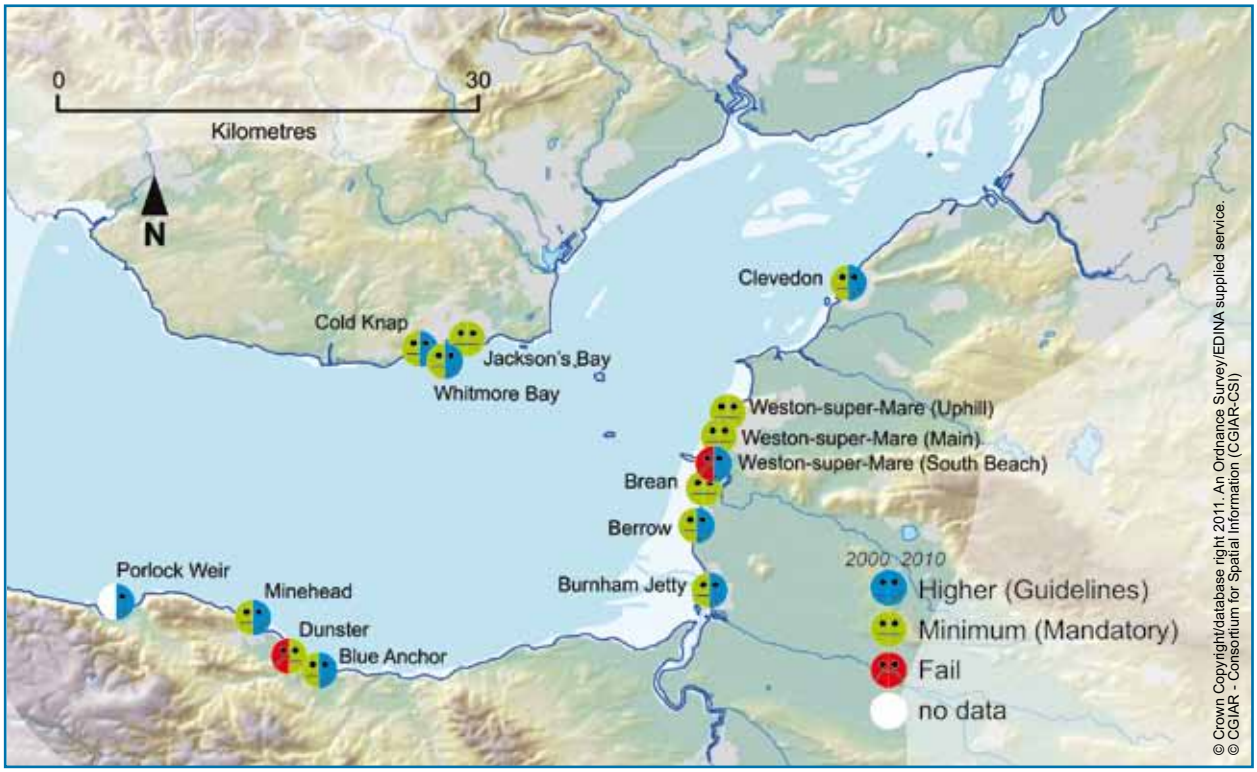


Fig. 5: Map showing compliance with the Bathing Waters Directive at various beaches within the Severn Estuary in 2000 and 2010. Source: SEP

For more information see the following links:

- Environment Agency, Bathing Waters, http://www.environment-agency.gov.uk/homeandleisure/recreation/119111.aspx
- European Commission. Environment; Bathing Water Quality, http://ec.europa.eu/environment/water/water-bathing/index_en.html
- Further references, pg 67.

Air Quality

Poor air quality caused by pollution can have significant adverse effects upon human health and ecosystems. Pollutants can be in the form of solid particles, liquid droplets, or gases. They may come from natural sources (such as volcanic eruptions) or man-made, such as power generation, industrial processes and transport emissions.

Some of the principal pollutants[1]

Sulphur Dioxide (SO_2) is produced when a material, or fuel, containing sulphur is burned. The predominant man-made source is power stations burning fossil fuels, principally coal and heavy oils.

Nitrogen oxides Nitric oxide (NO) is mainly derived from road transport emissions and other combustion processes. NO is not considered to be harmful to health. However, once released to the atmosphere, NO is usually very rapidly oxidised to nitrogen dioxide (NO_2) via a series of complex reactions involving ozone[2]. In relation to human health, NO_2 is considered the most significant[3]. NO_2 and NO are both oxides of nitrogen and together are referred to as nitrogen oxides (NOx).

Fine Particles or Particulate Matter (PM10, PM2.5 and PM1) are composed of a wide range of materials both natural and man-made, arising from a variety of sources. Most monitoring is currently focussed on PM10, but the finer fractions such as PM2.5 and PM1 are becoming of increasing interest in terms of health effects. The numerical values relate to the size of the particles and particulates in microns (µm) (1 µm = 0.001mm).

Carbon monoxide (CO) is a colourless, odourless poisonous gas produced by incomplete, or inefficient, combustion of fuel. It is predominantly produced by road transport, in particular petrol-engine vehicles.

Benzene and 1,3-Butadiene are emitted into the atmosphere principally from fuel combustion of petrol and diesel vehicles.

Ozone and volatile organic compounds (O_3) are not emitted directly from any man-made source in any significant quantities. In the lower atmosphere, O_3 is primarily formed by a complicated series of chemical reactions initiated by sunlight. These reactions cause the oxidation of volatile organic compounds (VOCs) in the presence of nitrogen oxides (NOx).

The health effects of poor air quality[4]

Many of the air pollutants have known adverse health effects above certain concentrations. In recognition of the potential harm, there has been a variety of legislation introduced over the last two decades, including European Directives, national strategies and regulations. The most recent, were the Air Quality Standards Regulations, which came into force in England and Wales in June 2010[3]. These Regulations consolidate previous legislation and set health-based standards and objectives for eight key pollutants.

Air Quality Standards

Fig. 1: Chimney at industrial works. © Environment Agency

European Directives' limits and target values have been incorporated as objectives within the UK Air Quality Strategy (2007) and the Air Quality Standards Regulations (2010). As each substance has different impacts, the standards set for each substance are different. Some substances have an impact on health in the short term, and so the standards set maximum levels for any 15 minutes, one hour or daily period, depending on the substance. Other substances have impacts on health in the longer term, and so the standards set annual maximum levels[5]. An exceedence of a standard is a period of time (defined in each standard) where the concentration is higher than that set down by the standard[6].

The Environment Agency (EA) regulates the release of air pollutants from large or more complex industrial sites and local authorities have the responsibility of ensuring that standards are met at a local level by monitoring smaller industrial processes and ambient air quality.

Operators of the EA regulated sites must measure the amount of emissions of each controlled substance every year. They must also specify "notifiable" releases. These are where there has been an emergency, mismanagement, accident or plant failure which has caused pollutants to be released[7]. In 2010, there was only one notifiable release reported at a regulated site around the Estuary – the release of five tonnes of sulphur oxides from an installation on the South Wales coast[7]. There was no direct contribution from any of the sites to any Air Quality Objective level exceedances. Fig. 3 overleaf shows 2010 emission levels for 4 of the principal pollutants around the Severn Estuary area.

Fig. 2: Traffic congestion. © Environment Agency

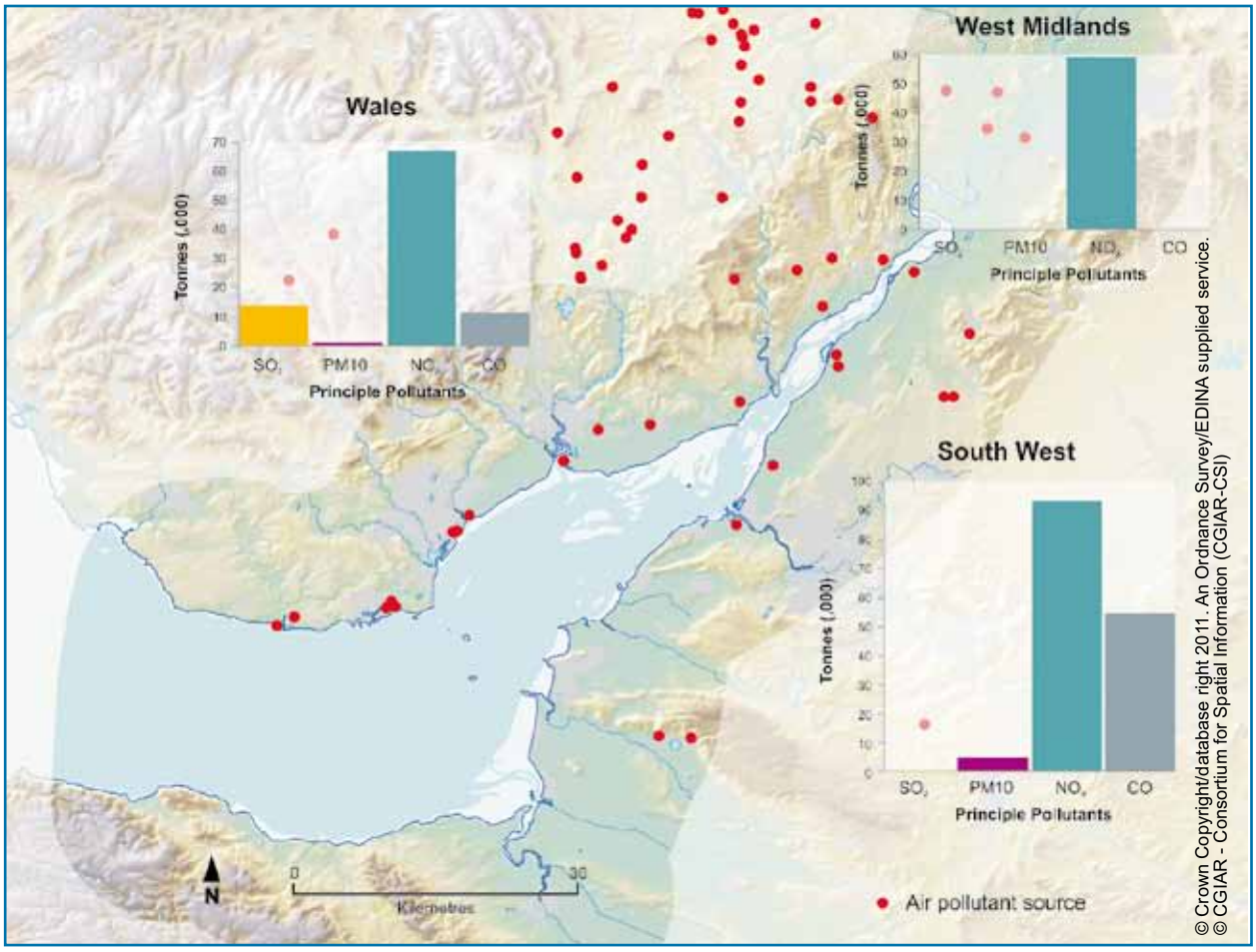


Fig. 3: 2010 emission levels of principal pollutants from Environment Agency Regulated sites.
Source: SEP and EA

Currently the majority of air quality problems, within the Severn Estuary area as it is nationally, are largely related to emissions from road transport, on major highways and within conurbations generally[8]. Road traffic is an important source of carbon monoxide, nitrogen dioxide and volatile hydrocarbons (VOCs) such as benzene and 1,3-butadiene and primary particles (PM_{10}). Concentrations of all these pollutants are therefore usually highest in built-up urban areas[1], particularly during periods of poor atmospheric dispersion.

Table 1: EU Limit and Target Values (µg/m3 = micrograms per cubic metre of air)
Source: Air Pollution Wales 2009

Pollutant	Averaging period	Limit value
Sulphur dioxide	One hour	350 µg/m3, not to be exceeded more than 24 times per year
	One day	125 µg/m3, not to be exceeded more than 3 times per year
Nitrogen dioxide	One hour	200 µg/m3, not to be exceeded more than 18 times per year
	Calendar year	40 µg/m3
Benzene	Calendar year	5 µg/m3
Carbon monoxide	Maximum daily eight hour mean	10 mg/m3
Lead	Calendar year	0.5 µg/m3
PM_{10}	One day	50 µg/m3, not to be exceeded more than 35 times per year
	Calendar year	40 µg/m3
$PM_{2.5}$	Calendar year	25 µg/m3
Ozone	Maximum daily eight hour mean	120 µg/m3, not to be exceeded on more than 25 days per year averaged over 3 years

Table 2: Target values for various pollutants.
Source: Air Pollution Wales 2009

Pollutant	Target value for the total content on the PM10 fraction averaged over a calendar year
Arsenic	6 ng/m3
Cadmium	5 ng/m3
Nickel	20 ng/m3
Benzo(a) pyrene	1 ng/m3

Air Quality Management Areas

The Environment Act 1995 made provisions for local authorities to assess the air quality in their area and compare it with national objectives for certain pollutants. The Act introduced the concept of Local Air Quality Management and as such local authorities are under a statutory obligation to review and assess air quality in their area according to the Standards and Objectives contained in the relevant Regulations[4]. If problems are identified in meeting the objectives for any of the pollutants the local authority is required to declare an Air Quality Management Area (AQMA) and produce an action plan to tackle the problem.

Of the 16 local authorities which operate within the Severn Estuary area, 7 local authorities have declared one or more AQMA due to poor air quality. All of the 19 AQMA were declared for the exceedance of nitrogen dioxide objectives due to emissions from road transport, with the Bristol City Centre AQMA being established to monitor both nitrogen dioxide and particulate matter, (see Table 3).

Table 3: Management areas declared by Local Authorities.

Local Authority	Air Quality Management Areas
Vale of Glamorgan[9]	None
Cardiff[4]	2
Newport[9]	7
Monmouthshire[10]	2
Forest of Dean[11]	1
Gloucester[12]	3
Stroud[13]	None
South Gloucestershire[14]	3
Bristol[15]	1
North Somerset[16]	None
Sedgemoor DC[17]	None
West Somerset[18]	None

It should be noted that the size of AQMAs listed in Table 3 vary considerably, as does the number of households potentially affected. For instance, the one AQMA in Bristol covers much of the inner city area, yet the seven AQMAs in Newport have a total combined population of only 135 people[19].

Air pollution and climate change

Nationally, air pollutants are primarily monitored because of their effect on human health and ecosystems. However, some pollutants can also contribute towards climate change and these impacts have to be taken into account when planning national and local abatement strategies[1].

Greenhouse gases (see Table 4) contribute to long term global climate change by a process known as the greenhouse effect. Light and heat energy (infrared radiation) from the sun is absorbed by the surface of the Earth during the day, and is released again slowly over time. Greenhouse gases in the atmosphere absorb the infrared radiation and re-radiate it in all directions, including back to the Earth´s surface. In this way heat is trapped in the lower levels of the troposphere, causing warming and higher temperatures than would be experienced if there were no greenhouse gases[1] (see section on Weather & Climate Change).

Table 4: Main sources of Greenhouse gases[1]

Greenhouse gas	Main sources
Carbon dioxide	Combustion of fossil fuels
Methane	Agricultural, waste disposal, leakage from the gas distribution system and coal mining
Nitrous oxide	Agriculture, transport, industrial processes and coal combustion
Ozone	Secondary pollutant formed in the atmosphere by chemical reactions with other pollutants, initiated by sunlight
F-gases	Refrigeration

The Eyjafjallajokull volcanic ash cloud

On March 20th 2010, Iceland's Eyjafjallajokull Volcano burst into life, sending vast amounts of glass-rich ash and sulphur dioxide into the atmosphere. The size of the particles in the ash cloud was on average about 1.5 microns (0.0015 mm) in diameter[20]. This fine particulate matter can be hazardous to human health, causing or exacerbating respiratory and cardiovascular diseases. Though UK airspace was closed from 15th to 21st April due to the high risk of damage to aircraft flying through the plume and the more localised disruption in May (Cardiff and Bristol Airports closed on May 17th), there was no evidence that the plume reached the breathing zone or had any effects on background values of particulate matter and sulphur dioxide; the main pollutants of concern in volcanic ash[20].

For more information see the following links:

- Welsh air quality Forum, www.welshairquality.co.uk
- South West Observatory, www.swo.org.uk
- Environment Agency, www.environment-agency.gov.uk
- Local Authority websites – see Reference section
- Further references, pg 67.

Weather & Climate Change

The marine environment of the Severn Estuary is one of the most dynamic in Europe, with changes in sea level, waves and storms all playing their part in shaping this coastline. Historical records show that severe storms have caused much coastal erosion and flooding and modern research suggests such events are likely to occur again in the future. Perhaps one of the biggest threats to the Estuary is from rising sea levels which, coupled with a significant storm event, could exacerbate the effects of coastal erosion and flooding and cause significant issues for coastal planners, engineers and local communities. The Severn Estuary coastline is already considerably defended, especially around the Wentlooge and Caldicot levels and the Somerset Levels, with several small scale localised defences existing elsewhere.

Changes to the local climate of the Severn Estuary will have impacts on its social, economic and natural characteristics and it is therefore important to understand these changes for effective adaptation. Current research and evidence from the Estuary suggests that air and sea temperatures are rising in line with global trends[1]. Local impacts of particular concern include coastal flooding and erosion. A significant proportion of critical infrastructure such as roads, rail tracks, power stations and industrial developments are located on low lying land within the Estuary and as such, are potentially at risk from these impacts[1].

Sea level

A recent comprehensive review[2] of tide gauge data for the Severn Estuary and Bristol Channel conducted over 15 years (1993 to 2007) concluded that there had been a rise in mean sea level. The review suggested a rising trend in sea level of 2.4mm/year^{-1}, which is in line with other climate change research results[3] and UK Climate Projections 2009[4]. Local research estimates that by 2080, sea levels at Cardiff will be 30-40cm higher than 1990 baseline level[1] (see Fig. 2).

Fig. 1: Storm defence on Severn Beach. © SEP

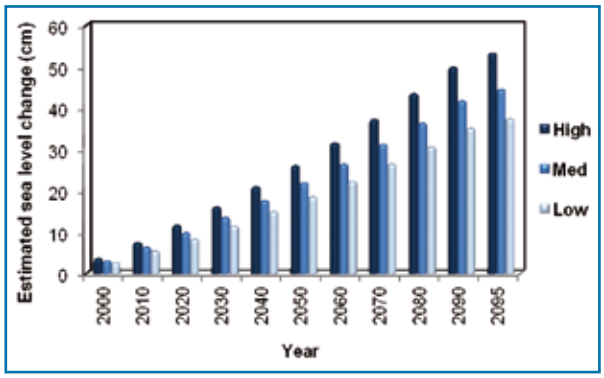


Fig. 2: Central estimates for Cardiff of relative sea level changes (cm) at each decade with respect to 1990 baseline levels.
Source: UKCP09

Wave Climate

Seasonal average and extreme waves are generally projected to increase slightly to the south west of the UK, including the Bristol Channel and Severn Estuary, which is consistent with rising sea levels[5]. Models suggest that coastal squeeze (see Fig. 3), habitat loss, coastal erosion and the steepening of intertidal (beach) profiles will all increase in the future due to both sea level rise and possible changes in wave conditions[5].

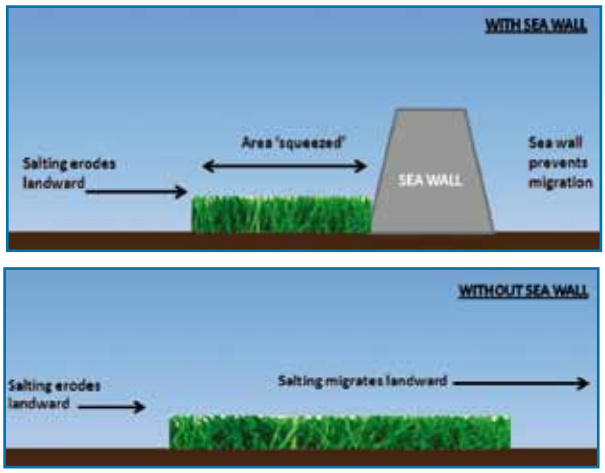


Fig. 3: Coastal Squeeze.
Source: SEP, based on a figure by Havant Borough Council, 2011

Storms

Numbers of severe wind storms in the UK have increased since 1960; however they have not increased above levels recorded during the 1920s[4,6] (a particularly stormy period).

Fig. 4: Storm on Flat Holm Island. © Sam Whitfield, 2010

Recent local research in 2008 has supported this trend[7]. Projections are uncertain and there is no consistent indication of any change in storms near the UK in either Met Office or other weather models. Such changes are seen as relatively modest, and the potential for substantial changes appears to be small[7].The Bristol Channel and Severn Estuary are likely to see an increase in storm surge height of about 0.8mm/year[4]. Although only a small increase, when taking into account sea level rise, this could exacerbate the impacts of flooding and erosion.

Isostatic adjustment

The landmass of the UK has been attempting to achieve equilibrium since the last ice age, in a process known as 'isostatic adjustment'. On the Severn Estuary and Bristol Channel, this has resulted in sinking of the land at a rate of 0.6-0.9mm/year for the past 4,000 years[8]. This trend is expected to continue for the next 100 years[9].

Rainfall

The nature of rainfall over the Severn Estuary has changed over the last 30 years and is likely to continue to do so, with seasonality of rainfall becoming increasingly important[10,11]. This has consequences for river and groundwater levels and possible issues related to future land use and catchment management. However, the UK exhibits highly variable storm and rainfall patterns[12] and, as of yet, there are no clear trends of change in annual mean rainfall levels[13]. Some research suggests that between 2040 and 2069, average summer rainfall levels may decrease by about 18% and average winter precipitation may increase by around 12%[13].

Temperature

UK marine air and sea surface temperatures have increased by about 0.7°C per decade since the 1980s, with strong regional variations[13]. By 2080, the average temperature in winter is projected to increase by about 2.8°C and the summer average temperature by about 3.9°C[13]. By the mid century the Severn Estuary may have warmer drier summers and milder wetter winters.

Impacts of climate change

There are many potential direct and indirect impacts of climate change, as illustrated in Fig. 5.

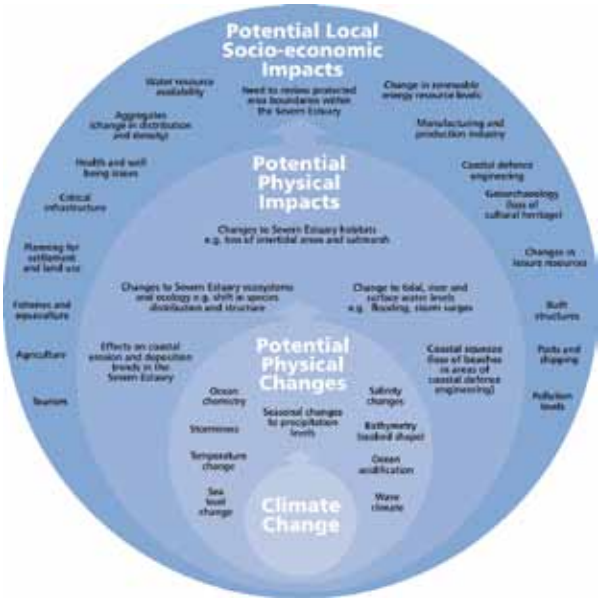


Fig. 5: Direct and indirect impacts of climate change on the Severn Estuary[1].

Impacts on the human environment

Socio-economic losses - Significant urban development's and critical infrastructure on low-lying parts of the Estuary need protecting from flooding and the erosive impacts of severe storms; in conjunction with the continued effective maintenance of current coastal defences[14].

Tourism - There may be potential for increased tourism within the Severn Estuary region in the summer months; however this could put strain on existing resources unless adequately managed (see section on Tourism & Recreation).

Agriculture - There are possible adaptation issues for the agriculture industry within the Estuary, in terms of soil quality and types of crops that will grow in a new warmer climate with a longer growing season[15,16].

Impacts on the natural environment

Changes in habitats, ecosystems and ecology - Higher air and sea surface temperatures across the Estuary, along with variations in salinity and chemistry, could affect coastal and marine ecosystems as species try to adapt. This in turn can lead to habitat loss and changes to migratory species. Reduced sediment supply, (due to coastal defence construction associated with climate change adaptation), may further exacerbate such habitat losses[17]. A knock-on effect of such changes in habitat, could be a review of protected area designations at national and international levels.

Intertidal salt meadows - Saltmarsh areas within the Severn Estuary have been retreating inland since 1980 due to sea level rise[16]. Current predictions suggest that over 1,000ha of inter-tidal habitat will be lost in the Severn Estuary by 2100.

Intertidal mudflats - Mudflats comprise a large proportion of the Severn Estuary intertidal habitats and can be closely interlinked with salt marsh habitats and the protection from the erosive power of wave energy these can provide. Climatic drivers are changing the landforms of open coast sediment systems via increasing wave height, storm surges and increased water depth[17]. However, it is not yet possible to accurately identify the various effects of climate change, such as temperature and sea level rise, from other factors such as damage caused by human activities (e.g. scallop fishing gear and bait digging) which also impact negatively on mudflat habitats[17].

Seagrass beds - The species *Zostera noltii* prefers a low salinity environment for germination. Increased freshwater runoff in recent years may have been the driver for the increased success of this species in Welsh seagrass beds[17] (including the Severn Estuary and Bristol Channel).

Major limitations in data and information

It should be noted that there are significant issues associated with gaps in the information base in predicting impacts from climate change; particularly with respect to the social and economic characteristics of the Estuary. Severn–specific scientific predictions of climate change impacts are also limited by monitoring deficiencies and information gaps; as noted in recent meetings of the Severn Estuary Climate Change Research Advisory Group (http://www.severnestuary.net/sep/imcore/index.html).

For more information see the following links:

- DEFRA, Charting Progress, http://chartingprogress.defra.gov.uk/
- Severn Estuary Climate Change Research Advisory Group, http://www.severnestuary.net/sep/imcore/index.html
- Met Office, http://www.metoffice.gov.uk/
- Further references, pg 67.

Managing the Severn Estuary

The complexity of uses and environments of the Severn result in many different people and organisations with interests in the Estuary and its adjoining areas. The Estuary's management is further complicated by its administrative fragmentation: not only are there two national governments involved (Westminster and Wales), but there are also many local authorities and other bodies. In total over 50 organisations have powers to regulate or control activities in and around the Estuary. These bodies, at one time or another, consult on their activities and plans with other organisations, users and the general public.

Key organisations and their roles

Around the Severn Estuary there are many public, private and voluntary organisations with coastal responsibilities and interests; including government agencies, port and harbour authorities and local authorities, to name but a few. Many of these bodies have interests confined to particular sectors (e.g. ports and shipping, coastal defence, environmental management) as well as to specific geographical areas.

Fig. 1: Key organisations involved in the planning and management of the Estuary at the SEP Forum 2011. © SEP

Fig. 2: Open panel discussion at the SEP Forum 2011. © SEP

Whilst key organisations are listed in Box 1 and their principal characteristics are summarised below, the Severn Estuary Partnership's 'Who Does What Guide' provides further information on many of these bodies (see the 'for more information' box).

Box 1: Key organisations involved in planning and managing the Estuary

- Local Authorities
- Government departments and statutory agencies
- Industry, Ports and shipping
- Wildlife and conservation
- Archaeology and heritage
- Local groups and landowners

Local Authorities

Local authorities play a key role in the land-based planning and management of the Estuary. There are 16 of these authorities around the Estuary area, as shown in Fig. 3. These include county, district and unitary councils. Some of their most important powers relate to:

- development planning and development control
- emergency planning
- coastal defence and flood risk management
- community well being (economic, social and environmental)

These authorities also produce plans and strategies detailing many environmental and economic aspects, including wildlife and heritage, local economic development and tourism.

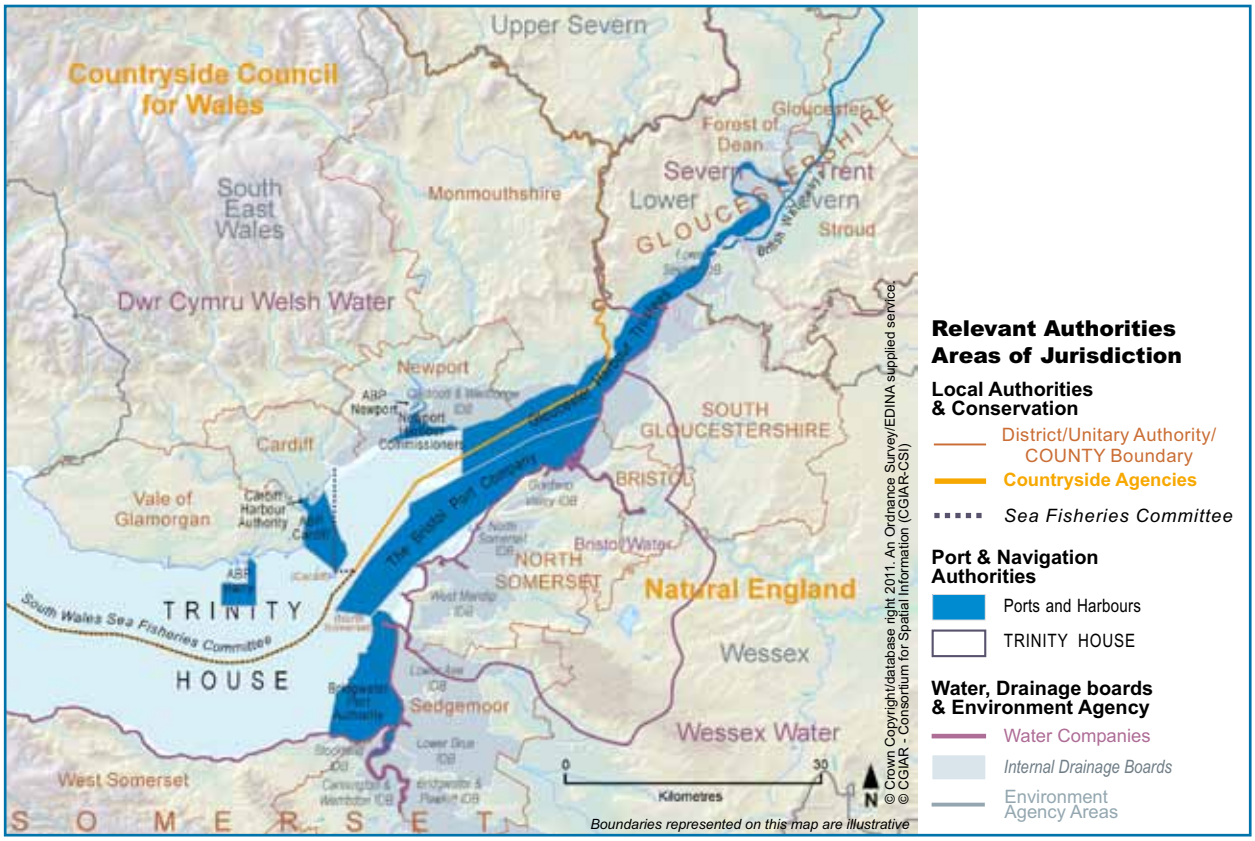


Fig. 3: Relevant Authorities Areas of Jurisdiction. Source: Courtesy of ASERA

Table 1: Key Government departments and agencies involved in Estuary matters[1]

Key responsibilities	England	Wales
Government Departments		
Environment, rural development, the countryside, wildlife and sustainable development.	Department for Environment, Food and Rural Affairs - (Defra) http://www.defra.gov.uk/	Welsh Government http://wales.gov.uk/?lang=en
Energy policy and climate change.	Department for Energy and Climate Change (DECC) http://www.decc.gov.uk/	Welsh Government http://wales.gov.uk/?lang=en / DECC http://www.decc.gov.uk/
Support for local government and communities; regeneration, housing and planning.	CLG http://www.communities.gov.uk/corporate/	Welsh Government http://wales.gov.uk/?lang=en
Marine planning and licensing, aspects of fishing and marine protected area networks.	Marine Management Organisation (MMO) http://www.marinemanagement.org.uk/	Welsh Government http://wales.gov.uk/?lang=en
Government Agencies		
Flood risk, hazardous waste management, air and water quality, fisheries, inland water-based recreation and navigation.	Environment Agency (EA) http://www.environment-agency.gov.uk/	Environment Agency (Wales) http://www.environment-agency.gov.uk/aboutus/organisation/35675.aspx
Natural environment including marine conservation and seascape issues in England and Wales' territorial waters (from the coast to 12 nautical miles offshore).	Natural England (NE) http://www.naturalengland.org.uk/	Countryside Council for Wales http://www.ccw.gov.uk/?lang=en
Protection and promotion of the historic environment including supporting research and engagement.	English Heritage http://www.english-heritage.org.uk/	Cadw http://cadw.wales.gov.uk/about/?lang=en
Other bodies		
Independent body that examines applications for national significant infrastructure projects (inc. transport, waste, energy infrastructure).	Infrastructure Planning Commission (IPC) http://infrastructure.independent.gov.uk/. Under the Localism Bill the IPC will be abolished in April 2012 and its decision making powers transferred to the relevant Secretary of State.	

Welsh and Westminster Government departments and agencies

Welsh and Westminster Government departments and agencies play important roles in both setting policy and directing management. Table 1 summarises some of the main bodies and their roles in relation to the Estuary.

Industry, Ports and Shipping

Control of ports and shipping is the responsibility of harbour authorities which, on the Severn, are a mixture of private and public bodies. These include the large private Bristol Port Company and the Associated British Ports (ABP) of Cardiff, Barry and Newport as well as smaller public ones such as the Gloucester Harbour Trustees (see section on Ports and Shipping). As noted in the Population and Development section, there is a wide range of industries around the Estuary. Some of these use the Estuary directly – for example, the ports, water companies and other companies abstracting water for cooling processes.

Wildlife and Conservation

Wildlife and conservation are largely the responsibility of Natural England and the Countryside Council for Wales. Non-government organisations, such as the Royal Society for the Protection of Birds (RPSB), the Wildlife and Wetlands Trust and the County Wildlife Trusts are also heavily involved. Competent and Relevant Authorities under the Habitats Regulations have a statutory duty to ensure that they carry out their functions and comply with this legislation. In addition to general management and regulatory functions, many relevant authorities are also competent authorities and have statutory functions to make decisions on applications for consents, authorisations, licences and permits as governed by statute for European sites (see section on Nature Conservation Designations).

Archaeology and Heritage

English Heritage and Cadw in Wales are the Government bodies with responsibilities for protecting and promoting the historic environment as well as facilitating research and understanding of such features. The Glamorgan Gwent Archaeological Trust which covers the Welsh side of the Estuary holds the official register of archaeological sites in

Southeast Wales, providing advice, heritage management and an active outreach programme. The Somerset Heritage Service provides these functions on the English side of the Estuary. Additionally, the long standing Severn Estuary Levels Research Committee covers both the English and Welsh sides of the Estuary, promoting archaeological research into the Severn Estuary.

Local groups and landowners

These groups have particular interests in the Estuary and are as much a part of the organisational structure as the authorities and organisations listed previously. For the Severn Estuary and Inner Bristol Channel; the Crown Estate, the Duke of Beaufort Estate and the National Trust are particularly important landowners. Collectively, they all have a role and responsibility for the Estuary's well being.

Estuary-wide management and planning

In an attempt to provide an estuary-wide approach to management and planning and in response to a range of legal and other requirements, a number of organisations and associated plans and strategies have been developed over the last couple of decades (see Table 1). Of particular note are the following plans, strategies and estuary-wide initiatives:

- **The Severn Estuary Partnership (SEP)**
  - SEP's Severn Estuary Strategy: http://www.severnestuary.net/sep/publications/severn.html
- **The Association of Severn Estuary Relevant Authorities (ASERA)**
  - ASERA: http://www.severnEstuary.net/asera/index.html
- **Coastal Groups and associated shoreline management plans**
  - The Severn Coastal Group (SECG): http://www.severnestuary.net/secg/index.html
  - The North Devon and Somerset Coastal Advisory Group (NDASCAG): http://www.ndascag.org/
- **The Severn Estuary Flood Risk Management Strategy (SEFRMS)**
  - SEFRMS: http://www.severnestuary.net/frms/index.html
- **The Bristol Channel Standing Environment Group (BCSEG)**
  - BCSEG: http://www.severnestuary.net/bcseg/index.html

Details of each of these can be found on the Severn Estuary Gateway website: http://www.severnestuary.net/index.html

Integrated Coastal Zone Management and Marine Planning

The cross-border nature of the Severn Estuary also poses additional challenges for management and for taking an integrated approach, particularly as there are many different organisations, plans and policies for the English and Welsh sides of the Estuary. Alongside existing management such as the Natura 2000 Management Scheme, initiatives such as Integrated Coastal Zone Management (ICZM) and Marine Planning offer opportunities to provide a more coordinated approach. Although currently there is no legal requirement for ICZM, ICZM strategies do exist for both England and Wales in line with the European Communities ICZM Recommendation. However, these are largely defunct documents, now that the Welsh and UK Governments are focusing more on marine planning under the Marine and Coastal Access Act 2009. With respect to marine planning, separate marine plans will be produced for the English and Welsh sides of the Estuary, although there is a commitment from both the Marine Management Organisation (MMO) and the Welsh Government to ensure that necessary cross-border liaison occurs. It is imperative that organisations such as the Severn Estuary Partnership work jointly with the MMO, Welsh Government and local stakeholders to ensure cross border working occurs wherever possible.

Fig. 4: A Severn Estuary Partnership workshop. © Gethin While

For more information see the following links:

- The Severn Estuary Partnership, 'Who does What Guide', http://www.severnEstuary.net/sep/whoswho.html
- ASERA, http://www.severnEstuary.net/asera/index.html
- MMO, http://www.marinemanagement.org.uk/
- Nature 2000, http://www.natura.org/
- Further references, pg 67.

Looking to the Future

This report celebrates the diversity of the Severn Estuary offering an easily accessible, up to date overview of the Estuary's broad characteristics, uses and resources. The report aims to engage with a wide range of Severn Estuary stakeholders, raising the baseline knowledge of communities and visitors alike.
The report compliments the 'Strategy for the Severn Estuary'– 2001, which still provides the only strategic management framework for the entire Estuary, promoting an integrated, sustainable and co-operative approach to action.

The Severn Estuary Partnership sees the 'State of the Severn Estuary' reporting as an ongoing project. It is therefore the Partnership's intention to develop reporting to include:

- Annual updates on relevant themes;
- Identification of robust and relevant indicators to assist in the development of a more appropriate and technical monitoring system to inform future 'State of the Severn Estuary' reports;
- Inclusion of more up to date, relevant and comprehensive data sources, where resources allow;
- Greater and continued stakeholder engagement;
- Identification of environmental, social and economic changes in the 'State of the Estuary' - particularly in the context of emerging policy implementation;
- Review of climate change predictions in the context of new scientific evidence and natural events.

All feedback and assistance with future reporting on the
'State of the Severn' is gratefully received by the Partnership.

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Lesser Black-backed gulls. © Sam Whitfield, 2010.

To receive more information about the Severn Estuary and the work of the Partnership (including copies of all our publications) why not become a member at:

- http://www.severnestuary.net/sep/partnership/membership.html
- SEP Business Plan, http://bit.ly/tQut8F

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Managing the Severn Estuary

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The Severn Estuary Partnership, *Partneriaeth Môr Hafren,* was set up in 1995. It is an independent, estuary-wide initiative led by Local Authorities and Statutory Agencies, involving all those interested in the Severn Estuary.

The Strategy for the Severn Estuary was launched in 2001 after several years of work developing consensus and agreement. Many people continue to come together to look at issues and opportunities relating to management and use of the Severn.

The 'State of the Severn Estuary Report', aims to provide a non-technical overview of the human and natural aspects of the Estuary; to inform a wide ranging audience, including local people and industry professionals alike, on why the Estuary is so unique.

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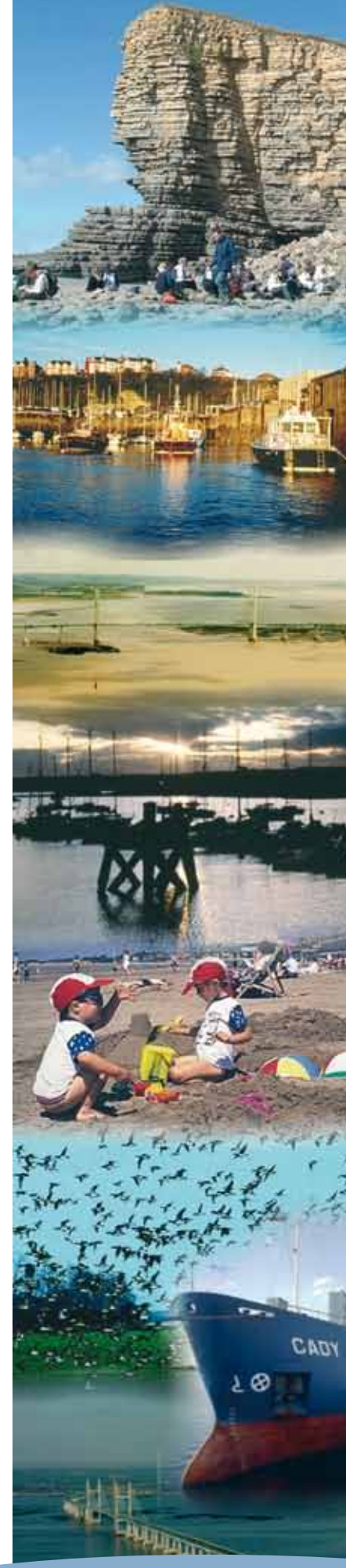

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