Marine Biological Association
of the United Kingdom

Occasional Publication No. 14

Characterisation of the South West European Marine Sites

Summary Report

W.J Langston, B.S. Chesman, G.R. Burt, S.J. Hawkins,
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MBA

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Characterisation of the South West European Marine Sites

Summary Report

W.J. Langston*[1], B.S.Chesman[1], G.R.Burt[1], S.J. Hawkins[1], J.Readman[2] and P.Worsfold[3]

April 2003

A study carried out on behalf of the Environment Agency, Countryside Council for Wales and English Nature

by the Plymouth Marine Science Partnership

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Titles in the current series of Site Characterisations

Characterisation of the South West European Marine Sites: **The Fal and Helford cSAC**. Marine Biological Association of the United Kingdom occasional publication No. 8. pp 160. (April 2003)

Characterisation of the South West European Marine Sites: **Plymouth Sound and Estuaries cSAC, SPA**. Marine Biological Association of the United Kingdom occasional publication No. 9. pp 202. (April 2003)

Characterisation of the South West European Marine Sites: **The Exe Estuary SPA** Marine Biological Association of the United Kingdom occasional publication No. 10. pp 151. (April 2003)

Characterisation of the South West European Marine Sites: **Chesil and the Fleet cSAC, SPA**. Marine Biological Association of the United Kingdom occasional publication No. 11. pp 154. (April 2003)

Characterisation of the South West European Marine Sites: **Poole Harbour SPA**. Marine Biological Association of the United Kingdom occasional publication No. 12. pp 164 (April 2003)

Characterisation of the South West European Marine Sites: **The Severn Estuary pSAC, SPA.** Marine Biological Association of the United Kingdom occasional publication No.13. pp 206. (April 2003)

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1. EXECUTIVE SUMMARY

The UK and EU have recently committed to an ecosystem-based approach to the management of our marine environment. In line with the requirements of the Habitats regulations, all consents likely to significantly affect Special Protection Areas (SPAs) and Special Areas of Conservation (SACs) are to be reviewed[1]. As part of this process, '**site characterisation'** has now been accepted as an important requirement within the Environment Agency's Review of Consents procedures, particularly with respect to complex systems such as estuaries.

The current project, undertaken by the Plymouth Marine Science Partnership (PMSP), represents the first phase in this site characterisation – the collation and assessment of existing relevant information (up to 2002). Using published information and unpublished data-sets from regulatory agencies, conservation bodies and research institutes, evidence is compiled on the links between potentially harmful 'activities', environmental quality, and resultant biological consequences. The focus is on the effects of water and sediment quality on the key interest features of European Marine sites in the South West of England, namely:

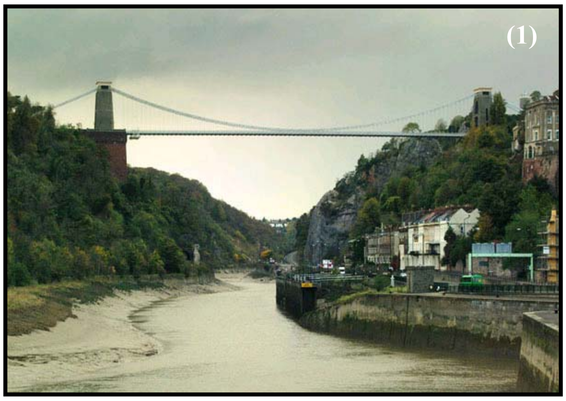
- Fal and Helford cSAC
- Plymouth Sound and Estuaries cSAC/SPA
- Severn Estuary pSAC/SPA
- Poole Harbour SPA
- Exe Estuary SPA
- Chesil and the Fleet cSAC/ SPA

Detailed analysis for each of these sites is provided individually, under separate cover (see page ii for full list of titles in this series). This summary report contains an overview of physical properties, uses and vulnerability for each of these sites, together with brief comparisons of pollution sources, chemical exposure (via sediment and water) and evidence of biological impact (from bioaccumulation to community-level response).

Limitations of the data, and gaps in our understanding of these systems are highlighted and suggestions are put forward as to where future research and surveillance is most needed. Hopefully this may assist the statutory authorities in targeting future monitoring and remedial activities.

[1] In England, a recent amendment to legislation allowed all candidate SAC's to be treated (from 28th February 2000) as if they were European sites (enabling consents on these sites to be reviewed prior to the EU formally adopting the site)

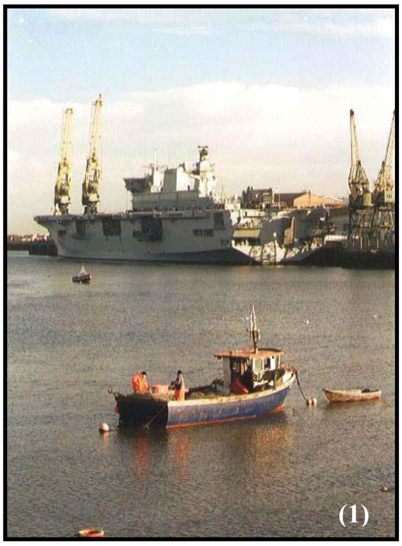
Plate 1. Some of the operations/activities which may cause disturbance or deterioration to key interest features of South West European Marine Sites



Diffuse sources of contaminants include rivers and streams **(1)**, agricultural and road run-off **(2-5). Point sources** include discharge from industrial installations **(6)** and sewage treatment works **(4 & 7)**

Photographs: **1, 3-7:** Ian Britton, Freefoto.com **2:** MBA

Plate 2. Some of the operations/activities which may cause disturbance or deterioration to key interest features of South West European Marine Sites



(1-3) The continuing contribution from legal (and possible illegal) usage of TBT in antifouling, and the persistence of TBT in sediments implies a long-term hazard in some southwest marine sites. The impact of copper and zinc in antifoulants for commercial, military and leisure craft has still to be evaluated in many areas.

Many catchment areas in the southwest are highly mineralised and have a history of mining activity **(4)**. Despite current treatment schemes **(5),** drainage channels and adits **(6&7)** and run-off from mine sites still impact on several of the southwest marine sites

Photographs: **1, 2:** Ian Britton, Freefoto.com. **3, 6, 7:** MBA **4:** Steve Johnson, Cyberheritage **5:** Unipure Europe

Plate 3. Some of the Interest Features and habitats of the South West European marine sites

The Sea Lamprey *Petromyzon marinus* **(1)** and extensive subtidal reefs of the honeycomb worm *Sabellaria alveolata* **(2)** are found the Severn Estuary pSAC

Maerl biotopes such as *Phymatolithon calcareum* **(3)** in the Fal and Helford cSAC, are well recognised as having particularly rich and diverse communities and can be sensitive to changes in water quality

Chesil and the Fleet cSAC has a sizable population of a rare charophyte, the foxtail stonewort *Lamprothamnium papulosum* **(4),** which is sensitive to high levels of phosphate

Avocet *Recurvirostra avosetta* **(5)** is one of the Annex I bird species common to three of the South West marine sites; Plymouth Sound and Estuaries, The Exe Estuary and Poole Harbour

Allis shad *Alosa alosa* **(6)** is declining throughout its range on the western coasts of Europe, and is rare in the UK. The Tamar Estuary, Plymouth Sound and Estuaries cSAC, is the only recently-confirmed spawning site is in the UK.

Photographs: **1:** Erling Svensen **2&3:** Keith Hiscock, MARLIN 4: Pietro Pavone, Dept. of Botany, University of Catania**. 5:** Eric Islay **6:** Willy Van Cammeron

Plate 4. Some of the Interest Features and habitats of the South West European marine sites

Specialised flowering plant, the yellow-horned poppy *Glaucium flavum* **(1)** is part of the perennial vegetation of stony banks in Chesil and the Fleet cSAC. Shore dock *Rumex rupestris* **(2)** thought to be the world's rarest dock and one of the rarest plants in Europe is an interest feature of the Fal and Helford cSAC.

Common Tern *Sterna hirundo* **(3)** in Poole Harbour SPA, and the Slavonian Grebe (*Podiceps auritus*) **(4)** in the Exe Estuary SPA, are part of the internationally important populations of regularly occurring Annex 1 bird species.

The Severn Estuary pSAC is considered to be one of the best areas in the UK for Atlantic salt meadows (*Glauca-Puccinellietalia maritimae)* **(5)**

Plymouth Sound and Estuaries cSAC supports a significant presence of mudflats and sandflats not covered by seawater at low tide **(6)**

Photographs: **1:** Stan Beesley **2:** Roger Mitchell, English Nature **3:** Helen Baines 4: Keith Regan **5:** English Nature (www.oursouthwest.com) **6:** Cornwall Wildlife Trust

CONTENTS

2. INTRODUCTION

The EU Habitats Directive[2] is founded on the 'precautionary principle'[3] and stresses the need for prevention of deterioration of European sites designated under the Habitats and Birds Directives. Through the Conservation (Natural Habitats, etc.) Regulations 1994 (The Regulations), which implement the Habitats Directive, it introduces new requirements upon competent authorities, such as the Environment Agency (EA), local authorities and ports authorities to assess plans and projects which could effect the nature conservation objectives of European Sites. The nature conservation bodies also have a role to play in this process by providing advice, and in some cases, may be required to carry out assessments themselves. Thus, the purpose of the assessment is to ensure that the ecological integrity of a European site is not adversely affected by proposed or existing schemes.

Environmental Authorities therefore need to develop a greater understanding of the key cause and effect relationships between the human activity they regulate and the potential effects on the habitats and species for which the site was designated. More specifically, they must assess and predict the likely effects of consented permissions and activities on the designated habitats and species in view of the Conservation Objectives. This includes assessment of the effects of consents 'in combination'.

In line with the requirements of the Habitats regulations the EA is currently reviewing all consents likely to significantly affect Special Protection Areas (SPAs, designated under the Birds Directive) and Special Areas of conservation (SACs, designated under the Habitats Directive). As part of this process, '**site characterisation**' has now been accepted as an important requirement within the Agency's Review of Consents (see joint EA/EN paper August 2001).

The current project represents the first phase in this site characterisation – the collation and assessment of existing information (up to 2002) which is relevant to the issues of concern. The focus of the site characterisation is on the effect of water quality on the interest features of the European sites in the South West of England (Fal & Helford cSAC; Plymouth Sound and Estuaries cSAC/SPA; Severn Estuary pSAC/SPA; Poole Harbour SPA; Exe Estuary SPA; Chesil & the Fleet cSAC/SPA – see Figure 1).

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[2] EC Directive on the Conservation of Natural Habitats and of Wild Fauna and Flora (The 'Habitats Directive')
Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora came into force on 21 May 1992. The central aim of the Directive is to conserve biodiversity across the area of the European Union through a coherent network of Special Areas of Conservation (SACs). Seven marine habitat types are listed in the Directive and nine of the species listed are marine or spend part of their life in the sea and have breeding populations in the United Kingdom. SACs together with 'Special Protection Areas' (SPAs) identified under the Birds Directive will create a network of sites described as 'Natura 2000'.
Further information see: http://europa.eu.int/comm/environment/nature/legis.htm

[3] The precautionary principle is a recognised legal mechanism used in British, Canadian, New Zealand, and Australian courts. It says that "Where there are threats of serious or irreversible environmental damage, a lack of full scientific knowledge shall not be a reason to take preventative action." (Bell, 1997)

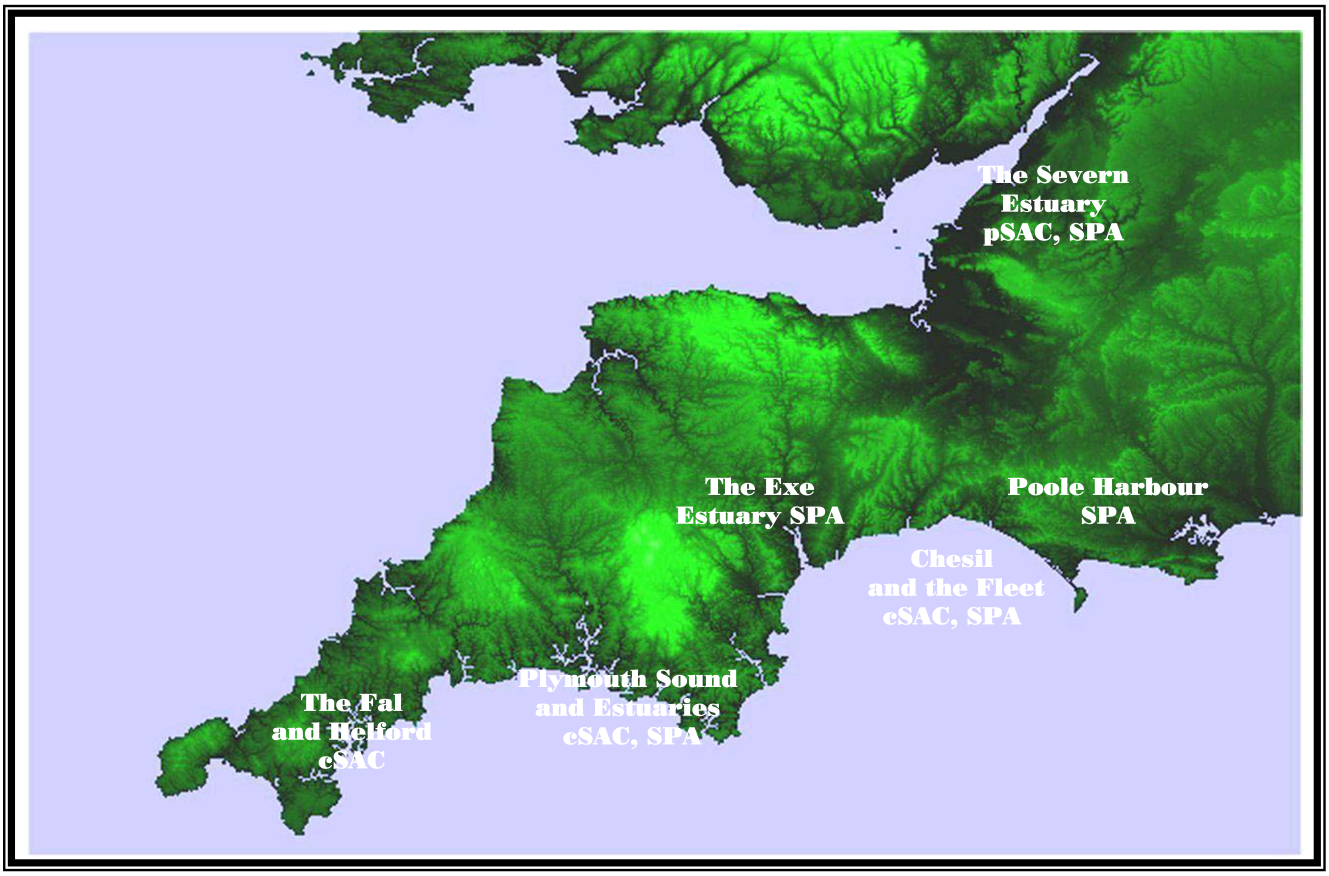

Figure 1. Location of the South West European Marine Sites

3. OBJECTIVES

The overall objective of the project is to evaluate, critically, all available information and assess whether biological communities within European marine sites of the South West are likely to be adversely affected by anthropogenic influences. Of particular concern is the quality of water and sediment within, and adjacent to, habitats nominated as European interest features, including large shallow inlets and bays, subtidal sandbanks, intertidal mudflats and sandflats, and Atlantic "salt meadows" (see Annex 2 for full lists).

To achieve this goal, specific objectives were:

- To prepare comprehensive reference lists of previous investigations and existing datasets. This includes published research articles and unpublished reports relevant to an assessment of the effects of water quality on the marine sites and identified interest features.

- To review the existing information thus identified, pinpoint key studies, collate and summarize their findings.

- To identify site-specific models predicting pollutant concentrations and their links to impact.

- To prepare a summary of existing datasets (spatial and temporal) on water and sediment quality up to 2002 (e.g. determinands and summary statistics where available).

- To integrate and evaluate biological information, with specific reference to water/sediment quality.

- To conclude if there is any evidence that existing water (or sediment) quality is causing impact, and highlight limitations of available data.

- To identify and recommend further research which will address limitations of current information and establish cause/effect relationships.

In view of the project's emphasis on consents, we have focused on the vulnerability of each site to toxic contamination (metals, artificial radionuclides, synthetic organics) and non-toxic contamination (nutrients and related water quality parameters such as dissolved oxygen, chlorophyll a and turbidity) unless any other operations were seen as highly relevant.

Several key questions, which we have tried to incorporate into our considerations of site characteristics are drawn from the Agency's Management System i.e.

- Is there a potential hazard mechanism by which the consent/activity could affect the interest features of the site (directly or indirectly)?
- Is there a probability that the consent/activity could affect the interest features of the site (directly or indirectly)?
- Is the scale and magnitude of any effect likely to be significant[4]?

Clearly if the answer to all three questions is positive a more detailed assessment is likely to be required.

We have also kept in mind similar criteria which EA/EN/CCW may need to apply during the review process as outlined in their *Guidance for the Review of Environment Agency Permissions: Determining Relevant Permissions and 'significant effect'* (March 1999):

A. The designated feature is in favourable condition and there is no evidence to suggest existing consents are currently having a significant effect.

B. The designated feature is in favourable condition but there is concern that a water quality problem caused by a consented discharge may be threatening that condition and/or causing a decline in it.

C. The designated feature is in unfavourable condition, but this can be attributed to a factor unrelated to water quality, e.g. vegetation management, and there is no evidence to suggest relevant consents are currently having a 'significant effect'.

D. The designated feature is in unfavourable condition and poor water quality may be or is likely to be responsible.

[4] Examples of 'significant' effects criteria:
- Causing change to coherence of the site
- Causing reduction in area of the habitat
- Causing change to the physical quality and hydrology
- Altering community structure (species composition)
- Causing ongoing disturbance to qualifying species or habitats
- Causing damage to size, characteristics or reproductive ability of qualifying species (or species on which they depend)
- Altering exposure to other impacts
- Causing a reduction in resilience against other anthropogenic or natural changes
- Changing stability of the site/feature
- Affecting a conservation objective

4. METHODOLOGY AND APPROACH

Relevant information appertaining to water quality, sediments and biota at SW European sites and interest features therein has been identified, including published research, unpublished reports, and spatial and temporal datasets. Searches were carried out using electronic bibliographic databases at the National Marine Biological Library (NMBL, Plymouth) and included Aquatic Sciences and Fisheries Abstracts (ASFA), Web of Science (WOS), National Information Services Corporation (NISC USA), and the 'in-house' search engine WinISIS, together with NMBL books and serials. Comprehensive reference lists were created and reviewed enabling key studies and information to be identified, for each site. A combined bibliography is included in Annex 1.

Unpublished reports and data-bases of particular importance were provided by the Environment Agency, English Nature, Fleet Study Group, Joint Nature Conservancy Council (JNCC) Coastal Directories, Centre for Environment, Fisheries and Aquaculture Science (CEFAS), Cornish Biological Records Unit, Cornwall Wildlife Trust and Cornwall County Council.

The research organisations which make up the Plymouth Marine Science Partnership (PMSP) – namely the Marine Biological Association, Plymouth Marine Laboratory and University of Plymouth - have undertaken a large range of studies across the south west European Marine sites. These include work on the chemistry, bioavailability and impact of contaminants, the ecology of benthic organisms and modelling. Access to expert opinion and, in some cases, unpublished data for these and other UK sites, has been helpful, particularly in scaling the relative importance of contamination.

Characterisation of each of the European Marine sites comprises:

- Descriptions of the main physical, chemical and biological features which shape the nature of the sites, together with the perceived threats to favourable conservation status. The biology and ecology of benthic communities, many of which support the bird populations for which several sites are designated, are also reviewed.

- Identification and descriptions of the key interest features of each site. These are derived from English Nature Regulation 33 packages (see Annex 2), and we have drawn on EN's opinions on operations which may cause disturbance or deterioration to these features to provide the focus of our assessments.

- A substantial part of each of the individual site characterisation studies involves a synthesis of environmental quality data for both toxic (metals, TBT, petrochemicals, pesticides, PCBs, volatile organics, artificial radionuclides) and non-toxic contaminants (nutrients, turbidity, dissolved oxygen). Where published data on water, sediments and biota exists this has been reviewed, with special reference to the processes that modify distribution and bioavailability. Since recent published papers on contaminant levels are relatively sparse, however, statistics for raw data (up to 2002), provided by the Environment Agency (extracted from WIMS), have been summarized in an attempt to provide a more complete overview of water-quality. In the absence of integrated chemical/ biological-effects monitoring, these data are presented in relation to Environmental Quality Standards and guidelines (listed in Annexes 3,4) as a crude means of attempting to tease out the main water quality issues (see ‘constraints’).

- A synthesis of available information on sediment quality, which, for metals, often relies on unpublished MBA data. In the absence of any UK standards, interim guidelines adopted by Environment Canada serve as a rough indication of the risk to biota from sediment contaminants. Available data from each of the European marine sites are compared with Threshold Effects Levels (TELs) and Probable Effect Levels (PELs) derived from published toxicity data (CCME, 1999; see Annex 4).

- A brief description of modelling exercises of direct relevance to the environmental quality status of the site, where applicable.

- Concluding remarks regarding the status of each of the European marine sites (up to 2002), including a summary of evidence for impact from different classes of contaminant.

- Recommendations for future research and surveillance, to help fill the gaps in our understanding of these systems.

5. CONSTRAINTS AND UNCERTAINTIES

Because of the paucity of published contaminant studies at most sites, assessment of environmental quality draws heavily on data for key determinands supplied by EA (except for sediment metals and organometals where we have drawn on some of our own unpublished data to supplement this assessment). Summary statistics have been drawn up by the EA (based on monitoring since 1990), and the raw data analysed in an attempt to establish further evidence as to whether or not existing water quality is likely to cause impact. Where relevant, temporal trends have also been discussed. Though Quality Assurance was generally good[5] it should be noted that EA monitoring data is often several years old, is often fragmentary or incomplete[6], and, for many toxic contaminants may be for the purpose of compliance monitoring only. Detection limits are frequently set with that specific intention in mind, such that the data may be of limited value for environmental behaviour studies. Nevertheless (half) detection limits have usually been included in summary statistics since it allows at least a crude assessment of water quality issues. Where this is problematic in the interpretation of data, caveats have been applied.

Some major industries, now under IPC regulations, are responsible for monitoring their own compliance with consents, for example at Avonmouth. Although public summaries of these records are available we have not been able to access raw data, therefore only an 'impression' of environmental status is given. Some industries may have closed or changed names during the period since 1990, but where they appear in the statistics provided by EA, they are referred to under the sampling point name used in the WIMS database.

For the SACs/SPAs examined here, the absence of site-specific biological effects information necessitates the comparison of water-monitoring results with Environmental Quality Standards (EQS) in order to gain a first-order approximation of possible impact on biota. Thus, in the context of the current project, descriptions of 'threat' or 'risk' to the site from individual contaminants are scaled against the relevant EQS, assuming this to be an appropriate threshold for the protection of aquatic life. For a number of reasons this is an uncertain supposition. The compliance limits for contaminants and other water quality parameters are themselves based on reviews of general toxicity data for aquatic life, coupled with a safety margin below the lowest reliable adverse effects concentration. The assumption is that below the EQS, adverse biological and ecological effects *are unlikely*. Above the EQS, effects *might be expected to occur* though this will depend on the magnitude and duration of the exposure. The application of EQS values

[5] QA procedures: The Agency has recently (May 2002) been accredited by UKAS to BS EN ISO/IEC 17025. Prior to this formal accreditation (when most of the analyses considered here would have been performed), internal QA/QC procedures and inter-laboratory calibrations were operated. Unpublished MBA metals data on sediments and biota in the European Marine Sites, used in this project, are based on similar internal QA/QC protocols: the methods used have been validated in a number of intercalibration exercises (e.g. Quasimeme) and for the last 10 years has involved regular use of certified reference materials as checks on quality of the data. Samples are expected to be accurate to within ± 10%.

[6] There are some factors, related to inconsistent sampling and analysis frequencies, which can make interpretation of the EA data complex e.g. the nutrient determinands measured can differ between sites and times: nitrogen, for example may be measured as dissolved N, total nitrate or total inorganic nitrate (TIN). This example leads to particularly difficult comparisons, as the proportion of bioavailable nitrogen may differ seasonally as well as according to operational definitions. Also changes to the limits of detections makes trend determination difficult (where half-detection limits are substituted for '<' values to evaluate the data).

involves uncertainties arising from limited toxicity data, differential responses between chronic and acute toxicity, inter-species variation in sensitivity, and modifying factors within each individual ecosystem (notably, the issue of synergy and additivity discussed below). Sensitivity may also vary between different levels of biological organisation; lower-order effects (molecules and cells) are likely to occur at lower levels of contamination, and in advance of, community and ecosystem-level response. Often this involves a high degree of precaution in setting standards and could give rise to an apparent mis-match between chemical data and measured biological responses, particularly at the level of biological diversity. Conversely, it is also possible that subtle effects may occur at concentrations below the EQS, giving rise to a failure to protect the system. Compliance/non-compliance patterns are therefore not necessarily synonymous with ecological implications: at present the latter can only be gauged by considering a wider array of ecosystem characteristics. EQS values are used here merely help to prioritize some of those sites and contaminants which merit closer investigation. They do not necessarily assure Favourable Condition[7].

As yet, sediment quality guidelines have not been validated in the UK. Principal limitations are the possible variations due to fundamental differences in sediment geochemistry and the use of non-indigenous test species in deriving thresholds. Nevertheless, in the absence of any UK standards, interim guidelines adopted by Environment Canada (CCME 1999; see Annex 4) serve as a rough indication of the risk to biota from sediment contaminants. Hence, their application will help to identify instances where efforts should be made to minimise further inputs of these substances, as may be required, for example, under the Habitats Directive, in the attainment of Favourable Conservation Status (FCS)[7]. For some contaminants (e.g. many List I substances) there is also a requirement to ensure 'Standstill' conditions in sediments (and biota) under the Dangerous Substances Directive.

Clearly, the process of predicting risks posed by discharges to aquatic environments is subject to a number of reservations, even when only one stressor is involved. Predicting total exposure risks in receiving waters subjected to 'complex mixtures' often compounds these uncertainties. Wherever possible we have attempted to provide measures of the uncertainty associated with risk predictions and the degree of quality assurance for the data. It has to be acknowledged however that unlike chemical data whose authenticity can often be validated against certified reference materials there is seldom authentication for biological response data. This should be seen as an important goal for ecotoxicologists. One of the most important constraints, however, is that biological effects data simply does not exist for many important study sites. **The report is therefore a synthesis based on best available evidence. The opinions expressed are largely those of the authors and do not necessarily reflect the views of EA, EN or CCW.**

[7] Favourable Conservation Status (FCS). This requires that the condition has to be characterised and, if considered necessary, brought up to a level where species/habitats are sustainable in the long term. English Nature has produced Favourable Condition tables to aid this process, which encompasses a number of attributes, including the extent and biological quality of the interest feature (summarised in annex 2 for south west European Marine sites).

6. SITE CHARACTERISATIONS

6.1 THE FAL AND HELFORD cSAC

The Fal and Helford estuaries are rias whose topography was determined at the end of the last glaciation when sea level rise led to flooding of river valleys and formation of present day creeks. This has led to the creation of extensive 'wetlands' in parts of the upper Fal system and, in the lower, deeper sections, to one of the largest natural harbours in the world, Carrick Roads.

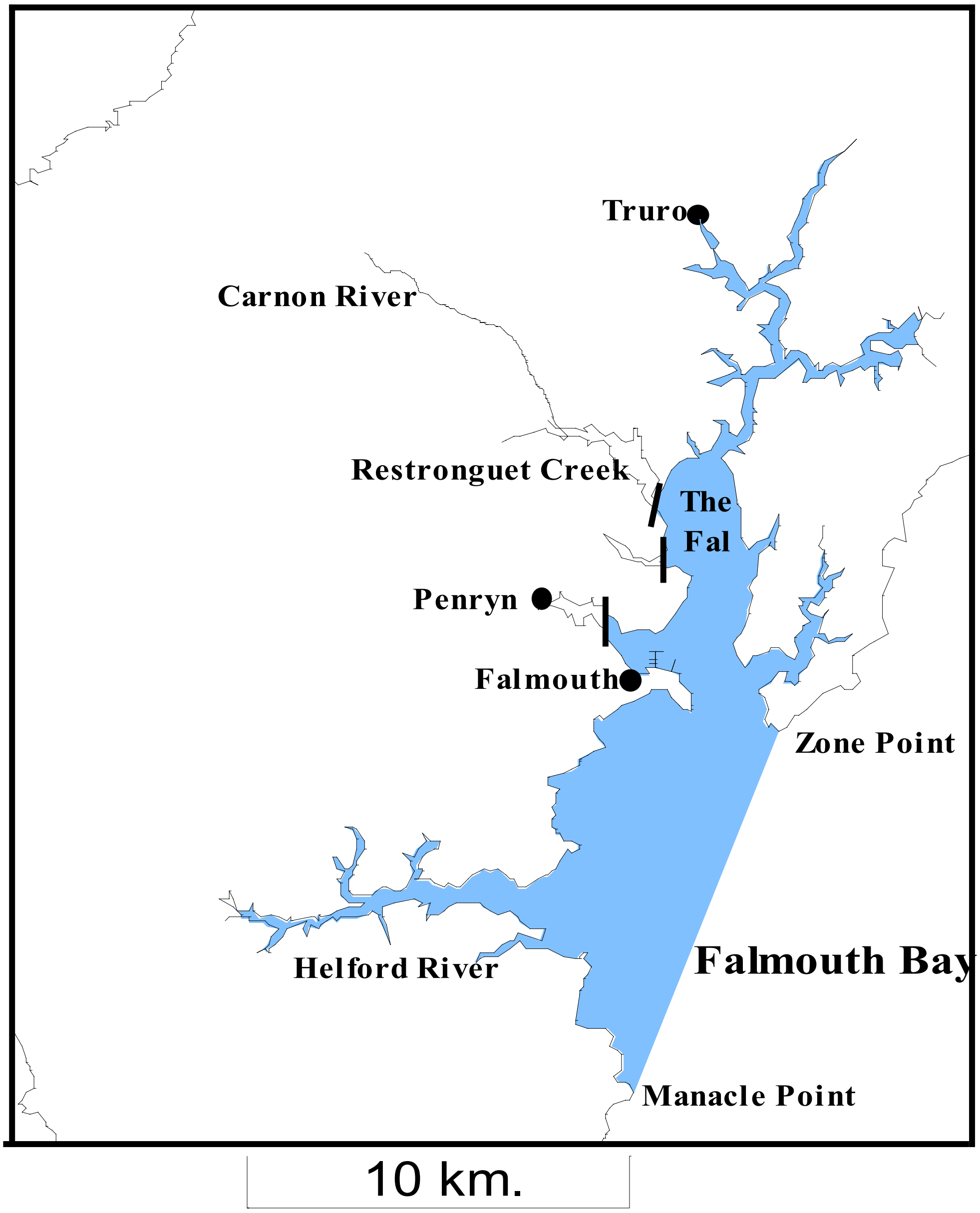

Figure 2: Fal and Helford cSAC showing boundaries of marine site

The catchment and sediments of the Fal reflect its underlying geology and, most significantly for the current synthesis, are heavily influenced by the Carnmellis granite and surrounding metamorphic aureole to the west of the estuary. Mining of the metalliferous deposits has been a major feature of the area since the Bronze Age and at the peak of activity in the 19th century, ore processing in the Carnon Valley in particular, remobilised millions of tons of tailings. Much of this has been deposited in Restronguet Creek making it one of the most metal polluted estuaries in the UK. Though the creek is outside the boundaries of the cSAC, there is evidence that some metals have been transported to other parts of the system, especially to adjacent creeks on the western side such as Mylor and Pill, and to the upper Fal. The last active mine (Wheal Jane, upstream of Restronguet Creek) was finally abandoned in 1991 and there are ongoing efforts to treat waste-water from this source. However, residual drainage from old mines, spoil heaps and groundwater continue to influence sediment geochemistry. Parts of the cSAC are therefore impacted by past mining activities (albeit outside the marine site), which includes an important contribution from sediments. Metals of most concern are probably As, Cu, Zn, Cd and Fe.

Arsenic concentrations in sediments of Restronguet and the upper Fal are in the 'probable effect level' (PEL) range. Cu in sediments of all major rivers and creeks of the system (including the Helford) are above the PEL. In the most contaminated areas, some organisms, e.g. cockles, accumulate Cu to levels which can have lethal or sublethal effects, and desorption from sediments may be an important additional source for such infauna. Generally, measured Cu concentrations in overlying water outside Restronguet Creek appear to be below the EQS and are unlikely to result in acute toxicity, though chronic effects are possible. The impact of increasing use of copper-based antifoulants by the leisure fleet has still to be evaluated. A further source of Cu in the Fal is the outfall at Falmouth Dockyard and this is reflected by elevated Cu concentrations in waters and sediments of the area. Again, however, relatively little is known of the implications of this for many potentially sensitive species in the Fal and Helford cSAC.

Apart from Restronguet Creek, occasional high values for dissolved Zn have been recorded in waters of the upper Fal (Tolverne, Truro, Old Kea and Tresillian), and probably originate in sewage discharges. High concentrations of Zn are also associated with Falmouth Dockyard combined outfall. These warrant further investigation in view of the use of Zn compounds in antifouling paints. Zn levels in sediments are a further concern, and, based on 'probable effect levels', pose a threat to benthic organisms in most of the creeks and tributaries of the system. In addition, the tolerance developed to elevated Zn (and Cu) by some organisms can result in high elevated body burdens which may present a hazard to predatory fish and birds of the cSAC.

With the exception of elevated levels near Devoran Bridge, cadmium is below EQS and not considered to be an acute water quality problem. However, Cd in sediments could be a cause for concern and should be investigated further. Cd is not generally associated with sewage discharges in to the cSAC and any elevated levels in the area are likely to have arisen as a result of past mining and ore processing activities.

Apart from Restronguet Creek, Truro STW, and the occasional elevated value near Falmouth dockyard, levels of dissolved Fe at other locations in the cSAC are close to background and below EQS, therefore direct effects of Fe are not usually a water quality issue. The distribution of Fe in the cSAC is strongly influenced by salinity; on mixing with seawater the dissolved Fe which is present in freshwaters entering the estuary oxidises and rapidly precipitates (hence the discoloration associated with the 'Wheal Jane incident' in 1991). This precipitation process has implications for other dissolved metals, which may be scavenged by the Fe oxyhydroxides produced during estuarine mixing. Following the introduction of minewater treatment at Wheal Jane, Fe inputs and oxyhydroxide production have been reduced considerably (to prevent further discoloration events), and scavenging of other metals in the estuary may be less pronounced. Thus, Fe has become an important factor in the sedimentation of other, potentially more damaging, metals. The possibility of remobilisation from sediment, and the implications for the biota of the cSAC need to be examined as a priority.

The Helford catchment consists of Devonian carboniferous rocks, granite and associated Devonian rocks which contain small amounts of mineralisation. Freshwater inputs are small so that the Helford is largely a salt water estuary. Unlike the Fal, the Helford Estuary has no history of extensive mining complexes in the immediate vicinity, although small-scale mineral exploration and extraction has occurred. These workings will no doubt have contributed to the sediments of the main channel, as silt deposits in the upper reaches of the waterway exhibit Cu, Zn and Sn enrichment. Compared with Restronguet however, sediments in the Helford do not appear to represent an acute problem.

There is relatively little large industry left to affect the Fal, though Falmouth Docks and a number of marinas are potential sources of disturbance (dredging activities, oil, metals and release of antifouling and sewage). Much of the system, and in particular, the Falmouth area, is affected by organotin (TBT) contamination. The principal source is Falmouth Dockyard, although the relative contribution of sediments as a source is still to be resolved adequately. The potential for short-term sediment releases during artificial remobilisation (dredging, for example) may be considerable and is likely to contribute to ecological damage in the long term. There may also be a component arising from sewage inputs and shipping. TBT concentrations in parts of the Fal are high by national and international standards and do not appear to have been reduced by initial TBT legislation on small vessels. There is clear evidence of impact on dogwhelk populations, which have been eliminated from most of the Fal by TBT. There is also circumstantial evidence, based on comparisons with EQS values and sediment toxicity guidelines, that other infaunal organisms, particularly molluscs, will be affected. Most faunal surveys indicate that the Fal is impoverished compared to similar systems, and though this probably relates in part to the long history of mining impact, a significant component of the damage (and a continuing impediment to recovery) may be attributable to TBT. Unfortunately, there are constraints on providing a full assessment of TBT status, caused by a lack of detailed information; notably on inputs to the system, environmental inventories (particularly for sediments), and the variables controlling partitioning. This information is needed to clarify the processes that determine organotin distributions in the estuary and to develop models that simulate the fate of TBT in the cSAC.

Concentrations of hydrocarbons in the Fal and the mouth of the Helford suggest general contamination in the area which originates, possibly, from the dockyard and shipping, but may also be related to run-off and/or aerial deposition. In enclosed systems such as the Fal, the potential for dispersion of hydrocarbons is minimised, and much of the contamination can be washed ashore. Perhaps the most vulnerable areas are intertidal habitats where sensitive shoreline seagrass and saltmarsh communities could be at risk. Although EQS's for hydrocarbons are difficult to define, levels at some sites may exceed limits specified under the shellfish and bathing waters directives. The only available data for PAHs listed in the EA database were for the River Carnon at Devoran Bridge, where Naphthalene concentrations were below the EQS. However further investigation into the sources, levels and composition of PAHs and hydrocarbons in the cSAC would seem to be necessary.

Synthetic organic compounds have not been widely monitored, though concentrations of the majority of these substances (which includes many endocrine disruptors) are now generally very low in the cSAC. Diffuse agricultural sources and small contributions from STW probably account for any pesticide inputs. Values for PCBs in water and oysters, in the EA database are largely below limits of detection at shellfish sites within the cSAC, though an unpublished report from the early 1990s indicates measurable levels of 5 PCB isomers in oysters from the Helford Estuary (above the OSPAR upper guideline for mussels). These oysters were from a re-lay bed at Lower Calmansack and had been collected from a number of areas in Carrick Roads before their transplantation to the Helford Estuary. Since PCBs were not found in water or sediments from the re-lay site, it was concluded that the oysters (and their PCB burdens) originated from elsewhere in the Fal or Helford Estuaries. This incident highlights the need for more rigorous sampling in the cSAC for organochlorines and other organic substances that accumulate in sediments and affect estuarine biota through food-chain magnification.

Nutrient enrichment is a problem in parts of the Fal/Helford system. Elevated nitrogen and phosphorus species are an important factor in poor water quality, and can lead to symptomatic changes such as algal blooms, dissolved oxygen (DO) sags, and turbidity, which come under the broad heading of eutrophication. Exaggerated dissolved oxygen fluctuations (which indicate a high level of biological activity in the water column), coupled with high levels of chlorophyll *a*, have been observed intermittently, though the most potent indication of eutrophication was the 1995/6 harmful algal bloom originating in the upper Fal Estuary/Truro River. This event was particularly significant because it involved the 'red tide' dinoflagellate *Alexandrium tamarense* which produced PSP (paralytic shellfish poisoning) toxins, resulting in a prohibition notice on the collection of shellfish during 1995 and 1996. The upper Fal (Truro, Tresillian and the Fal Estuaries) were subsequently designated as a Sensitive Area (Eutrophic) under the provisions of the Urban Waste Water Treatment Directive (UWWTD), which it might be hoped, would herald improvements to the nutrient status of the area[8]. However, harmful algal blooms, linked to nutrient enrichment, continue to occur in the Fal and Helford system. The most recent incidence, in 2002 resulted in significant mortality of marine worm species *Nereis* and *Arenicola* as well as some shellfish, and was centred on Polwheveral Creek and Porth Navas, on the Helford Estuary, where high nutrient levels remain a cause for concern. This bloom was believed to be principally *Gyrodinium aureolum*, which produces toxins that can also kill fish. Calenick Creek near Newham STW in the upper Fal was also affected.

The principal sources of nutrients to the European Marine site as a whole are diffuse with a particularly important agricultural component for nitrogen, though areas of the Fal and Helford appear to be influenced locally by chronic contamination from sewage discharges. Modelling exercises indicate that the principal source of nitrogen in the upper Fal Estuary during summer months is Newham STW. The threat of eutrophication may be exacerbated by re-release of

[8] If a site is designated as a Sensitive Area (Eutrophic) under the Nitrates Directive, the objective is to "reduce water pollution caused or induced by nitrates from agricultural sources" and "prevent further such pollution". Therefore, improvements to STW are not an automatic result of designation. STW improvements may be instigated if the STW is considered to be an indirect nutrient source (ie, discharges upstream of the designated site) and serves a populace greater than 10,000 (population equivalent). However, there are no such qualifying discharges in the designated areas of the Truro, Tresillian and Fal estuaries.

phosphorus from sediments, small inputs from mine drainage (P), and seasonal fluctuations in N:P ratio of waters entering the tidal estuaries.

With the exception of the lower Fal Estuary, where there have been major upgrades to sewage treatment in recent years, there are no apparent temporal reductions in nutrient levels; in fact for many sites there is evidence of significant increases over the past 15 years. Contaminants associated with point-sources in the upper Fal are anticipated to decrease in the coming years as proposed improvement schemes to sewage treatment plants in the Truro area come on line (a schedule of water company improvements in the area is included in the main report). However, there appear to be no plans to reduce nutrient inputs from either the larger (e.g Newham) or the smaller STWs (e.g. Constantine and Gweek), which may affect the more enclosed areas of the upper Fal and the Helford Estuary.

Unfortunately the lack of water and sediment quality standards for nutrients make it difficult for consents to be judged in terms of statutory limits in receiving waters and this is identified as a significant gap in the ability to manage the system optimally. Also, current monitoring of nutrients in tidal waters appears to be non-routine; without up-to-date information, potential problems may go undetected until manifestations, in the form of harmful effects, occur. Hence, it would seem that an increase in nutrients should be strongly avoided, as a precautionary requirement. Changes to consents (quantities and location) should therefore be considered very carefully to avoid the risk of further hypernutrification.

Recent values for DO show that levels periodically fall below the recommended EQS for sensitive marine life in several areas of the system, particularly in the Truro and Tresillian area. Indications are that the DO status of the upper estuary is deteriorating and that levels in parts of the lower Fal (Carrick Roads) may also be a cause for concern. This situation reaffirms the notion that the symptoms of nutrient enrichment are an ongoing problem in the Fal.

The nutrient status in parts of the cSAC, notably the upper Fal and parts of the Helford, thus comprises a significant threat to many important conservation features. Though there is no confirmation of a clear link between nutrient enrichment and ecological status, evidence suggests indirect links to the decline of *Zostera* and Maerl beds, an increase in epiphytic (blanketing) algae, algal blooms (including toxin-producing algae), fish- and invertebrate-kills, and reduced biodiversity.

Values for faecal coliforms in the cSAC highlight sewage-related concerns in the upper Fal (Truro and Tresillian) and lower Carrick Roads (Flushing, Tolverne) areas. The Shellfish Hygiene Directive has been a significant driver for recent improvements to STWs and sewerage facilities in the cSAC. Water company plans to further improve water quality in these areas will include the addition of UV disinfection to the current processes, which may alleviate the problem somewhat, however careful monitoring of the situation is strongly recommended.

Sedimentation and turbidity have some influence on site characteristics. The large input of china clay wastes from the St Austell area has, in the past, had an important silting impact in the upper estuary and its saltmarshes. Though the primary source of turbidity is currently considered to be sediment resuspension, the levels of turbidity in parts of the cSAC suggest additional sources. Sewage discharges in the Truro/Tresillian area, and extraction of Maerl from the lower estuary, could have local significance on turbidity, and during blooms, it is likely that the suspended organic component includes significant amounts of microalgae. Temporally and spatiallylimited resuspension events also arise from dredging activity and may remobilise contaminants, locally.

Annex 2 lists the important features, communities and species of interest within the estuary which have resulted in it's candidacy as a European Marine Site. Amongst the most significant are the Maerl and *Zostera* beds, together with their diverse associated flora and fauna. As indicated above, however, the biological status of several biological features are considered to be under threat:

Maerl beds are comprised of some rare and important algae, whose slow growth rates (time scales of decades-centuries) make them extremely vulnerable to pollution. It has been suggested that the species typically associated with Maerl in the Fal, though exhibiting high variety, may be less diverse than assemblages in Maerl beds elsewhere. They may also be lower in abundance than might be expected, possibly due to the presence of larger quantities of mud and silt in the bed. Since many of the associated fauna include molluscs (species sensitive to pollutants such as TBT and metals), toxicity issues may be involved. Elimination of such organisms could have indirect implications for maerl as they are important to the structural integrity of the bed. To reinforce concerns over the conservation of this unique habitat there are reports of a reduction in the proportion of live Maerl in both the Fal and Helford Estuaries.

Similarly, the diversity of species associated with *Zostera marina* beds in the Fal is reported to be lower than *Zostera* communities in 'more pristine' areas such as the Isles of Scilly. In the Helford Estuary, reports indicate that *Zostera* beds have disappeared from many areas, and remaining beds are somewhat eroded, with adjacent areas of gravel and clitter becoming silted over. There is no clear evidence to pinpoint the exact cause of the decline of *Zostera* in the Fal and Helford cSAC, although *Zostera* beds are known to be susceptible to various forms of pollution, including metals and the indirect effects of nutrient enrichment. *Z. marina* readily takes up heavy metals, mainly through the leaves, and could in future be used as bioindicator. In the laboratory, metals and a number of organic contaminants have been found to reduce nitrogen fixation in the roots, and thus could affect *Zostera* viability.

Excessive nutrient enrichment can also cause damage to eelgrass beds. There are a variety of mechanisms for this damage, the most important of which are metabolic imbalance, proliferation of phytoplankton, epiphytic or blanketing algae, and increased susceptibility to wasting disease. The decline of *Zostera,* nationally, may have serious consequences for the rich and diverse associated fauna, and for the waders and wildfowl which feed amongst the beds.

Compared with other, less contaminated, estuarine systems in south-west Britain, the Fal has a very low abundance of the crustacean *Corophium volutator* and of *Cyathura carinata*, whilst certain small annelid worms (e.g. tubificids and spionids) are more abundant in the Fal than other estuaries. Metal pollution is implicated as the cause of these differences. Crustaceans are known to be among the most sensitive of all marine taxa to pollution, including heavy metals. Organic enrichment is less implicated, since the capitellid polychaetes (indicators of organic pollution) are relatively low in numbers in the Fal.

There is thus a tendency towards relative dominance by fewer species in the Fal, and the distinctive nature of the macro-invertebrate communities in certain areas (most marked in the vicinity of Restronguet Creek) is, to a large extent, due to metal contamination. These features have implications for higher trophic levels in the system (wading birds and demersal fish), which rely on the macrobenthos for food. Because metal concentrations in some areas have been elevated for such a long period, certain populations have developed tolerance, indicating that responses to metal toxicity may have been modified. What happens to these responses, as pollution pressures change, particularly in response to remediation measures at Wheal Jane, remains to be investigated.

The Fal does not now support a salmon fishery, though anecdotal evidence suggests it may once have done so. Sea trout are present in several tributary rivers and can apparently tolerate the moderately polluted conditions. As yet there is no run of sea trout through to the Carnon River, although sporadic records are mentioned for the Kennal. The impoverished status of these species of diadromous game fish has been linked to pollution, and it is metals that are of primary concern, although the effects of high nutrient levels, including reduced oxygen levels and high turbidity, may also be contributory factors.

The Fal Estuary, considered as a whole, supports no internationally important populations of birds but does support a nationally important population of black-tailed godwit (a biodiversity long-list species). Dunlin, Oystercatcher, Turnstone, Curlew, Heron, Redshank and various waterfowl are widespread, and are often concentrated near the tops of inlets which are subject to the influence of contaminants, including the Truro River and Restronguet Creek, but the consequences for birds have not been studied. Overall, the 1992 discharge incident at Wheal Jane is not thought to have had an appreciable effect on numbers of wildfowl and waders. One exception may have been the increasing mortalities and occurrences of sick mute swans observed between 1992 and 1995; however, although this has attributed largely to heavy metal toxicity, the evidence remains equivocal. In view of the fact that redshank and other waders may overwinter in Restronguet and some of the other contaminated sites, a study to investigate the uptake of contaminants from the diet during this period might provide valuable insights into risks for birds.

The number of studies and amount of information addressing impacts to the fauna and flora of the Helford is rather small in comparison to the Fal. This should be rectified, particularly in view of observations described above.

Thus, despite the importance of the Fal as a European Marine site there are indications of some environmental degradation. Most faunal surveys indicate that the Fal is impoverished compared to similar systems elsewhere. Future monitoring of water, sediment and biota should be modified according to the environmental issues of most concern so that they can be addressed adequately in future re-appraisals of the site. The introduction of targeted biological-effects monitoring, alongside chemical determinations, should be a priority.

6.2 PLYMOUTH SOUND AND ESTUARIES cSAC, SPA

Plymouth Sound and its associated estuaries comprise a complex of marine inlets (rias) of considerable biological and historical importance. The Sound itself is an open bay with a steeply sloping, rocky coastline to the east and west, and the inner Sound is sheltered by an artificial breakwater. The River Tamar provides the dominant freshwater input to the system, entering the Hamoaze to the northwest, with the Rivers Tavy and Lynher, combined, contributing half of the Tamar input. The catchment of the Tavy is largely agricultural with small urban developments and a few old mine workings. The catchment of the Lynher is primarily agricultural though the source of the River Tiddy, which joins the Lynher in the upper estuary, is in an old copper mining area. The Plym and Yealm estuaries open directly onto the Sound in the north- and south-east, respectively.

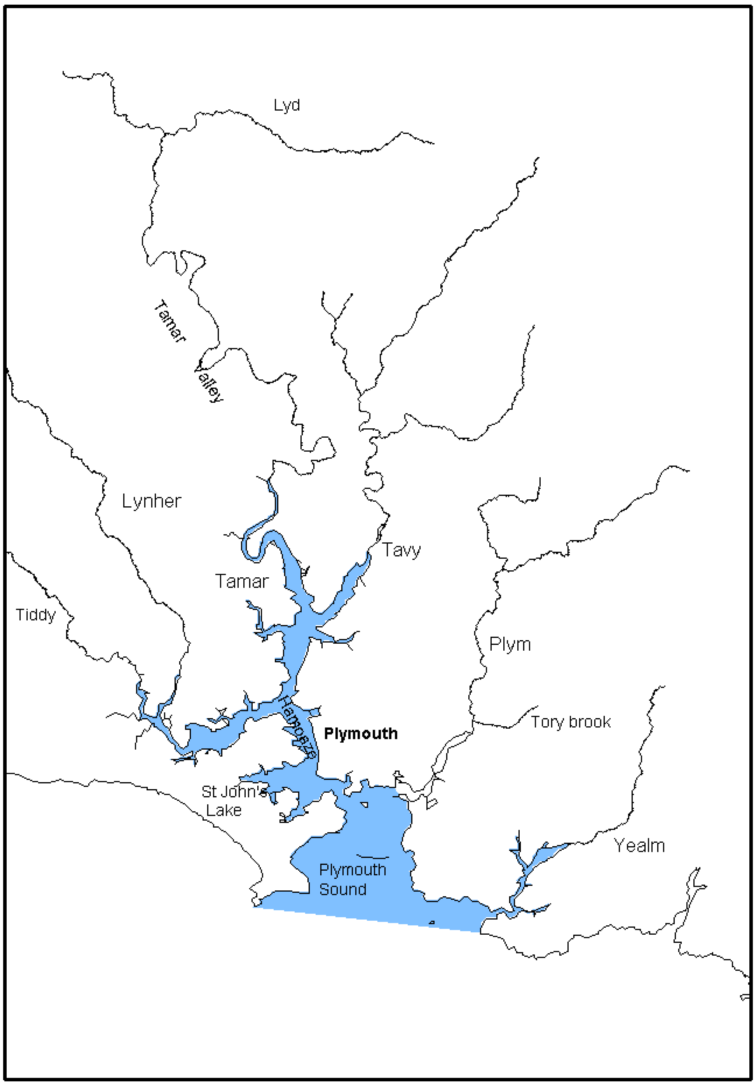

Figure 3. Plymouth Sound and Estuaries cSAC showing boundaries of marine site

The geology of the cSAC is variable and includes Plymouth limestone, Staddon Grits and mid-Devonian slates. Much of the area is highly mineralised and mining for metalliferous deposits has historically been a feature of the Tamar valley. Approximately 30km inland, at Gunnislake Weir, the River Tamar becomes tidal, and wide mudflats and saltmarsh support wading birds such as the nationally important little egret *Egretta garzetta*, and avocet *Recurvirostra avosetta,* in addition to wintering wildfowl and migratory birds. Further seaward the eastern shore of the lower estuary is dominated by the City of Plymouth, Devonport dockyard with its ship and boat-building yards, and the naval base and military port. On the opposite side of the river the land is comparatively less disturbed and there are extensive mudflats around the mouth of the Lynher and St Johns Lake. Thus, the catchment of the upper Tamar Estuary is very much influenced by agriculture and old mines, whilst the lower estuary is subjected to substantial urban/industrial development. Total consented volumes of sewage and trade effluent, discharged either directly into the cSAC or through adjacent estuaries, are estimated at 95,304 and 121m^3 d^{-1}, respectively.

The River Plym, to the east side of Sound complex lies outside the cSAC. Nevertheless it is possible that water/sediment quality issues within the Plym could have a bearing on other parts of the system. Indeed, the two largest (by volume) consented discharges for the area flow into the Plym. The large input of china clay wastes from the Lee Moor area has had a major silting impact in the upper Plym Estuary. Marsh Mills STW is situated at the head of the estuary. A major landfill site (Chelson Meadow) is situated on the east bank, and below the Laira road bridge the shores of the drowned estuary (Cattewater) are used for commercial and leisure marine industries and also for an oil tanker terminal. Plymouth Central CSO is sited here and has generated a significant number of ‘nuisance’ complaints in recent times. The catchment of the Plym is thus very much influenced by urban/industrial development.

The Yealm Estuary has a limited amount of freshwater inflow and the sand bar at the mouth shelters the lower estuary from wave action caused by the prevailing south-westerly winds. Consequently, it is a popular haven for small boats and yachts. A small marine coatings laboratory, established in 1920, has consented discharges and there are three testing rafts along the estuary. With the exception of aggregate extraction at Steer Point brick works, and oyster beds south of Steer Point, there are no other industrial activities on the shores of the Yealm and the only populated banks are those of Newton Creek to the east. The Yealm catchment is therefore primarily agricultural. The mudflats of the inlet support overwintering nationally important greenshank *Tringa nebularia*. There is a seagrass (*Zostera*) bed at Misery Point, with associated fauna including the greater pipefish *Sygnathus acus.* Just to the west of the estuary mouth is Wembury Voluntary Marine Conservation Area.

The range of habitats and communities throughout the cSAC reflect the changing salinity gradient from upper estuarine to open coast, across sediments and bedrock. The biodiversity of the area is also influenced by the warm westerly climate. The Sound supports a relatively rich marine flora and fauna, which includes abundant southern Mediterranean-Atlantic species rarely found in Britain, such as the carpet coral *Hoplangia durotrix*. Also notable are the littoral and sublittoral limestone reefs extensively bored by bivalves *Hiatella arctica* and harbouring a rich fauna. The reef habitats support some unique seabed communities, and include nationally rare species. The Sound, and several of its tributary rivers are important migratory routes used by salmon. In addition, the cSAC is a designated bass and Dover sole nursery area.

Much of the jurisdiction over Plymouth Sound and Estuaries falls to the Royal Navy, and although a primary requirement is to allow for Naval activities and shipping movements, many of its regulations benefit the conservation interests of the site. Similarly the Yealm Estuary is managed by a Harbour Authority, in a manner which aims to help maintain its conservation features. Recently, the Tamar Estuaries Consultative Forum, which encompasses all statutory and byelaw-making bodies, has been formed to respond to, and deliver, the requirements of the Habitats Directive.

Metals have had a well-documented impact on the character of the site, though this is primarily beyond the influence of present-day consents. Mining and smelting of metal ores (principally Cu and As, and to a lesser degree Sn, Zn, Pb, and W) has been evident since at least the thirteenth century, particular around the Gunnislake-Kit Hill mineral complex. Although the majority of this activity ceased at the end of the 19th century, drainage from sulphide loads, adits and spoil heaps still contribute to elevated metal concentrations in waters, sediments and biota, supplementing that released by weathering and erosion. In comparison with these historic sources, current industrial process and STW discharges probably have a low impact in terms of discharge of metals to the site as a whole, though they may increase concentrations locally.

Examples of metal related issues include elevated concentrations in freshwater immediately upstream of the SAC (Tavistock-Gunnislake area). These have posed localised questions over risks for drinking water. Dissolved concentrations are also elevated in the upper part of the tidal Tamar (and in the Tavy and Lynher), occasionally exceeding the EQS. Enrichment occurs as the river flows through the mineralised area between Gunnislake and Calstock which is littered with old mine workings, spoil heaps and adits. Reactivity during estuarine mixing is important in determining the distribution of many metals, though precise behaviour varies according to chemical characteristics. Upon mixing with salt water some removal of river-borne metals, to particles, may take place at low salinities, e.g. in conjunction with Fe removal and oxyhydroxide formation. Further downstream, sediments are periodically stirred into the water column, particularly during spring tides, and the interstitial water released can have a significant impact on the dissolved components in the water column. For a number of metals an extended maxima may occur in mid-estuary.

The bulk of this introduced metal is released on the outgoing tide, at the mouth of the Tamar, where estuary water is considerably diluted with sea water. As a result, concentrations in the Sound are seldom significantly above background. Occasionally, however, in periods of high run-off, low salinity water and entrained suspended solids may extend as a surface plume into Plymouth Sound and beyond, into the English Channel (though here concentrations are unlikely to exceed EQS values). Thus, the behaviour of sediment and contaminant movements in the Tamar Estuary are highly dependant on conditions of tide and river flow, reflecting the common influences of physical mixing processes. In particular the ‘turbidity maximum’, is highly influential in structuring the distributions of many contaminants, including nutrients and some organics, as well as various metals.

As indicated above, sediments across the cSAC reflect the influence of mineralisation. Extraction activities over the years have included granite quarrying, mining of the china clay deposits and peat works, though it is the impact of metal-mining which is of most widespread importance. The distributions of many metals are correlated in sediments (mostly decreasing downstream from the head of the estuaries) and concentrations are a function of grain size and particle mobility. In the Tamar transport processes responsible for these metal distributions may vary seasonally. In summer peak metal concentrations tend to occur (upstream) as a result of tidal pumping, whilst, in winter, profiles may be maintained by occasional influxes of contaminated land-based material. It is likely that localised hotspots occur in the lower reaches of the Tamar (and Plym) as a result of anthropogenic sources (road run-off, atmospheric, industrial and domestic). These should be investigated further.

According to the interim sediment guideline criteria, arsenic concentrations are above PEL (harmful effects to biota might be expected) for much of the Tamar, Tavy and to a lesser extent, the Plym. Zn, Cu and Pb concentrations in sediments throughout the cSAC generally exhibit similar distributions and the latter two elements are above PEL throughout much of the Tamar and Tavy. Hg concentrations suggest some effects are possible here and unusually, the same applies to Hg in sediments of the Yealm Estuary (though the source of this enrichment is unknown). Cadmium distributions are quite different and suggest other anthropogenic sources. Thus, although there is a degree of Cd enrichment in the upper Tamar, highest levels (>PEL) occur in the upper Plym, and probably reflect past industrial discharges, inputs from the Plympton STW and possible run-off from Chelson Meadows disposal site. These sources require further characterisation.

Depth profiles in core samples from the Tamar confirm that increases in metal concentrations (Cu, Zn, Pb) coincided with the onset of peak mining activity in the 19th century and appear to have been maintained to the present day as a result of run-off and leaching. Organisms in the estuary have therefore been exposed for more than a century to these conditions and no doubt have become partially adapted. Monitoring data for metals in species such as *Fucus vesiculosus, Nereis diversicolor, Scrobicularia plana* and *Littorina littorea,* provide useful information on spatial variation in bioavailability around the cSAC. Generally bioaccumulation patterns resemble those in sediments and indicate elevated body burdens in the upper-mid Tamar complex for most metals, whilst Cd bioavailability is highest in the Plym. Biota in the Yealm are relatively uncontaminated, compared to the Plym and Tamar complex, and may act as a regional reference for many metals. Elevated Sn levels in Yealm biota are an exception, however, and probably reflect previous inputs of TBT from local sources.

Very little is known of metal impact at offshore sites in the Sound. Tentative observations of induction of a metallothionein–like protein (a biomarker for metal exposure), in transplanted mussels, suggest that impact increases towards the land, reflecting Tamar sources, but with some anomalies close to the sewage sludge disposal grounds. However these observations, together with bioaccumulation and sediment data, described above, are mostly from the early 1980s and are in need of updating. The use of improved metallothionein assays (and other biomarkers) is recommended to map biological responses more thoroughly and to attempt to apportion the relative biological importance of different sources.

TBT inputs from ships and leisure vessels, situated towards the mouth of the Tamar Estuary, were a dominant feature, and cause for concern, in the late 1980s (when legislation and the introduction of containment processes by the naval base at Devonport were introduced). Since then, TBT levels in water, particularly in the Hamoaze, have decreased substantially. The most ‘recent’ axial profiles (in the early 1990s) tend to resemble those of metals, with TBT maxima (often above the EQS) linked to the turbidity maximum, and distributions presumably determined by internal interactions and particulate transport within the estuary.

In the years immediately after legislation (1987), TBT levels in mussels from the Hamoaze mirrored declining trends exhibited in the water column. In contrast, sediment concentrations in the Tamar Estuary did not change significantly. Simulations made in the early 1990s confirmed that losses of butyltins from the Tamar could be offset by continuing, albeit low-level inputs, which appear to be responsible for maintaining the 'steady-state' condition. The continued presence of TBT in sediments implies a long-term chronic hazard (Tamar sediments for the most part probably come into the lower end of the range where effects from TBT might be expected, though hotspots are likely in the lower estuary). As well as some continuing contribution from legal and illegal usage of TBT in antifouling[9], there has also been the possibility (until recently, at least) of a low-level TBT contribution from trade discharges in the Yealm, Plympton STW, Chelson Meadow disposal site and other discharges to the Plym.

TBT concentrations in Plymouth Sound water also declined markedly following legislation in 1987. Levels in front of Plymouth Hoe declined to around the EQS by 1992. However at a site in Batten Bay levels still regularly exceeded the EQS throughout this period. Furthermore a summary of water monitoring data for the cSAC collected by EA/CEFAS between 1995 and 1999 also places the median value an order of magnitude above the EQS.

Surveillance of imposex in dog-whelk *Nucella lapillus* populations from the cSAC, up to 1993, demonstrated that imposex was still prevalent, and that visibly-unaffected females were still a rarity. The breeding capacity of a partially-sterilised population just outside the Sound, monitored for a number of years, had markedly increased during this time, although significant recolonisation of areas denuded of *N. lapillus* had yet to occur. *Nassarius (=Hinia) reticulatus* is less sensitive to TBT than the dog-whelk *Nucella lapillus* but is a useful alternative at contaminated sites around the Sound where *Nucella* is absent. In the five years following the 1987 TBT restrictions, concentrations in water and tissues at some of the more polluted sites decreased by factors of between 5- and 10-fold. However, the intensity of imposex has declined very slowly due to the longevity of the snails, the limited reversibility of imposex and limited recruitment.

Much of the available data on TBT and it's impact is now ten years old or more and a thorough re-evaluation of the current status of TBT in the cSAC is overdue.

Hydrocarbons have not been widely monitored in the cSAC and most data relate to Tamar sediments. The presence of unresolved complex mixture (UCM), a sign of degraded oil contamination, together with more recent undegraded components, suggests some general chronic contamination in the area which possibly originates from the dockyard and shipping. Total hydrocarbon concentrations in fish from Plymouth Sound and estuaries are elevated in comparison to fish from other UK European marine sites (e.g. Chesil and the Fleet).

PAH concentrations appear to be relatively low in waters of Plymouth Sound and the Tamar Estuary. Some enrichment occurs at the turbidity maximum, in association with suspended solids, with a further concentration maximum localised to the lower, industrialised portion of the estuary (associated with anthropogenic inputs). The principal fate of most high molecular weight PAHs is sediment burial and the distribution pattern of PAHs in benthic sediments of the Tamar

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[9] Potential sources in recent years probably include Cattedown Wharves, Millbay Docks, an assortment of marinas around the cSAC and perhaps a small component from Devonport Dockyard (though most of the TBT from this source is transferred in bowsers to Chelson Meadow disposal site).

generally mirrors that of the waters. Concentrations in riverine sediments are low, attributable to the relatively pristine environment of the catchment area. However, in the upper estuary and turbidity maximum zone, where sedimentation and flocculation processes deposit particulates (usually in the region of Calstock), levels are higher. Toward the sea, concentrations of PAHs decrease, except for the secondary peak associated with the urbanised portion of the estuary (opposite the Dockyard). ISQGs and PELs are often exceeded for individual PAHs, including anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, phenanthrene, naphthalene and pyrene (some concentrations appear to represent an increase since the 1980s). Much lower levels occur in Plymouth Sound and off-shore.

In the Tamar River and upper estuary, away from urban areas, sources of PAHs are considered to be principally atmospheric deposition, although where the river runs close to major roads, polluted run-off is implicated. In the lower reaches of the estuary, close to Plymouth, road run-off may be an important source though in the Hamoaze, other possible localised inputs of PAHs include the oil depot at Torpoint and the dockyards.

EROD activity, which is indicative of exposure to PAHs (and PCBs), was low in eels *Anguilla anguilla* from the upper Tamar in comparison with eels from several other UK estuaries. More extensive information on biomarker-type effects would be useful to confirm the extent of biological responses, along with further investigation into the sources, levels and composition of PAHs and hydrocarbons the cSAC.

Concentrations of a number of pesticides were elevated in some freshwater inputs and close to STWs in the early 1990s. There is broad evidence that the frequency of these high values is decreasing. However, despite the reduction in concentrations of organochlorine (OC) pesticides such as lindane, dieldrin and endrin in environmental waters (generally well below EQS), they continue to be detected in sediment. Unfortunately, for many OC pesticides, detection limits are above sediment guidelines and detailed assessment is not possible. Data are also mostly for the mid 1990's or earlier. Nevertheless, they indicate that levels of lindane (γ-HCH), dieldrin and DDT sometimes exceed ISQGs and PELs. The sources are expected to be mostly agricultural, though elevated concentrations of γ-HCH in the vicinity of STWs confirm the latter to be important if intermittent sources. Trade discharges from the Chelson Meadows disposal site are also implicated as a source of lindane and some other OC pesticides in the Plym. Endrin has been detected above ISQG at the national marine pollution monitoring site, off Plymouth, though the source is unclear. Thus, even though many of these OCs have been banned from use as pesticides in the UK, their persistence in the marine environment, particularly sediments, remains a concern.

There is little recent information on triazines (simazine and atrazine), trifluralin (dinitroaniline), organophosphates (OP) or carbamate herbicides and pesticides, though there are indications that levels could be of significance. Some of the reported concentrations need to be confirmed by quality-assured data. Reduced cholinesterase activity, a specific biomarker for exposure to neurotoxins (particularly OPs and carbamates) has been observed in flounder from the Tamar. The herbicide Irgarol, used as a booster biocide in some antifouling preparations, has also been detected close to marinas in concentrations which might inhibit photosynthetic activity in algae and seagrass, though proof of effects in the environment has not yet emerged.

The phthalate ester di-2-ethylhexyl phthalate (DEHP), a potential endocrine disrupting compound, has been reported at elevated concentrations in the Sound, but implications for biota are not clear. Concentrations of the weakly oestrogenic degradation products of alkylphenol polyethoxylate (APE) surfactants (nonylphenol, octylphenol, nonylphenol monoethoxylate and nonylphenol diethoxylate) do not appear likely to raise cause for concern. To date, feminising effects have not been observed in flounder from the Tamar, however, further studies on endocrine disruption are perhaps a reasonable precaution.

There are few records of levels of PCB contamination in Plymouth Sound and estuaries, though there are indications that concentrations in some sediments may exceed quality guidelines and the probable effect level. Like the majority of organochlorine substances, PCBs are lipophilic, therefore tend to accumulate in the fatty tissues of living organisms, and PCB concentrations in invertebrates and fish from the cSAC are above background, but are not outstanding. Consumption of prey species such as molluscs and polychaetes, or accidental ingestion of sediment by waders feeding on mud-flats, represent as yet unquantified risks.

The radiological significance of current levels of radionuclides discharged into the SAC is reported to be low. However, the published data is not extensive. Discharges of tritium from the Devonport Dockyard are expected to rise in the near future as a result of a recent substantial increase in the consent. Although the biological impact is predicted to be minimal, more data and fundamental studies on tritium behaviour, bioaccumulation and effects on marine biota would be welcome.

Parts of the Plymouth Sound and Estuaries system, notably the upper estuaries, are subject to nutrient enrichment, and temporal trends for nitrogen and phosphorus in tidal waters during the 1990s indicate that nutrient concentrations were increasing across much of the cSAC. Modelling of nutrient budgets has shown that the majority of nutrient inputs to the system are due to diffuse sources such as agricultural run-off, and this proportion is becoming increasingly important, possibly because of changing land use in the catchment areas. However, it has been suggested that direct anthropogenic inputs of ammonia and nitrite prevail in the lower estuary and probably exceed the sum of riverine and upper estuarine sources. Generally, the weight of evidence implies that localised nutrient enrichment, along with chronic nutrient-associated water quality problems, can occur in the vicinity of point source inputs. Nutrient 'hotspots' include inner estuarine sites in the Lynher (Polbathic and the Tiddy), the Tamar (Morwellham and Calstock) and the Yealm (Newton Creek). Unfortunately, there is a lack of up-to-date information regarding the nutrient status of tidal waters.
High levels of nutrients have probably contributed, indirectly, to periodic occurrences of oxygen depletion, which in the past may have been responsible for salmonid deaths in the upper Tamar. The greatest depletion in dissolved oxygen (DO) tends to occur in summer, although annual median DO has fallen below the recommended EQS for sensitive saltwater life at several sites in the Lynher, Plym, Tamar and Yealm during the last decade, indicating more extended oxygen sags.

A further indication of nutrient enrichment is the rapid proliferation of phytoplankton, as reflected in elevated chlorophyll *a* levels. Over recent years, highest levels of chlorophyll *a* have occurred in the uppermost reaches of the Lynher and Tamar estuaries. Here, mean annual values have exceeded the UK 'benchmark' value for suspected eutrophic conditions by an order of magnitude, and extremely high individual values, indicative of bloom conditions, have been recorded during summer months. Again, monitoring appears to have ceased in 1997 at a point when chlorophyll *a* concentrations in tidal waters appeared to be increasing.

The issue of point source inputs has been recognised by SWW, and there is a current programme of upgrading several STWs which discharge into the cSAC and its tributaries, although very few sites which are due to be upgraded under AMP3 will have nutrient reduction. The major drivers are UWWTD, Bathing Waters and Shellfish Waters Directives, the latter two of which are most concerned with microbiological standards. Thus, despite a number of completed improvements to sewage treatment, the most recent data indicates that nutrient concentrations in discharges are still increasing in some cases.

Apart from the small number of observations described above, there have been few rigorous biological-effects studies specifically directed at anthropogenic impacts on designated conservation features (Annex 2) or other indicators of 'health'. Several seagrass beds have been described within the cSAC although the bed in the mouth of the River Yealm is believed to be the most extensive. Shoot density and macrofaunal abundance in this seagrass bed appears to be lower than that observed in seagrass beds elsewhere in the UK. The sparse evidence relating to seagrass beds in the cSAC suggests that they are relatively impoverished or declining, and an ongoing programme to survey, map and monitor the extent and well-being of these important features would seem prudent.

Several fish species found in waters of Plymouth Sound and Estuaries cSAC are of obvious commercial and conservation significance; salmonids and bass are prime candidates. Allis shad *Alosa alosa* is declining throughout its range on the western coasts of Europe and is rare in the UK. Although formerly known to spawn in several British river systems, the only recently confirmed spawning site is in the Tamar Estuary. Population declines in many parts of Europe have been attributed to the effects of pollution, overfishing and river obstructions to migration. No specific studies regarding *A. alosa* in the Tamar are available, although a recent report on the status of shad in the Severn Estuary gives some information on the life cycle and outlines environmental factors which may affect this species.

In terms of bird populations, potentially adverse factors such as changes in water quality and recreational disturbance do not appear to have affected numbers greatly. Long-term observations indicate that the nationally important populations of Avocet (*Recurvirostra avosetta*) were increasing in the Tamar during the latter part of the 20th century, and acute impacts seem unlikely. Sub-lethal responses and bioaccumulation trends are largely unresearched.

The benthic fauna and flora of Plymouth Sound and Estuaries have been the subject of several long-term studies, one of which (intertidal barnacles) spans more than half a century. This work could help to distinguish natural and anthropogenic influences which determine species distribution and abundance within the cSAC, and also biotic and abiotic factors which control the relative proportions of species in relation to temperature and climate. Ultimately, such studies may provide an early warning system for the biological effects of global change in climate, which is relevant to all SACs and marine systems.

Although infaunal communities at some estuarine locations show signs of modification due to anthropogenic activities, biodiversity in the Plymouth Sound and Estuaries cSAC, as a whole, is not overtly impaired, compared with other UK sites. It should be remembered however that the cSAC is fairly unique in its wide range of salinities and variety of interest features (annex 2).

With such a wide range of habitats within its boundaries, biodiversity within the cSAC might be expected to be significantly above average. Bioassays with oyster larvae (up to 1995) suggest there are areas of poor water quality in the cSAC, though no specific compound (or source) has been identified as being responsible. Better-integrated chemical and biological effects-type studies are needed to clarify these anomalies and to establish whether or not areas of the site are degraded.

6.3 THE SEVERN ESTUARY pSAC, SPA

The exceptional tidal range and classic funnel shape make the Severn Estuary unique in Britain and rare world-wide. Large tidal-currents are a dominating feature, reducing vertical stratification (compared with the Fal and Tamar) and providing a mechanism for transport of particles up to sand-size (moving as suspended solids or mobile bed-load). The associated variable frictional stresses result in variations in bed-types (and associated contaminant loadings), despite the constant turbidity of the water. In turn, the relatively sharp divisions between muddy, sandy and rocky areas dominate the distribution of benthic macrofaunal communities. A high proportion of the estuary is subtidal with a diversity of aquatic estuarine communities that includes the only extensive subtidal *Sabellaria alveolata* reef in Britain. The intertidal flats and rock platforms support a variety of invertebrate species. The upper Severn Estuary includes an extensive area of mudflats and sandflats bordered by large fringes of saltmarsh where *Spartina* is abundant, together with a single *Zostera* bed upstream of Newport. Much of the site is underlain by carboniferous limestone, which forms the islands of Steep Holm and Flat Holm as well as headlands along the estuary. These islands, together with Denny Island (SW of the Severn Bridge) and the intertidal mudflats and wetlands of the estuary, provide a haven for wild birds. Nationally- and internationally-important numbers of overwintering and passage migrant waders and wildfowl are supported by these habitats (annex 2).

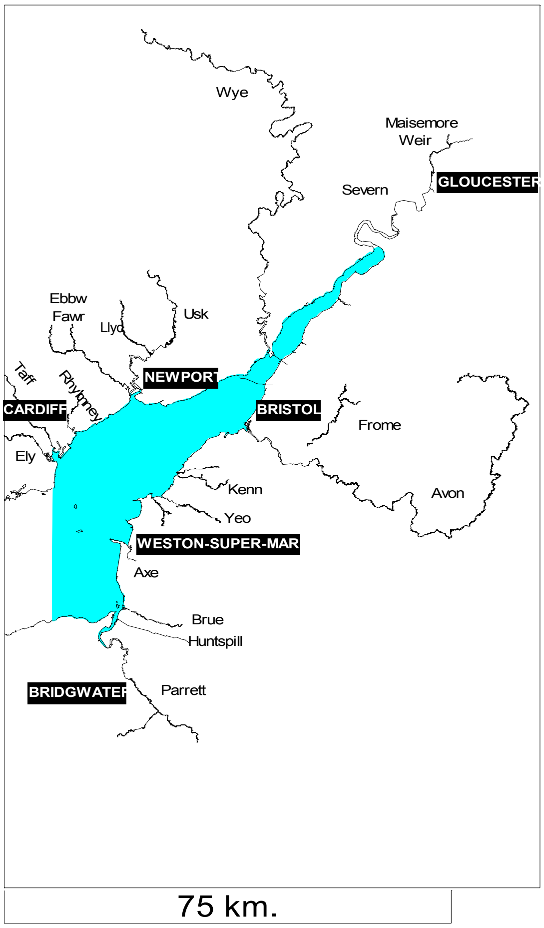

Figure 4: The Severn Estuary pSAC showing boundaries of marine site

The River Severn has a mainly rural catchment with a number of urban centres along its banks. There are other important freshwater sources feeding the estuary, and a variety of man made inputs which include an estimated 800,000 $m^3 d^{-1}$ from sewage and 200,000 $m^3 d^{-1}$ from industrial effluents. On the south-east side of the estuary, catchments include those of the Frome, Pill, Avon, Kenn, Banwell, Yeo, Axe, Brue, Parrett, Tone, Washford, and Donniford Stream. On the opposite bank (mostly in Wales) rivers and streams which flow into the estuary include the Rivers Leadon, Wye, Usk, Ebbw, Rhymney, Taff, Ely, Cadoxton, and the Col huw. On both sides there are also numerous ditches, drainage channels and streams, known locally as rhynes, or reens, which flow into the estuary and drain the Severn Estuary Levels. Many of the rivers are used by elver, eels and salmonids as part of their migratory routes, and some of the rivers (Wye, Usk) are cSACs in their own right.

The major conurbations at Bristol, Bath, Gloucester, Cardiff and Newport account for a significant number of consented trade and domestic discharges. Avonmouth is a centre for large industries including pharmaceutical manufacture, smelting, chemical recoveries, power production (from both gas, and clinical waste and tyres), chemical production and gas works. Industrial centres in south Wales include (or have included until recently) steel works, paper mills, chemical and pharmaceutical manufacturers. Many collieries and steel making sites in south Wales have now ceased production, resulting in predictable improvement to the quality of local rivers such as the Ebbw (n.b. closure of the Corus plant at Ebbw Vale). Corus (formerly BSC) Llanwern also stopped steel and coke production in 2001 and 2002, respectively, resulting in potentially substantial reductions in metals and PAHs, and there have been reduced coking operations at the Corus plant in Port Talbot. Though the latter is seaward of the SAC, tidal flow may still direct a portion of any load towards the Severn marine site.

The majority of remaining industries discharge either directly into the Severn, or into the numerous watercourses that run into the Severn. Sewage from the urban centres add directly to the pollutant load as do domestic and agricultural sources in the large number of tributaries entering the tideway. There are nuclear power plants at Hinkley, Berkeley and Oldbury which may utilise considerable quantities of water for cooling and other purposes.

The list of potential contaminant pressures is therefore substantial and includes metals, organometals, hydrocarbons, nutrients, solvents, mineral acids, biocides, fungicides, flame retardants, PCBs, pesticides and radionuclides. Nevertheless, the decline in heavy industry and introduction of pollution control in the later part of the 20th century has brought about a general downward trend in inputs. Improvements in waste treatment is likely to be an ongoing phenomenon and includes moves towards self-monitoring for major industries under IPC and PPC, notably those at Avonmouth: brief public summaries are available to help point to recent trends in discharges, though easier access to raw data under IPC would be useful for more detailed evaluation of environmental impact.

Metals have traditionally been a major concern in the estuary, because of smelting and other metal industries. The Severn receives the largest Cd input of all UK estuaries, principally from the smelting industry at Severnside (Avonmouth), where for much of the 1990s two of the UKs largest discharges (one sewage and one industrial) were situated. Notable quantities of other metals (Zn, Cu, Hg, As) are also discharged from these and other sources in the area. In terms of overall loadings, Cd, As, Cr and Hg probably originate mainly from industrial sources around the estuary whilst Cu, Zn and Ni are predominantly riverine in origin with additional inputs from trade and sewage discharges. Axial profiles of metals in estuary water reflect the relative importance of these different sources.

There are indications that environmental concentrations of Cd may have decreased in recent years. This broadly agrees with trend data on Parcom loadings estimates. Although inputs of several other metals appear to be declining, consistent long-term changes in environmental concentrations have yet to be established. EQS values are sometimes exceeded in waters of the mid-upper estuary (usually at near-shore stations close to outfalls) and continued surveillance is therefore recommended (notably for Cd, Cr, Cu, Hg and Zn).

Because of the energetic hydrodynamic regime in the Severn, and high turbidity, there is considerable mixing and redistribution of fines and their associated contaminant burden. As a result, sediment metal contamination tends to be dispersed over a large area, resulting in somewhat homogenous distributions, though Cd and Zn still tends to occur in highest concentrations in the Avonmouth area, near the expected anthropogenic sources. Core analyses at relatively undisturbed sites tend to confirm an overall increase in deposition since the middle of the nineteenth century, which signifies the onset of industrialization and anthropogenic inputs. For much of the Severn Estuary, however, it is not possible to reconstruct accurately the history of contamination due to the unstable nature of the surface deposits. There is a limited amount of data which indicates Pb, Cu, Cr, Ni and Zn concentrations in fine sediments may have decreased, slightly, since the 1970s, perhaps due to the contraction of metal industry.

For metals such as As, Cu and Zn, concentrations in Severn sediments pale in comparison to those derived from mining sources (e.g. Restronguet Creek). However, despite the fact that contaminant loadings in the Severn are ‘diluted’ by their widespread distribution, enhancement in fine fractions is observed for a number of metals, relative to ‘baselines’. In fact metals (As, Cd, Cu, Hg, Pb and Zn) in sediments exceed sediment quality guidelines (ISQG) widely throughout the Severn, though exceedences of probable effects levels (PEL) are rare (Zn and Pb). Unfortunately, sediment analyses are mainly from the 1980s and may not be representative of current status. It would seem important, therefore, to provide a more up-to-date appraisal of trends in sediment contamination and also, perhaps, to assess the relative significance of anthropogenic and geogenic components (for example, by comparing ‘elemental fingerprints’ in estuarine samples with sediments from appropriate catchments upstream of anthropogenic sources).

Bioindicator studies with organisms such as worms and clams have demonstrated significant bioaccumulation of metals, especially at upstream sites in the Severn and sub-estuaries. Bioavailability of ‘pollutant’ metals such as silver, cadmium and mercury tends to be most pronounced, reflecting their predominantly anthropogenic origin. Regionally, shellfish contain some of the highest concentrations of Cd (and Zn) in the UK. Thus in recent CEFAS monitoring surveys, Cd levels in mussels were in the ‘upper’ range of OSPAR Cd guideline values, whilst Hg burdens were in the ‘medium’ category. Oysters from Porthcawl, slightly seaward of the pSAC, were one of only two samples in the UK in 1997 which did meet the proposed EC food standard for Cd: smelting operations at Avonmouth, steelworks at Newport and the power station at Aberthaw were put forward as contributory sources.

In the past, elevated body burdens in invertebrate species have been shown to be reflected in residues in organisms from higher trophic levels, near industrial centres of the Severn.

Comparisons between fish species show marked differences in metal accumulation which appear to be related to the diet. Zinc concentrations in flounder were notably higher than most other species sampled which may be due to assimilation from Zn accumulators such as clams (in adult fish) or shrimps (juveniles). Cd levels were highest in the sea 'snail' *Liparis liparis* which feeds mainly on shrimp. Lowest concentrations were those in lamprey, which may reflect comparatively low levels in the muscle and blood of the teleost hosts on which they feed.

More work needs to be done to establish the physiological and ecological significance of body burdens in Severn Estuary biota and to ascertain the extent of temporal improvements. Some of the sub-lethal indicators described in Annex 5 may provide sensitive measures for quantifying effects and may also give indications as to which elements are most responsible for impact. Metals currently perceived as being important, toxicologically, are Cd, Cu , Zn, As, Hg and Ag.

Remarkably, there are scarcely any published records of organotin in water, sediment or biota from the pSAC. *Nucella lapillus* is not a widespread resident of the Severn Estuary and therefore its use in monitoring has been restricted to rocky shores further west. Of the limited number of TBT observations in the EA database (mainly for south Wales) the majority in tidal waters are close to detection limits (often close to or above the EQS), therefore it is not possible to establish distribution patterns or threats accurately. The TBT standard of 2ng l^{-1} was exceeded by almost 40-fold downstream of the old Cardiff east outfall and at the transporter bridge on the Usk, and by 10-fold downstream of the St Regis outfall (near the western end of the new Severn road bridge), implying some significant inputs via STW and trade discharges. The incidence of high values may be declining in some discharges; however, since organotin compounds can arise from various land-based sources (including PVC manufacture, agriculture, fungicides, wood preservatives), in addition to shipping, the distribution and impact of butyl and phenyltins may require further assessment. Analysis of dredge spoils in and around the pSAC suggest there may be localised reservoirs of TBT near major conurbations such as Newport and Cardiff, and presumably elsewhere. Processes including physical resuspension and bioturbation could remobilise these sinks. Furthermore, TBT in contaminated sediments is likely to be available and potentially harmful to deposit-feeders and infauna, and thence to higher organisms.

A number of hydrocarbon compounds, including PAHs, are present, locally, in elevated concentrations. Sources include a combination of fossil fuel combustion, shipping, urban run-off, STW and various point-source and diffuse discharges from industrialised areas (e.g. drains near Lydney Industrial Estate and Kingsweston Rhyne). Coal bearing strata of south Wales (and associated, historic, mining activity), together with the oil bearing shales exposed on the southern coast of the estuary (Bridgwater Bay) also make a contribution to PAHs in the Severn system. The relative significance of sources is difficult to quantify and may vary in different areas, though the principal component appears to be anthropogenic. In the Aust, Sharpness and Arlingham region, PAH composition has been variously attributed to land run-off, precipitation of airborne particulates derived from combustion products, and high coal dust content. In Bridgwater Bay two major sources were identified - pyrogenic (fossil fuels) and petrogenic. A significant unresolved mixture (UCM), indicative of degraded or chronic oil contamination, has been observed in sediments from several sites. At some locations these exceed the pyrogenic (PAH) component, implying localized oil contamination. Periodically, high hydrocarbon concentrations have been observed in several industrial discharges.

There are few reports relating to PAHs in waters of the Severn Estuary. Elevated levels have, in the recent past, been a feature at Lydney and Purton (paper mill and STW effluents): these may now be declining. At Nash Point (to the west of Cardiff and just outside the pSAC), levels in 1993/4 were measurable but low in comparison to industrialised hotspots. Higher concentrations were detected at Aberavon Beach near the Port Talbot steelworks, which is further west along the Bristol Channel. Offshore in the Celtic Deep, PAHs were undetectable.

High molecular weight homologues appear to be the dominant PAHs in the Severn and are readily adsorbed onto particulates and incorporated in benthic sediments. Moderately high levels of total PAHs are a feature of the extensive populations of fines within the estuary, but decrease outside the Bristol Channel. For a number of individual PAHs, concentrations exceed ISQG guidelines and occasionally PEL criteria. Concentrations of PAHs reported in some Severn sediments might, therefore, contribute to the increased levels of detoxifying enzymes, including ethoxyresorufin-O-deethylase (EROD), seen in eels and flounder. Bile metabolites of PAHs have been identified in these fish, notably in eels. Since sediments contain much higher PAH concentrations than water, species like eels, which spend much of their time buried in mud could be particularly susceptible to PAH exposure. Similarly, larval lamprey (one of the organisms for which the site was selected as a pSAC) burrow in sediments, feeding on diatoms (accumulators of hydrocarbons) and other micro-organisms. The duration of the larval life of lampreys represents an extended period (several years) for possible exposure, both from feeding and, directly, from sediments. Since PAH accumulation is evident in other taxa, including molluscs, biological responses should be investigated further (in relation to the bioavailability of these compounds in sediments).

In the past, several pesticides and herbicides have exceeded EQS in rivers entering the Severn Estuary. In 1994, for example, these included diazinon, dichlorvos, PCSD and dieldrin. In the previous two years, high levels of atrazine and simazine were also found in the Rivers Severn and Taff. Many of these pesticides have now been banned, or usage restricted, and it would appear that currently, exceedences in the Severn Estuary occur rarely, if at all. However, there is very little robust data with which to characterise the threats to the European marine site from the majority of these compounds. If such threats do occur, these would be expected to be localised issues. Only occasionally are elevated levels indicated by the EA data set (e.g. DDT, dieldrin and endrin in sediments; DDT, lindane and dieldrin in eels; dieldrin, triazines and endosulphan in water). Rivers probably introduce the largest loadings (particularly those from catchment areas with intensive agriculture) but there are indications from the EA data that high pesticide concentrations sometimes occur in discharges.

PCB contamination is related to past industrial production (at Newport on the Usk) together with more general anthropogenic usage and disposal patterns. Marine sediments are categorized as being 'heavily contaminated' close to river mouths and docks in the Severn Estuary/Bristol Channel, 'contaminated' at offshore sites in the Severn Estuary and Swansea Bay, and 'slightly contaminated' in the centre of the Bristol Channel. PCBs in eel tissue are highest in the lower reaches of industrialised catchments in south Wales and might contribute towards the increased levels of EROD, described above. Although other fish from Cardigan Bay and the Severn Estuary do not appear to be seriously contaminated with PCBs, high concentrations have been found in marine mammals from these locations. More information on distributions and sub-lethal effects (including the possibility of endocrine disruption) is needed for PCBs and selected pesticides in the Severn Estuary, in order to improve our understanding of their significance in the system.

Anomalously high concentrations of organically-bound tritium in sediments and benthic biota in the Cardiff area of the Severn Estuary have been attributed, primarily, to an industrial discharge. Remedial action has been initiated at source to reduce future discharges and the introduction of a new Welsh Water STW in 2002 should retain particle-entrained tritium along with the sludge, so that any discharge to the estuary is as tritiated water. An application for a revised discharge has been made. Whilst not considered to be a direct threat to humans, the bioavailability, assimilation pathways and genotoxic impact of organically-bound tritium on marine life require further investigation. There is no evidence to indicate that other sources of radioactivity are a cause for concern in the pSAC at the present time.

Concentrations of nutrients (nitrate and phosphate) are very high in waters of the Severn Estuary compared to levels in other marine sites. Estimates suggest that the greatest proportion of inorganic nitrogen (TIN) in the estuary comes from rivers and streams (mainly diffuse sources), and ammoniacal nitrogen from sewage discharges. Freshwater sources are also considered to contribute substantial inputs of orthophosphate to the estuary, although industrial effluent and domestic sewage comprise the greater proportion.

Elevated nutrient concentrations alone do not signify eutrophication and must be considered alongside chlorophyll-*a* measurements and dissolved oxygen status (as indicators of primary productivity). This is illustrated perfectly by the situation in the Severn Estuary, where the exceptionally high levels of nutrients might be expected to result in widespread algal proliferation. However, the lack of light resulting from large suspended sediment loadings limits algal growth in the main channel, off-setting the impact of nutrient enrichment. Eutrophication is therefore not a major issue across the pSAC as a whole. Nevertheless, there is evidence of localized nutrient enrichment, coinciding geographically with areas where suspended solids are high and DO is low (Avon, East-Severn[10], Parrett). Indications are that point source inputs contribute significantly to this problem, either directly through discharges to tidal waters, or, indirectly, through discharges to contributing rivers and streams. Nitrate and phosphate concentrations in waters from the Avon catchment are consistently high, and presumably contribute significantly to the observed elevated nutrient levels in adjacent tidal waters. The lower Bristol Avon was designated as a Sensitive Area (Eutrophic) in 1998 under the provisions of the UWWTD and nine qualifying STWs were identified and required to install nutrient stripping treatments by 2004. Subsequent monitoring has continued to provide evidence of eutrophication in the Lower Avon and has identified four additional qualifying STWs which compromise the ecology of the river and are in need of similar treatment. Trade discharges, notably at Avonmouth (fertilizer plants and other industries), also constitute a significant localised source of nutrient enrichment, particularly nitrogen (nitrate and ammonia).

Intermittent oxygen sags occur in low salinity regions of the Severn, in the Wye and Parrett estuaries and in some of the principal rivers feeding the estuary (Usk, Ebbw). In tidal waters, these probably originate from the high densities of suspendable solids and associated particulate organic matter, perhaps enhanced by discharge outfalls. In the outer estuary, the larger volume of receiving waters contains sufficient DO to fulfil the high Biological Oxygen Demand (BOD) associated with discharges. However in the more restricted upper 20km of the estuary, oxygen levels are more readily depleted. In rivers, effluent discharges are also likely to create high BOD on localised stretches.

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[10] 'East-Severn' corresponds broadly to the coastal strip on the English Bank between Clevedon and Severn Beach, encompassing Avonmouth.

Despite its proposed designation as an SAC, the Severn as a whole supports a relatively impoverished fauna and flora, generally characterised by somewhat low biodiversity. The very high turbidity impacts on biota in a number of ways. High suspended solids loadings limit light penetration and hence algal productivity, but at the same time provide abundant surface area for microbial process. As a result organic carbon may be enriched, and BOD levels high, in fluid muds. These can disperse at spring tides to produce DO sags in the upper estuary, as discussed above. In areas frequently covered by turbid layers, colonisation by filter-feeders, in particular, is likely to be sparse. Much of the sub-tidal Severn mud is impoverished and even some sandy areas may be depleted because of extreme mobility of silts at spring tides: as a result productive areas are restricted to the more stable marginal zones[11]. The fate of the large quantity of sediment that is resuspended and recirculated on each tide will clearly play a major role in the mobility, bioavailability and impact of associated contaminants. However, because physical conditions dominate, and communities are modified as a result, it is often difficult to gauge any additional impact which may be due to contaminants, using traditional ecological survey methods, except close to major discharges.

Populations of several invertebrate species appear to be dominated by smaller individuals in the Severn than in other SW estuaries, suggesting a shorter life-span, although it is not clear whether is attributable to the harsh environmental regime of the estuary or other factors.

The density and size of eelgrass *Zostera,* which occurs in only one area of the Severn Estuary between Magor and Caldicott, was affected by additional sedimentation arising from the construction of the nearby second Severn crossing in the early 1990s. Invertebrate populations associated with the *Zostera* may also have been affected by extreme episodes of erosion and deposition of sediment. Sediment accretion is, however, only one of a number of parameters (including metals, herbicides and indirect effects of nutrients) which may contribute to a decline in *Zostera* beds, although in the Severn Estuary, it is probably the single most important factor.

Temporal trends in loadings estimates, concentration data and EQS compliance frequencies suggests continuing improvements in water quality for some of the major contaminants (e.g. Cd, Cu and Zn). The balance of evidence indicates that these may coincide with small biological improvements (e.g. at the Severnside industrial site, Avonmouth), though, for the reasons described above relating to the dominating influence of turbidity, the extent to which these events are linked remains uncertain. In view of recent advances in biological effects monitoring, it may be timely to consider more definitive assessment of major discharges, using some of the sub-lethal indicators described in Annex 5. The persistence and behaviour of sediment-bound contaminants, and their potential combined effects, gives rise to uncertainty about the prognosis recovery.

Thus, although the long-term trend in fish surveys (samples from power station intake screens) suggests increasing species richness, and a shift to warmer-water species, populations of, for example, eel and Twaite shad (both vulnerable to sediment bound contamination, particularly as larval and juvenile stages) are purported to be in decline - contrary to the general perception of

[11] It is interesting to note that by reducing turbidity a future Severn Barrage, if constructed, would theoretically increase primary productivity and the diversity of bottom fauna)

recovery[12]. It has been suggested that numbers of the common eel (*Anguilla anguilla*) may continue to decline without vigorous conservation effort. Concerns have been expressed that the environmental quality of the estuary could affect the passage and survival of migratory fish, particularly shad, which are thought to have been lost from several rivers. Both Twaite shad (which spawns in the Wye, Usk and Severn), and the eel, may be vulnerable to sediment contamination either directly, or via their diet of benthic invertebrates and fish. A further concern is that the sensitive olfactory responses of anadromous fish could be disturbed by metals and other contaminants. Severn eels undoubtedly accumulate these contaminants, though relationships between tissue burdens and sub-lethal effects have not been studied extensively; there is no information on levels or effects of contamination in shad. Until further evidence is produced, causes of declining migratory fish remain speculative - whether they be related to water quality or other factors within, or even outside, the pSAC (e.g. fishing pressures, natural variability of stocks).

Trends in bird numbers over recent years signify declines in 12 out of 16 designated species evaluated, including all five species for which the Severn Estuary SPA is internationally important (Shelduck, Pintail, Dunlin, Curlew and Redshank). There appears to be a strong case for investigation into causes, as recommended by the British Trust for Ornithology. Priorities for consideration should include industrial pollution, since concentrations of certain metals (Ag, Cd, Hg) and organic contaminants are relatively high in some Severn invertebrates; food chain biomagnification could provide an important exposure route for birds (and other predators). Recreational disturbance, habitat loss, dredging and erosion are other factors to be considered.

[12] Numbers of pout, hake, poor cod, thornback ray, plaice and sea snail are also reported to be declining in the Severn

6.4 POOLE HARBOUR SPA

The Harbour occupies a shallow depression towards the south-western extremity of the Hampshire Basin, which has flooded over the last 5,000 years as a result of rising sea levels. The area was formerly the upper course of the Solent River, a major Pleistocene drainage system. Extensive erosion of the underlying tertiary formations (Eocene sands) has resulted in the present shape of the Harbour. The geology of the catchment is dominated by these deltaic sands and seams of clay of the Bagshot Beds.

The Harbour is a bar-built estuary of nearly 4,000ha.with an unusual double-high water, micro-tidal regime. The tidal range (mean springs) is only of the order of 1.7m. Most of the Harbour is shallow with depths varying between 0.5m below and 2.5m above chart datum. This increases to 10m below chart datum near the Harbour mouth at Sandbanks. The North Channel and middle ship channel are regularly dredged. The narrow opening to Poole Bay means that a significant body of water may be retained throughout the tidal cycle giving the Harbour its lagoon-like characteristics with relatively low tidal energy. Holes Bay, the largest secondary embayment also has a narrow entrance, reducing mixing still-further. The sheltered nature and reduced currents, particularly in the upper part of Holes Bay, encourage siltation.

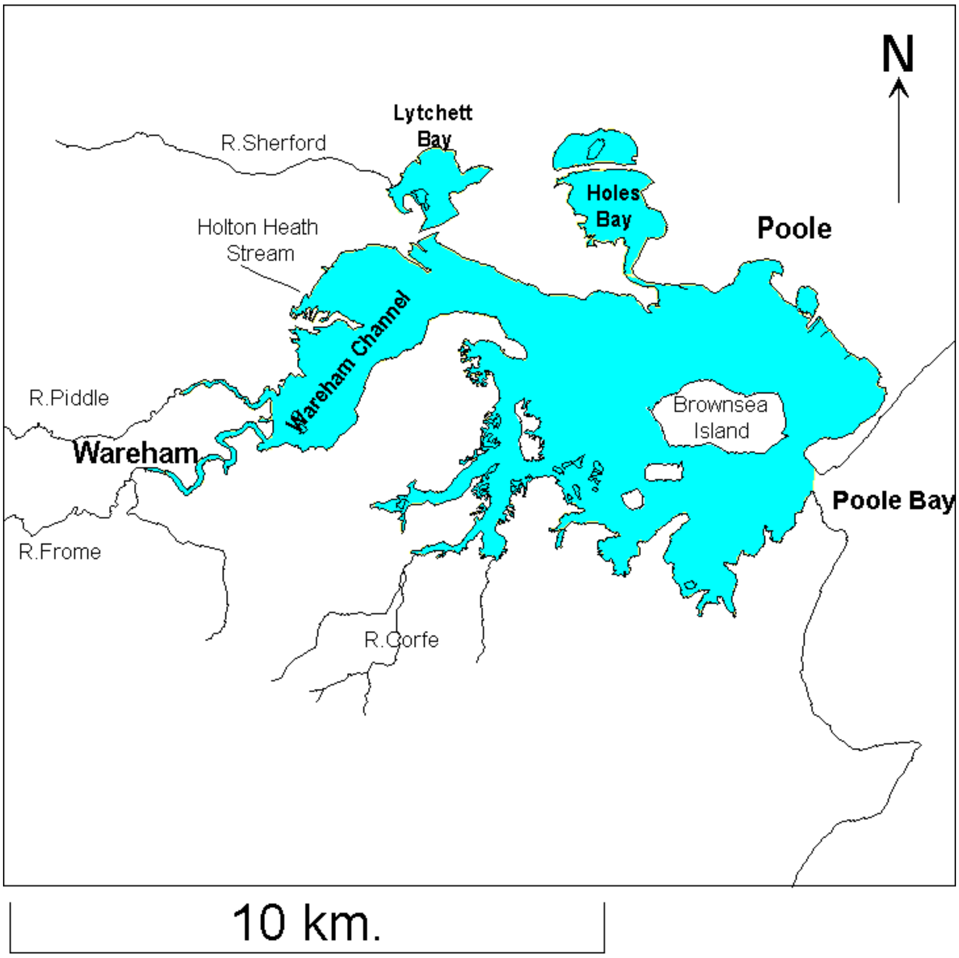

Figure 5: Poole Harbour SPA showing boundaries of marine site

Poole Harbour is one of a number of natural saline lagoons in England and Wales, but it's importance lies in the fact that it occupies 75% of the total area represented by this type of habitat. The boundaries of the European marine site, which essentially incorporates the entire marine component of the Poole Harbour SPA, does not include a substantial subtidal component: some 80% of it's area is composed of inter-tidal fine-grained muds, sands and salt marshes.

The extensive intertidal mud-flats extend widely throughout most of marine site, though the predominant areas of saltmarsh and reed-bed are to the south and west. Intertidal flats are comprised of two major habitat types; firstly fine silts and clays (usually in sheltered embayments and creeks) and, secondly, sediments with a wider range of grain size (subjected to greater wave action and tidal currents). As there is virtually no natural hard substrate apart from rocky outcrops on the islands and mainland promontories, diversity is somewhat limited and dominated by Annelida and, occasionally, other detritivores such as *Abra tenuis* or the crustacea *Corophium volutator*. However, nationally important aquatic species are present and include the peacock worm *Sabella pavonina* and the sponge *Suberites massa,* whilst regionally important species include two bryozoans *Anguinella palmata* and *Farella repens*. The northern shoreline to the east of Lytchett Bay is urbanised, with man-made structures such as piers and sea walls offering additional 'hard-substrate' habitats.

There are two major freshwater sources to Poole Harbour, the Rivers Frome and Piddle, together with a smaller number of tributaries. These river valleys support grazing marsh that contributes to the importance of the SPA for wintering birds. Migratory salmon and trout spawn in both the Frome and the Piddle, and both species have been recorded in tidal reaches of the Sherford. Bass are also found in the tidal reaches of all three rivers. Low flows on the Piddle (potentially harmful to wildlife and amenity) are caused by abstraction of groundwater by Wessex Water. In response, a statement of intent to restore acceptable flows by March 2003 has been agreed by the Environment Agency, OFWAT, English Nature and Wessex Water.

The catchment of Poole Harbour is predominantly rural but experiences some urban influences at Dorchester and downstream at Wareham. The town of Poole and suburbs of Bournemouth, which border the north east of the Harbour, provide potentially more direct sources of urban and industrial impact. The pressures of urbanisation in Poole have resulted in some loss of intertidal estuarine habitat in recent years. In particular, Holes Bay has undergone a degree of infilling to accommodate industrial developments, trunk road construction in the east and marina expansion. Physical loss of habitat through development would reduce both availability of roosting habitats and food-supply. Noise and disturbance are inevitable in such a populated area and have obvious additional impact on roosting, feeding and nesting birds. Physical consequences may also arise, intermittently, through siltation and dredging (estimated to amount to some 70,000 m^3 y^{-1}). Associated high turbidity could affect invertebrates, fish and algal productivity, and theoretically could reduce visibility of prey items to birds such as the common tern. There is also the possibility of transient re-release of contaminants during dredging.

A number of trade and sewage discharges, of varying sizes, impinge on water quality in the marine site. Consented sewage discharges (which may contain some trade wastes) amount to more than 100,000 m^3d^{-1} for the SPA as a whole (not including inputs upstream of the tidal limits). One of the most significant and sensitive discharges arises from the STW at Poole. This partly arises because of the enclosed and sheltered nature of the receiving environment in the north east corner of Holes Bay. On a number of occasions in recent years the sewage effluent discharging into the Fleetsbridge Channel, a tributary of Holes Bay, has exceeded its ammonia limit by over 20 per cent. Wessex Water identified the need for improvements at the works in May 2001 and these were completed in November of that year. Light industries discharge to this plant. Until recently, direct discharges into Holes Bay included the Merck chemical plant (stopped in 1998), and electroplating works. Other major STW discharges are at Wareham and Lytchett Minster. Specific trade discharges include discharges from Wytch Farm oilfield.

Poole Harbour is a designated shellfish area. As of September 2001, waters throughout the Harbour (except the Wareham Channel) were designated as class B bivalve production areas for Pacific and native oysters, manila clams, mussels and cockles; Wareham Channel has a class C designation for clams. In addition, for native oysters, Poole Bay is a class B production area and South Deep, within the Harbour is a designated relaying area. Improvements to treatment of wastes under the Urban Waste Water Treatment (UWWT), Shellfish and Bathing Water Directives are on-going. Between 7 and 9 storm overflows to Poole Harbour have received attention between 2001/2. Water company improvements anticipated in the near future include addition of UV disinfection to the secondary treatment at Poole, Wareham and Lytchett Minster Sewage Treatment Works by 2003. The storm tanks at these works are also due for improvement. A storm overflow in Upton is due for improvement by April 2003.

Poole Harbour is one of the world's largest natural harbours attracting a large number of leisure vessels which are provided for by a number of marinas and boatyards along the northern shoreline. There is an active fishing fleet - particularly for shellfish, crabs and lobsters. Some 60 acres are devoted to commercial Port operations. These marine activities inevitably impact on the site in terms of disturbance and diffuse pollution e.g. from antifouling paints, sacrificial anodes and oil.

Diffuse pollution from agricultural land run-off is also seen as an important issue in the South Wessex Area. Intensive agricultural practices can increase soil erosion. Resultant run-off from eroded land can lead to water quality problems (siltation, eutrophication, pesticide residues and River Quality Objectives compliance issues). Farm animal waste and fuel oil storage facilities are also a potentially significant source of pollution to rivers feeding the Poole Harbour SPA.

Thus, the enclosed nature of Poole Harbour and its secondary embayments make it vulnerable to the effects of a wide assortment of chemical contamination (metals, TBT and other antifouling agents, hydrocarbons, nutrients, volatile organics, herbicides and pesticides) introduced to the system through accidental spillage, rivers, urban and agricultural run-off and point-source discharges.

Metals have historically been a concern, particularly in Holes Bay. Trade discharges (now ceased) and STW have led to concentrations in sediments which exceed sediment quality guidelines widely, but most consistently in the upper, eastern part of Holes Bay. The metals most likely to be of significance in terms of bioaccumulation and toxicity are Cd, Hg, Ag, Cu, Zn and Se, and juvenile bivalves are amongst the most sensitive groups. The extent of ecological impact due to metal contamination is largely unknown, however, and it seems likely that a combination of features (organic enrichment and anoxic conditions in sediments of the inner bay, large salinity variations, and a cocktail of contaminants including metals) are of significance in modifying communities in the Bay. Deployment of specific sub-lethal indicators may be useful in future to provide more sensitive and selective measures of biological response.

Current chemical compliance monitoring of tidal waters is restricted to the outer Harbour, where water quality generally conforms to statutory limits. Nevertheless, Zn levels in water (and seaweed) from the Lake Pier area appear to be anomalously high and may reflect additional sources from antifouling and sacrificial anodes.

In the late 1980s TBT was present in high concentrations in parts of Poole Harbour, particularly in marinas and secondary embayments along the northern shoreline. As a result, molluscs were affected at some sites. Since legislation in 1987 there has been a significant reduction in TBT levels in water, but a more gradual decline in sediment concentrations. The prognosis for the recovery of mollusc populations in parts of Poole Harbour might be expected to be slow in view of the persistence of TBT in sediments, though there are preliminary indications of improvement. Nevertheless, there may still be substantial reservoirs of TBT in sediments, albeit localised to areas near marinas and boatyards in the north, which should raise caution - particularly if they are to be dredged. Processes including physical resuspension and bioturbation could remobilise these sinks. Furthermore, TBT in such contaminated sediments is likely to be available and potentially harmful to deposit-feeders and other infauna.

The classic TBT indicator *Nucella lapillus* is not a native of Poole Harbour (unsuitable substrates and other physical and chemical constraints), though imposex has been observed in dog-whelks from nearby Swanage. Closer to Poole (Studland), there are indications that the species may have been eliminated by TBT in the late 1980s. It is not known whether TBT concentrations have returned to no-effects levels and re-survey of the area is recommended. The effects of other endocrine disruptors have not been studied at the site and should, perhaps, also be addressed.

Hydrocarbons and PAHs are probably at safe levels in water but, locally, may contribute towards reduced water quality. Hydrocarbon levels in sediments sampled prior to the commissioning of the Wytch Farm site were moderate and 'fingerprints' were consistent with long-term, low-level exposure to weathered petroleum contamination (probably from boating, shipping and sewage). PAHs are present in some sediments (in Holes Bay at least) at concentrations which, though by no means extreme, are of potential biological relevance. The source of PAHs may include airborne particulates derived from combustion products (close to the former site of Poole power station), urban run-off, various trade and domestic inputs, and marina activity. Acute toxicity seems unlikely, though further work is needed to assess the extent of their biological significance in terms of contributions towards sub-lethal effects.

Many sediment-dwelling organisms are essential food items for the important bird species and assemblages for which the site was designated. The threat posed by bioaccumulation and food chain transfer of, for example, PAHs, PCBs and metals, needs to be quantified and requires a much more extensive data set. The same is true of many pesticides and herbicides: although limited sampling in major rivers and the outer harbour suggests that toxicological impact is probably small, or transient, there is very little accurate information to assess the most-likely affected areas of the site, such as Holes Bay, where there are small inputs of, for example, γ-HCH.

Much of the marine site, notably the North Harbour and secondary embayments, is subject to eutrophication. Nutrient-associated water quality problems have been recorded for several decades and include macroalgal, and to a lesser extent, microalgal blooms and periodic oxygen sags. These manifestations have been implicated in shellfish mortalities and occurrence of ASP and DSP toxins in shellfish (leading to shellfishery closures twice in 2000 and near collapse of the local industry). There has been a significant increase in the intertidal area of Holes Bay covered by macroalgae (*Enteromorpha* and *Ulva*) since 1995.

Zostera beds are reported to have once been widespread in Poole Harbour, but by 1980 appeared to be confined to the East side of Saltern Pier, in the main channel. There is no direct evidence as to the cause of this disappearance, although macro-algal blooms are implicated (a thick blanket of *Enteromorpha*, such as that occurring in Poole Harbour is considered to have eradicated *Zostera* in Langstone Harbour further along the south coast, for example). Other ecological impacts of macroalgal blooms include exclusion of surface deposit feeders and reduced abundance of invertebrate prey for fish and shore birds.

Modelling exercises have shown that the Rivers Frome and Piddle, and Poole STW constitute the greatest nutrient loads to Poole Harbour. The highest sampled levels of orthophosphate, nitrate and ammonia in tidal waters occur in the north of the Harbour (Wareham Channel and Poole Bridge – at the mouth of Holes Bay). Significant nutrient inputs to the system are due to diffuse sources (agricultural run-off), although sewage discharges constitute an important additional loading, especially for phosphate, and result in chronic contamination of the affected areas. It is apparent that high levels of nutrients from Poole STW impact upon the North of the Harbour, although there is no information available on nutrient levels in Holes Bay itself.

Poole Harbour is regarded as being hypernutrified throughout, and the problem has lead to the designation of Poole Harbour as a Sensitive Area (Eutrophic) & "Polluted Waters" (Eutrophic) and its catchment area a Nutrient Vulnerable Zone (NVZ), which, it is hoped, will herald long-recommended reductions in nutrient loadings from both point- and diffuse-sources. Measures to improve the situation are due to be instigated under Wessex Water's AMP 4 plans, scheduled for 2005 – 2010.

Enhanced algal activity can have a considerable influence on DO, artificially boosting levels during the hours of daylight and resulting in O_2 supersaturation of the water column, whilst at night severe depletion of DO (to almost 0%) can occur due to respiration. During bloom die-offs (macro- and micro-algae) microbial decomposition of algal cells may also lead to acute DO depletion. These fluctuations can cause problems for fish and invertebrate communities. Low levels of DO have been suspected of being a contributory factor in sporadic salmon mortalities in the past. Parts of Poole Harbour may be especially vulnerable to oxygen depletion, in particular the secondary embayments of Holes Bay and Blue Lagoon, where nutrient levels are high.

Effects of nutrient enrichment on individual species in the Harbour are thus likely to be indirect, but are largely unresearched. However, in view of the conservation importance of the Harbour, any increase in nutrients should be avoided and changes to consents (quantities and location) should be considered carefully to avoid the risk of further enrichment. Reductions in the nutrient content of discharges appear to be long overdue. There are important lessons to be learned from Poole Harbour regarding the siting of outfalls as, clearly, the enclosed nature and restricted flushing characteristics of the Harbour (in particular Holes Bay) exacerbate hypernutrification and subsequent eutrophication.

It is evident from accounts of the flora and fauna in Poole Harbour, and from various diversity indices, that biodiversity is relatively low in comparison with other UK estuaries and coastal sites. This may be due, partly, to the restricted range of habitats in the Harbour and, partly, to ongoing problems of hypernutrification and contamination. Holes Bay, in particular, is impoverished in terms of diversity and density of organisms which is probably a result of the hydrodynamics (restricted flushing), combined with the effects of discharges, which render the Bay eutrophic and encourage deposition and retention of contaminants in sediments. Many inter-tidal areas in Poole Harbour are characterised by a poor fauna with dominance of certain species (notably cirratulid or capitellid polychaetes and oligochaetes) which is indicative of contaminated sediments. Oyster embryo assays, using surface water samples have indicated that water quality of the SPA appeared to be relatively good towards the seaward boundary, with gradual deterioration in 'biological condition' landwards and inside Holes Bay. The failure rate in the oyster larvae development may have been due to a combination of contaminants rather than any single compound.

Non-native species feature high on lists of common epibenthic species, notably slipper limpet *Crepidula fornicata*, tunicate *Styela clava* and 'jap weed' *Sargassum muticum*. Saltmarsh areas are dominated by the cord-grass *Spartina anglica*, a hybrid resulting from a cross between an introduced and a native species. However, *Spartina* marsh is currently declining within the Harbour and consequently saltmarshes are undergoing considerable change.

The mudflats and salt marshes in and around Poole Harbour are of great ecological value for feeding and roosting birds and constitute an important breeding site for terns and gulls, hence its designation as an SPA (see annex 2). Over winter, the area regularly supports around 30,000 individual waterfowl. Despite some short- and medium-term fluctuations, there is no consistent evidence for long-term decline in any of the 12 species evaluated in the Harbour as part of The British Trust for Ornithology's recent review of bird numbers in SPAs. Indeed, Avocet (a species of national importance) have become more numerous during the last 15 years. On the basis of these bird counts BTO concluded that possible adverse factors were not sufficiently important to trigger further investigations. However, as yet, there is no detailed information on contaminant levels or sub-lethal effects in birds from the site.

Similarly, the potential significance of body burdens in fish has yet to be evaluated. Since numbers of the eel (*Anguilla anguilla)* are declining in Poole Harbour and several of its tributary rivers, including the Frome and Piddle, it may important to address the issue - if only to eliminate contaminants as a cause. At present this species is still subject to a fishery.

In summary, despite its high conservation value, the threats to the biota of Poole Harbour from contaminants and other anthropogenic stressors are not insignificant. Consents concerns focus on Holes Bay and are dominated by inputs from Poole STW, though diffuse sources, notably sediments, probably contribute to the wider impact on biota. Dredging activities and other disturbance will inevitably remobilise and redistribute some of this loading. The persistence and behaviour of sediment-bound contaminants, and their potential combined effects, require further, more rigorous characterisation.

6.5 THE EXE ESTUARY SPA

The Exe Estuary opens into the western side of Lyme Bay and was formed through the drowning of the lower Exe River valley, during the post-glacial rise in sea level. The tidal estuary now occupies a basin of about 15km long and 1-2km wide, and is situated in Permian deposits (Dawlish Sandstones, Exe and Langstone Breccias, and Exmouth Mudstones).

An unusual feature of the estuary is a double spit across its mouth: the dunes of Dawlish Warren, and Pole Sand (an area of shoaling sediment) on the western side restrict sea access to a long narrow channel, resulting in very strong tidal currents in this area, particularly on the ebb tide. The mean tidal range at Exmouth is 3.8m for spring tides, and 1.5m for neaps. There is a similar range at Topsham, diminishing to 1m at the Countess Wear Road Bridge, near the head of the estuary (usually taken to be St James Weir). Estimated residence time for water within the estuary is 6 days.

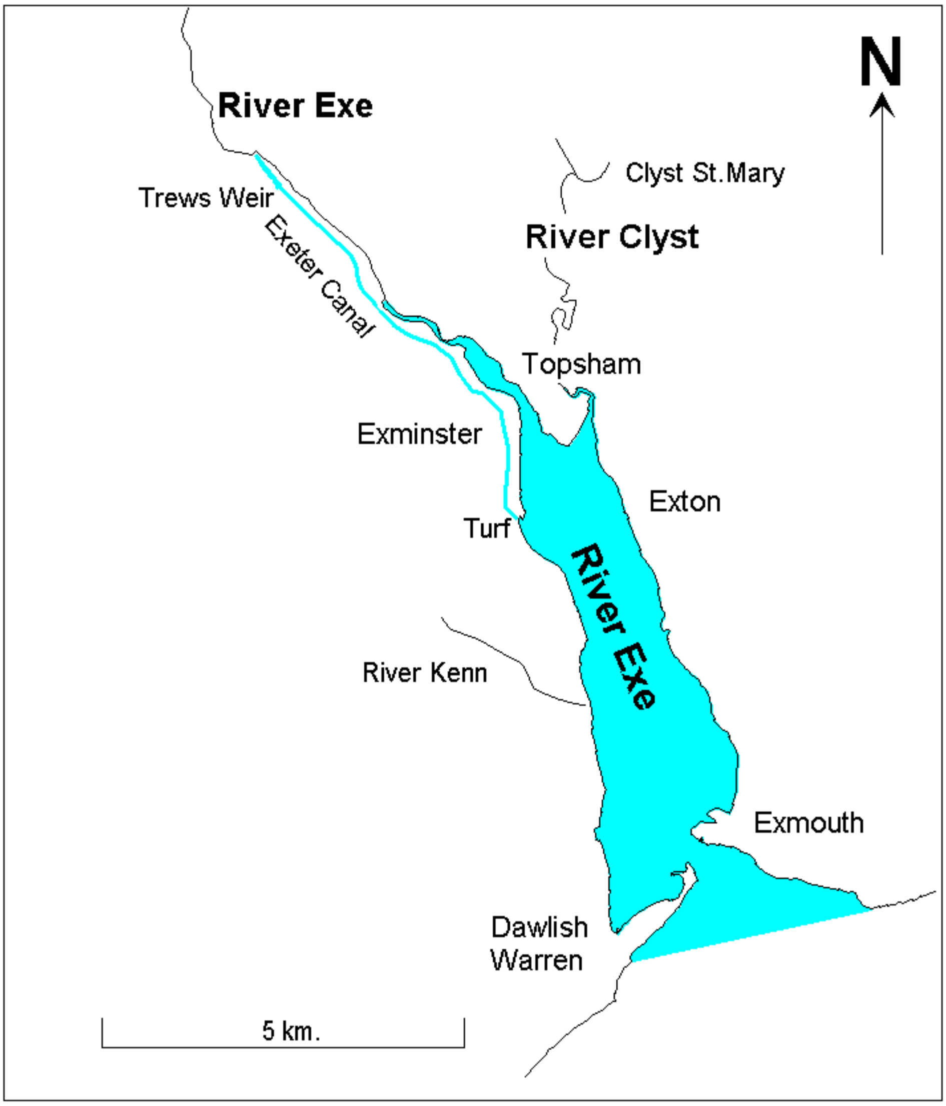

Figure 6: The Exe Estuary SPA showing boundaries of the marine site

The upper reaches of the estuary are partially stratified, particularly in summer and during neap tides, whilst the lower estuary is characterised as being well mixed. At spring tides, a combination of high current speeds, limited water depth, and river and sewage discharges can result in high levels of suspended solids in the region of Starcross. At low tide, much of the estuary dries, exposing a narrow channel (~500m wide), which winds along the estuary (mainly on the west side) between extensive intertidal mud and sand flats. Bait diggers use several areas, and sheltering tiles and pipes are used to catch peeler crabs. The latter practice has increased over recent years, and there are indications that this has led to a decrease in both the number and size of crabs. The greater part of the main channel has a depth of less than 1-2m below chart datum, although depths of up to 5m occur in isolated spots.

Much of the shoreline has been modified by the construction of railway embankments and there are no natural rocky shores within the estuary. The hard substrata present consist of stones and small boulders concentrated around the high water mark, together with those stone embankments which lie within the upper intertidal zone. Subtidal habitats are also primarily sedimentary, and the character of the bed sediment is fairly homogeneous throughout, with a median grainsize diameter between 10 and 100µm. Low energy environments (in the upper estuary mainly, and behind Dawlish Warren) encourage the deposition of finer fractions which may be enhanced by local sewage discharges. Some organic enrichment has also been observed at Exton in the past, attributable to local inputs of untreated sewage, although these discharges are being improved.

The Exe Estuary supports important numbers of Avocet, Slavonian Grebe and waterfowl assemblages, hence its designation as an SPA (see annex 2). Because of the lack of stable hard substrata, epifaunal and algal diversity tends to be somewhat limited, although in heterogeneous muddy and sand areas, infaunal populations may be less sparse. Nationally-important aquatic species include the polychaete worm *Ophelia bicornis* and also the tentacled lagoon worm *Alkmaria romijni.* Pink sea fan *Eunicella verrucosa* is found on near-shore reefs close to Exmouth. Several areas support regionally important habitats, such as eelgrass *Zostera spp,* and saltmarsh, part of which is a cordgrass (*Spartina. spp*) monoculture.

Pacific oysters and mussels are farmed on the estuary (beds were designated as class B bivalve production areas in 2002) and in Sandy Bay, just outside the estuary mouth (classified as a provisional class B for clams *Spisula solida*). There is a limited amount of netting for migratory species of salmonid fish and eels, controlled by the Environment Agency. Outside the salmon season, there is also a small fishery, drift netting for marine species such as bass, mullet, herring and mackerel. The whole estuary has been designated a Bass Nursery Area, reflecting its national importance for this species.

There are two major urban areas, Exeter, at the head of the estuary, and Exmouth, on the eastern bank at the mouth, with several smaller settlements situated in between. With minimum industrialisation, the catchment has retained its predominantly rural nature and supports dairy and mixed farming, and market gardening, accounting for ~80% of land use.

Fresh-waters from the Exe, the Creedy and the Culm catchments, meet north of Exeter and flow into the estuary as the River Exe. The River Clyst joins the estuary to the north-east, at Topsham, and there are a number of smaller tributaries. The Exeter Canal, now used principally for recreation purposes, stretches from Exeter Quay to Turf Locks, running parallel to the Exe behind the west bank of the upper estuary.

The marine site is used intensively for recreation, including most water sports, with the highest concentrations of boats near the main channel at Cockwood, in the lower estuary. Potential threats to SPA features associated with leisure usage include disturbance, waste (sewage and domestic) and the effects of antifouling compounds. There is some limited military use of the estuary near Exton, and a small arms range at Straight Point.

Diffuse pollution, particularly from agricultural land run-off, is a key concern. Farm animal waste is a significant potential source of pollution to rivers feeding the Exe Estuary SPA and although there have been improvements in farming practice, and an overall improvement in water quality over the last decade, there is a need for further improvement. The area around Dawlish has recently been designated as a Nitrate Vulnerable Zone (NVZ) to help address the problem of diffuse source pollution. Consented sewage discharges (which may contain some trade wastes) amount to roughly 107,754 m^3d^{-1} (dry weather flow, DWF) for the SPA as a whole (not including inputs upstream of the tidal limits). Countess Wear and Kenton & Starcross are the principal STWs discharging directly to the marine site. The former (40,486 m^3d^{-1} DWF) is considered to be the most significant and sensitive discharge, and exceeded its ammonia limit in over 10% of samples in 2001. The greatest impact from Countess Wear, in terms of nutrient enrichment, occurs in summer at Lower Wear.

A review of toxic contaminants suggests acute direct threat to biota is unlikely across most of the estuary, though for many chemicals the data are not sufficiently robust to provide detailed analysis.

Rivers entering the Exe Estuary are unlikely to cause problems with regard to metals though elevated levels are reported near the head of the estuary at Countess Wear, most notably for Zn (for which STW effluent appears to represent a sizeable, but decreasing, loading). Metal concentrations in sediments are also highest in the upper estuary (due to proximity to STW, and to enriched organic and oxyhydroxide coatings which sequester metals). The only metal above sediment 'probable effects levels' here was Zn, though Cd, Hg, Pb, Cu and As exceeded guideline values (ISQG). Concentrations of most elements decrease to background levels towards the mouth of the estuary, as estuarine silts become mixed with low-metal particulates of marine origin, and it is only in the region of Countess Wear, near the tidal limit of the estuary, that deterioration due to metals could be expected. Thus, apart from slight enrichment in Ag, Cd, Hg, Sn and Pb in the upper estuary, there is little to indicate that metal bioaccumulation is significantly above normal across much of the site. In the past, elevated burdens of Cd and other metals have been observed in mussels close to Exmouth Dock (perhaps originating from metal scrap-heaps), though these appear to be a localised phenomenon. Shellfish from commercial beds display little evidence of contamination except perhaps, slightly, for Pb. Recent bioaccumulation data for the Exe would be useful to confirm these trends.

Most organic compounds analysed in rivers and tidal waters of the Exe (including a range of pesticides, herbicides, chlorinated solvents, hydrocarbons and alkylphenols) tend to fall below detection limits, but appear to comply with EQS standards and, in the water column at least, are generally anticipated to be of little toxicological importance[13]. However, the available data on

[13] Levels in a limited selection of commercial shellfish samples also appear to be low.

some compounds such as TBT, though suggesting little threat, are not considered adequate for an accurate appraisal (small number of sites, detection limits often above the EQS, few sediment or biological analyses). *Nucella lapillus* is not a native species within the Exe Estuary; nonetheless, TBT-induced imposex has been observed in this species on adjacent shorelines in the past, and appears to have led to their extinction at Maer Rock and Orcombe Point. As far as we are aware there are no indications that these dog-whelk populations have recovered and, despite the fact that other mollusc species in the Exe Estuary show little evidence of impact, the threats from TBT should be updated and quantified more comprehensively.

STW and diffuse agricultural inputs along the estuary have contributed reckonable loadings of γ-HCH (and probably other pesticides and herbicides) to the estuary in the recent past, and concentrations in estuarine sediments in the early 1990s were above the PEL. However, inputs now appear to be declining substantially. STWs have also been a sporadic source of atrazine and simazine to the Exe, though again the magnitude of extreme values in effluent is decreasing, generally, and seem unlikely to pose a threat. More accurate information on estuarine distributions of selected herbicides and pesticides is needed for confirmation.

Small loadings of PCBs may have been carried in particulate form into the estuary where they have tended to be concentrated in the region of the turbidity maximum. Superimposed on this main input from the River Exe there may have been irregular, localised sources of PCB within the estuary. Some sediment PCB values have, in the past, approached or exceeded quality guidelines and PEL, and are therefore of possible biological significance, although more recent EA data do not corroborate this contention. PAHs are, like PCBs, 'concentrated' in the upper estuary due to the high levels of suspended solids, and decrease towards the mouth of the estuary. Thus, concentrations of ΣPAH and some individual PAHs are moderately high in sediments upstream, occasionally exceeding ecotoxicological guideline values by a small margin. Possible hydrocarbon sources include shipping, river-borne discharges (including road runoff and licensed and unlicensed discharge to sewers), diffuse discharges from industrialised municipal areas and the atmosphere (PAH's). The M5 and other roads in close proximity to the Exe constitute a relatively direct route of entry of PAHs (also lead and zinc) to the estuary, either in road run-off or *via* deposition.

In general, any effects due to metals or organic contaminants, if they occur, are likely to be chronic rather than acute and restricted to sites towards the head of the estuary, rather than in sandier sediments further downstream. More extensive, targeted sediment and bioaccumulation data would be useful to confirm recent trends. On current evidence, consumption of prey species, or accidental ingestion of sediment during feeding on mud-flats, appear to represent relatively negligible risks to birds within the Exe SPA. However, the potential for food chain transfer and bioconcentration of toxic contaminants, and margins of safety, have scarcely been addressed in the Exe or any other of the south west European marine sites.

Nutrient-associated water quality problems in the Exe Estuary, first described during the early 1970s, appeared to have been alleviated with the opening of Countess Wear STW. Unfortunately, the estuary is again experiencing symptoms of eutrophication, periodically. As indicated above, parts of the Exe catchment suffer from nutrient enrichment and rivers and streams constitute a principle source of nutrients in the estuary, introducing contributions from agricultural run-off and sewage discharges higher up in the system. A stretch from the River Creedy at Crediton STW to the normal tidal limit of the Exe has been recognised as a Sensitive

Area (Eutrophic) for almost a decade, and the Agency are currently carrying out a study of the trophic status of the Exe from Tiverton to the Creedy confluence. However, measures to address diffuse sources of nutrients are usually only undertaken if the area is also designated as a nitrate vulnerable zone (NVZ).

Direct sewage discharges to the estuary constitute additional nutrient loadings and result in chronic contamination of the affected areas. Countess Wear STW is implicated as the major point source impinging on estuarine water quality, contributing on average 25% of the total inorganic nitrogen load from the River Exe during the summer months (~10% of the load annually). Nutrient concentrations in the estuary generally decrease with distance downstream from the discharge.

Nutrient and BOD levels appear to be increasing over recent years. Phytoplankton blooms (roughly centred in the mid-estuary) are also increasing in intensity, and although not persistent (due to the flushing characteristics of the estuary), are an important indication of enrichment problems. Exaggerated dissolved oxygen (DO) fluctuations occur as a result of algal activity in the estuary and are a further symptom of eutrophication. Whilst daytime levels are high to the point of supersaturation, DO at night may drop below mandatory levels required by the shellfish directive and, possibly, those required for sensitive saltwater life. High concentrations of ammonia in tidal waters have been recorded for some years, and are also of concern due to possible toxicity to estuarine organisms, particularly fish. Countess Wear STW is again, a significant source: highest concentrations of ammonia are recorded downstream of the STW and in mid-estuary, and decrease toward the mouth.

As indicated, these manifestations led to the Exe being investigated as a Sensitive Area (Eutrophic) during 2001. However, on the grounds of insufficient evidence of effects, and perceived excellent flushing characteristics of the estuary, the site was not put forward to DEFRA and therefore it will not be designated as SA(E) in the foreseeable future. Nevertheless, in view of the conservation importance of the Exe Estuary, it would seem important that any increase in nutrients should be avoided and that changes to consents (quantities and location) should be considered carefully to avoid the risk of further enrichment.

Information on biological effects (of any kind) is, indeed, extremely limited and, to an extent, equivocal. There may have been a long-term decline in the diversity of algal species, and in the extent of seagrass (*Zostera*) beds in the estuary, although it is difficult to speculate on the exact causes of the change. One possible explanation is green macroalgal proliferation, which may occur as a result of elevated nutrient levels, and could have serious implications for *Zostera* in the estuary (green macroalgal blooms have been implicated in its decline elsewhere). Further research and surveillance is needed to evaluate this risk.

Existing reports suggest that, quantitatively at least, the intertidal sediments and fauna of the Exe may have remained relatively unchanged for much of the 20th century. The composition of sediment-dwelling communities differs in different parts of the estuary, but appears to be determined largely by natural environmental conditions (notably salinity and grain size-characteristics). Biodiversity generally increases seawards and highest numbers of infaunal species have been recorded at Exmouth and Shutterton (although diversity at these sites has been reported as being relatively low, compared with similar locations elsewhere). Quantitative indices used to assess the effects of environmental degradation on the biodiversity of natural assemblages also suggest that diversity may be impaired in localised inter-tidal areas in the Exe Estuary, and that abundance may be somewhat low for many species, though this could be due to natural factors.

BTO observations on bird populations have indicated declines for Widgeon, Dark-bellied Brent Goose, Oystercatcher and Avocet at various times over the last 25 years, though these are set against fluctuating trends and are not considered cause for concern.

In these terms, the Exe appears to be comparable to, or even healthier than, a number of other UK estuaries and, overall, there is no compelling evidence that biodiversity of the site is significantly degraded by anthropogenic features. However, in common with many estuarine and coastal locations, information on biological condition in the Exe is scarcely adequate and needs to be developed in order to assist future management of the site.

6.6 CHESIL AND THE FLEET cSAC, SPA

The boundaries of Chesil and the Fleet cSAC cover an area of some 1600 ha, and the site is largely natural and undeveloped, principally because the lagoon bed and the majority of the shore has been owned and managed privately by the Ilchester Estate for over 400 years.

The Chesil Bank stretches 29km from West Bay to Portland, and is one of the five largest shingle beaches in Britain. In geomorphologic terms, Chesil Bank is known as a tombolo - a coastal feature above sea-level for most of the time, formed when a belt of sand and/or gravel is deposited between an island and the mainland. The bank varies in height, generally increasing from the west, and is at its maximum (~14m) at Ferrybridge in the east. On the seaward side, the shingle extends to a depth of 18m below low-water mark (some 270m offshore) in places. On the landward side, the shingle rests on a bed of clay 1 to 1.2m below the low water-mark of the Fleet Lagoon.

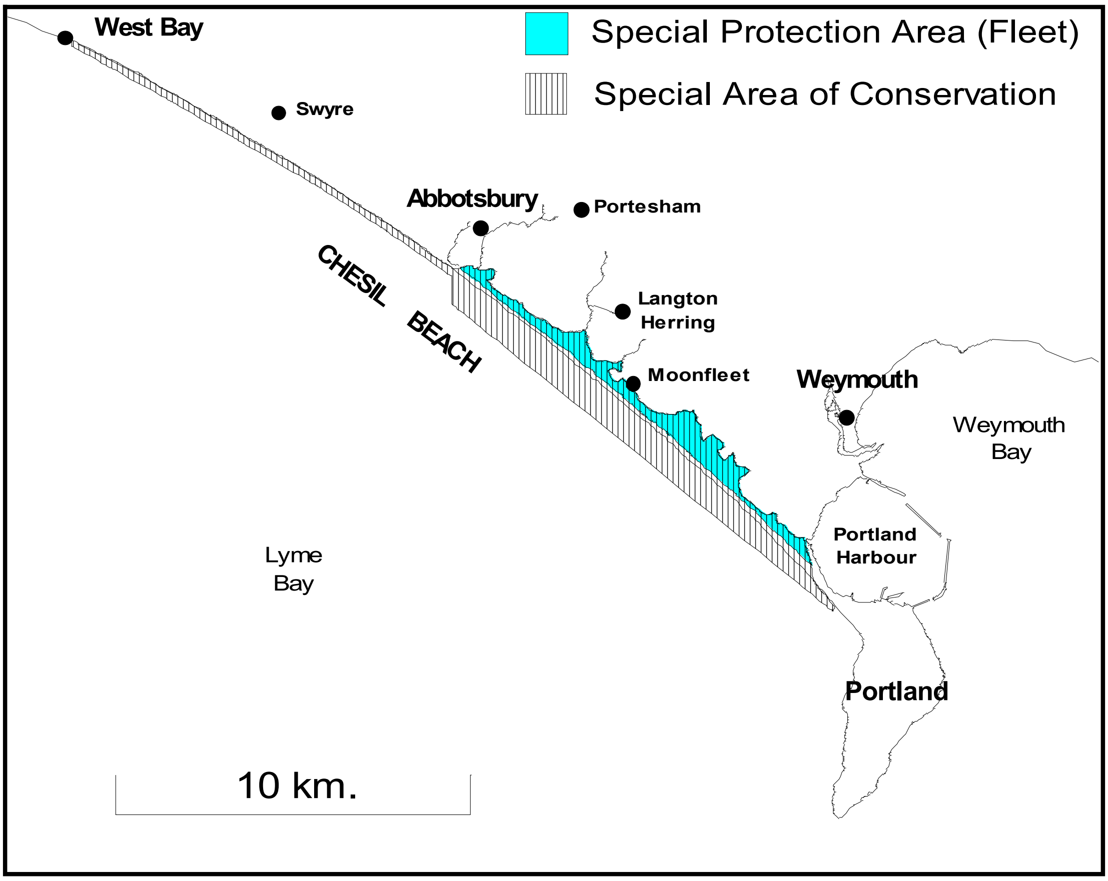

Figure 6: Chesil and the Fleet European marine site showing boundaries of the cSAC and SPA

Sandwiched between Chesil Bank and the mainland coast, the Fleet Lagoon is the largest regular tidal lagoon in Britain (500ha at high tide), stretching 13km from Abbotsbury, in the west, to Ferrybridge, where tidal waters enter the lagoon through a small opening (Small Mouth). There is also small-scale saline intrusion via intertidal saline springs and seepage through the shingle of the bank. The lagoon is very shallow, with a nominal depth of approximately 0.3m at the western extreme, and some 5m under Ferrybridge. At its widest point (Littlesea) the lagoon is 900m wide; this varies to 65m at the Narrows.

The Portland sea area is microtidal with a range of only 1.5m at spring tides. This is combined with an unusual double low cycle causing prolonged low water stands of up to 4 hours. The effect within the Fleet lagoon is an attenuated and phase-lagged tidal cycle, which is increasingly eccentric toward the western reaches, where tidal influence is weakest. The lagoon generally shows a continuous salinity gradient from Small Mouth to Abbotsbury although this can be variable according to rainfall. Values in excess of 30psu are typical of East Fleet, and can sometimes occur in the West Fleet, though they are usually lower here (salinities as low as 10psu have been recorded at Abbotsbury during high rainfall periods). The shallow nature, and generally poor flushing characteristics of the Fleet result in exaggerated maximum and minimum water temperatures in comparison with other south coast inlets. Extensive icing can occur in cold weather, whereas during hot spells, temperatures can exceed 20°C throughout the lagoon, and up to 30°C has been recorded in West Fleet.

Saltmarsh areas are distributed around the shores of the lagoon and are best developed around inlets and bays at either end of the Fleet. Freshwater marsh is found adjacent to some of the saltmarsh areas e.g the Abbotsbury embayment. Extensive meadows of eel-grass *Zostera spp,* and wigeongrass *Ruppia spp*. carpet much of the subtidal, and support a rich and unusual invertebrate fauna.

The lagoon is, in fact, often described as being divisible into two ecologically-distinct zones - determined, primarily, by shape and tidal regime; these are the 'lagoonal basin', and the 'inlet channel'. Both regions are highly sheltered against wave action, but the two differ in terms of tidal energy. The 'lagoonal basin' experiences a minimal tidal range, weak currents and very poor flushing. Salinity is low and variable. The substratum of the basin is mainly soft organic muds supporting extensive meadows of sea grasses and algae during summer months. The 'inlet channel' occupies the south-easterly quarter of the lagoon from Small Mouth to the Narrows (a 1 km rapids system) and extends through a tidal basin to the man-made entrance at Small Mouth. This section experiences a pronounced tidal rise and fall, strong currents and better flushing than the western reaches. The channel bed supports an unusual and diverse assemblage of algae and sedentary invertebrates, particularly within the Narrows. Rare, or scarce species include the red alga *Gracilaria bursa-pastoris,* the sponge *Suberites massa* and the southern black-faced blenny *Tripterygion delaisi*. A specialist lagoonal polychaete worm, *Armandia cirrhosa,* is found on subtidal sediment flats.

Abbotsbury Embayment, at the western end of the lagoon, is noted for its ancient colony of mute swans, historically (since at least the 14th century) farmed for the table but now the focus for a wildlife reserve (the Abbotsbury Swannery). A wide variety of other wildfowl also inhabit the lagoon and, as a whole, the site is important to a large number of bird species (Annex 2). Brent and Canada Geese overwinter in the Fleet and many rare species such as Little Auk, Fosters Tern and Great Northern Diver are blown into shore or pass through. The area is also important, to a lesser extent, for breeding species. The Chesil is one of the few sites in the southwest with populations of Little Tern, Common Tern, and Ringed Plover.

The Fleet is a designated bass nursery area and fishing from boats is prohibited at all times. This prohibition does not apply to the shore, however, and small-scale netting for bass has been reported in this area. There is also a prawn fishery, a private fish farm, and licensed eel fishing. Other fish in the Fleet include large shoals of small grey mullet, sandsmelt, sandeels, flounder, rockling, blenny, wrasse, pouting, and stickleback. Currently the pacific oyster *Crassostrea gigas* is farmed on a relatively large scale upstream of the Narrows, where trestles are situated along the margins of the channel. Fleet beds were designated as class B bivalve production areas in 2002 - a deterioration from the A classification in 1995.

Human disturbance at the site is largely controlled by the resident warden for the Chesil Bank and Fleet Nature Reserve. A limited amount of bait digging takes place on the intertidal mudflats, and is not considered a problem (although there is little quantitative information available). There are a few moorings for small boats within the Fleet, but again any impact is likely to be small in scale. Two military training camps (Wyke Regis and Chickerell) use areas of Chesil bank for training and there is a small-arms range, with a safety area which extends across the Beach and out to sea; these also appear to present few concerns for the condition of site as a whole.

The catchment area for the Fleet is predominantly rural, relatively small ($28km^2$) and drained by seven freshwater flows, some of which are dry during the summer months. There is one groundwater abstraction licence for public water supply within the Fleet catchment. This allows removal of between 0.5 and 5.0 Ml d^{-1} from tributaries at Portesham near Abbotsbury.

Diffuse pollution, particularly from agricultural land runoff, is seen as a key concern for the Fleet. Farm animal waste is a significant potential source of pollution to rivers feeding the Fleet, and the area is targeted under the Countryside Stewardship Scheme to implement buffer zones to reduce run-off into the reserve.

There is little industrial activity in the catchment and there are few consented discharges to the lagoon. However, two potentially important Wessex Water Services consented STW discharges flow into tributaries of the Fleet, at Abbotsbury[14] and Langton Herring (estimated <100 m^3day^{-1} DWF). A further four private sewage treatment schemes discharge to the Fleet at Abbotsbury, Langton Hive, Chickerell, and the west end of the Narrows. The most significant of these is considered to be Abbotsbury, due to the enclosed nature of the waterbody.

The largest urban conurbation in the region is at Weymouth and Portland (until recently a major naval base). It is possible that shipping activity or terrestrial run-off in to Portland Harbour could impinge to a small extent on water and sediment quality of the east Fleet (though evidence of this is limited, as indicated below). New treatment facilities (a large sewage farm) serving Weymouth and Portland have been sited close to the headworks at Wyke Regis, but discharge into Lyme Bay, via a long-sea outfall pipe. There is also a long-sea outfall at West Bay. Neither of these offshore inputs seem likely to impact on the Fleet.

Arguably, therefore, the most pressing form of anthropogenic impact in the lagoon is the threat of eutrophication. Problems relating to nutrient enrichment have been apparent in the Fleet for several decades. The inherent poor flushing characteristics of the lagoon, particularly West Fleet,

[14] The consented DWF of 140 m^3 day^{-1} at Abbotsbury STW is likely to have been exceeded for many years. Wessex Water has calculated a theoretical DWF of 243 m^3 day^{-1} based on the connected population, and this is predicted to increase to 290 m^3 day^{-1} by 2020 (EA pers comm.). As a result previously modelled contributions of P and N may be underestimated.

coupled with its shallow depths, extremes of temperature, and high pH, compound the enrichment problems of the affected areas. Much of the western lagoon, notably the Abbotsbury embayment, displays typical symptoms of eutrophication, characterised by macroalgal, and microalgal blooms, and periodic oxygen sags. The algal blooms appear to be increasing in regularity and intensity. Diarrhetic Shellfish Poisoning has been detected in mussels and oysters, leading to a Temporary Prohibition Order on shellfish harvesting from the lagoon in 2000.

Despite concerns over the adequacy of some of the data, results from modelling exercises imply that nutrient loads are derived primarily from agriculture and that streams to the western end of the Fleet represent important inputs of both N and P to the lagoon. Arable cultivation (fertiliser application) is a particularly important source of nitrogen and, since this type of land-use is centred somewhat further eastwards in the catchment, notably around Langton Herring, it is conceivable that N inputs to the East Fleet could be even higher than the western reaches. However, as tidal exchange is more pronounced towards the eastern end of the lagoon, manifestations of eutrophication are less likely than in the Abbotsbury embayment.

Whilst the majority of nutrient inputs to the system are thought to be due to be due to agricultural run-off (perhaps accounting for as much as 84% N and 70% P), enrichment from point sources and the swannery may be important, locally. Abbotsbury STW is likely to be the most significant point source to the Fleet, particularly for phosphate (previous estimates may have underestimated this input- *see footnote*[14]). Its discharges enter the most sensitive area of the lagoon and provide bioavailable nutrients, the concentrations of which increase during summer months, a time when algal and plant growth are at a maximum.

The problem of hypernutrification has lead to the recent designation of the Fleet Lagoon as a Polluted Water (Eutrophic) under the Nitrates Directive (91/676/EC), and the catchment area for the Fleet as a Nitrate Vulnerable Zone (NVZ), which could provide the framework to reduce nutrient inputs from all sources. Regular nutrient analysis in the lagoon has been recently reinstated, presumably to monitor accurately the effectiveness of any remediation measures.

Ammonia levels in some of the discharges to the Fleet are relatively high, and have been increasing over recent years. Additionally, there is a potential for the release of ammonia from sediment when macroalgal biomass declines. Conditions in the lagoon, particularly West Fleet, are liable to increase the toxicity of ammonia, posing a threat to sensitive lagoonal communities.

Preliminary research into the effects of the high levels of nutrients on individual species in the Fleet has provided some evidence for impact on the rare charophyte *Lamprothamnium papulosum*, which is sensitive to high levels of phosphate and has become locally extinct in the Abbotsbury embayment. There have also been increases in macro- and micro-algae, which could have consequences for other key features at the site, including *Zostera* and its associated community. In view of the sensitive nature and important conservation status of the Fleet Lagoon it is essential that changes to consents should be considered carefully and efforts made to avoid the risk of further enrichment wherever practical.

At present there is little explicit evidence that modifications to biota of Chesil and the Fleet cSAC, SPA have occurred, or would be expected to occur, due to toxic contaminants. Site-specific studies on possible biological effects are virtually non-existent. To address this issue in the future, a more subtle, targeted assessment of impact is required. At present it is only possible to assess, intuitively, the possible impact (or lack of impacts) of individual contaminants, or groups of contaminants, based on insubstantial chemical data.

For example, there have been no measurements of TBT (or other organotins) in water, sediment or biota from the Fleet itself. TBT levels in adjacent tidal waters in Portland Harbour, sampled by EA since 1997, have usually been below detection limits, though these have frequently been set higher than the EQS for coastal waters (2 ng l^{-1}). At two of the Portland sites, values in 2001 were above the EQS and could impinge to some extent on the Fleet, though probably only close to the entrance. The source of this TBT may be partly from antifouling paints on boat hulls although a small input from STW cannot be excluded. Concentrations up to 76 ng l^{-1} and 161 ng l^{-1} TBT (as cation) have been measured in effluent samples from Weymouth STW and West Bay Pumping station.

It is likely that Fleet sediments are low in TBT and of little concern. Sediment samples taken from one site in Portland Harbour, in 1997 and 2001, were without exception below detection limits. However, as these limits are above provisional ecotoxicological guidelines set by OSPAR, a more detailed survey is needed to establish current status and trends for TBT in Fleet sediments.

In 1992, imposex in *Nucella lapillus* from Portland Bill (commercial and naval vessels, leisure craft) and West Bay (small boats predominantly) was manifested at similar levels of intensity. Six years later (1998) there were clear signs of improvement at West Bay whilst, in contrast, the dogwhelk population at Portland Bill had been eliminated. Presumably, levels of TBT in the latter area have been high enough at times to sustain the phenomenon in *Nucella*. Samples of less sensitive *Littorina littorea* collected from Portland Harbour (near to docks) contain TBT residues which are ten times higher than reference samples outside the harbour in Weymouth Bay. These concentrations are unlikely to impair reproduction in winkles, but illustrate the scale of bioaccumulation. Further monitoring of TBT should be considered in the future, if only to establish or eliminate the possibility of ingress of significant levels of TBT to the Fleet from Portland Harbour.

There are no data for metal concentrations in rivers or consented discharges entering the Fleet and monitoring of tidal waters of the Fleet lagoon is limited to a single site in the East Fleet (the Narrows). There have been no cases of EQS exceedences here in recent years though in 1996 the standards for copper and zinc are reported as being exceeded at adjacent sites in Portland Harbour (possible sources include antifouling paints, sacrificial anodes and urban run-off). Again it would be beneficial, for future assessment purposes, to establish better data on the extent of incursion of metals during tidal exchange.

Metal concentrations in sediments of the Fleet appear to be fairly typical for estuaries in the region (based on a single study of unknown QA). None of the sediment metals measured was above sediment ‘probable effects levels’. Lead and zinc were generally below the ISQG (interim sediment quality guideline) except at Ferrybridge. Mercury concentrations were also low throughout the area except at one site in the Fleet (east Fleet) and in Portland Harbour. Copper and arsenic concentrations exceeded the ISQG throughout the Fleet, though by a relatively small margin. On this basis, according to the guideline criteria, no harm to biota would be predicted, though, where concentrations exceed the ISQG, chronic effects cannot be excluded. The small degree of metal enrichment seen in these coastal sediments, relative to off-shore samples in

Lyme Bay, may be due in part to urban sources (run-off and sewage); however, it is also likely that the relative abundance of organic and oxyhydroxide coatings and sulphides – characteristics which govern the ability of sediments to sequester metals and act as sinks – are a factor.

There is little information on metal bioavailability or bioaccumulation in the Fleet other than in occasional commercial oyster samples. Body burdens of several metals (As, Cu, Pb, Ni, Zn) would register as being 'high' in most bivalve classification schemes, though oysters are exceptional natural accumulators of metals such as Cu and Zn and are not necessarily the best bioindicators. EA survey data in Lyme Bay suggests that the Weymouth long-sea outfall increases metal bioaccumulation, to a small extent, near to the discharge, though this is outside the cSAC, SPA and not expected to influence the site itself.

Ecological impact due to metal contamination in the Fleet lagoon is not anticipated, based on the available evidence. Nevertheless, conditions in Fleet sediments, particularly localised zones of anoxia, could increase the bioavailability of certain metals (Cu, Cd, Ag and Hg). Better characterisation of metal 'speciation' in sediments is therefore recommended, alongside bioindicator studies with infaunal species such as worms and clams, to help resolve this issue. At the same time, there is scope for more research to establish the physiological and ecological significance of metal body burdens using sub-lethal biomarkers such as metallothionein induction.

The EA database contains no information on 'hydrocarbon oils' in freshwaters, discharges, tidal waters, sediments or shellfish in, or adjacent to, the SPA/cSAC. The hydrocarbon content of a single water sample from Portland Harbour, taken independently in 1994, was made up predominantly of an unresolved complex mixture (UCM), indicative of biodegraded products of petroleum (possibly from chronic oil pollution as a result of general shipping activity or terrestrial run-off). If representative, this level of contamination is probably of little cause for concern in the Fleet, in relation to ecotoxicological thresholds. Similarly, total hydrocarbons (THC) in sediments in the Lyme Bay area do not appear to represent a threat though they do display substantial heterogeneity: highest concentrations, found in Portland Harbour and the Fleet lagoon, contain an elevated UCM content, consistent with biodegraded inputs from fuel or lubricating oil dispersing from shipping or from runoff. THC concentration in oysters from the East Fleet in 1995 – the only bioaccumulation data available – was fairly typical of mildly contaminated sites. Although the perceived threat to the Fleet from oil is probably low, it would seem important to establish more extensive baseline information as a means of monitoring future improvement/deterioration at this site.

The general distribution pattern of PAHs in sediments is consistent with the THC data: highest concentrations in the region are associated with Portland Harbour muds and sediment of the Fleet lagoon. Elsewhere in Lyme Bay and Weymouth Bay, PAH concentrations are generally an order of magnitude lower. Pyrogenic components are dominant, indicative of fallout from incomplete combustion of fossil fuels (perhaps concentrated in urban runoff). Comparison of PAH concentrations in sediment with ecotoxicological guideline values indicates that values in the Fleet are above the ISQG but below the PEL and, on this basis, sub-lethal effects caused by PAHs would not be predicted but cannot be ruled out. Concentrations of PAHs in the single sample of *Crassostrea gigas* from the East Fleet would meet OSPAR guidelines. Although there appear to be no immediate concerns for the Fleet shellfish, based on this evidence, it would be useful to broaden the data on PAHs to obtain a more extensive picture of PAH bioavailability in, and adjacent to, the European marine site.

For the majority of pesticides, herbicides, PCBs, and chlorinated solvents, there are no data to evaluate riverine sources and only limited information for STW discharges. Effluents from Weymouth and West Bay STW have contributed small loadings of γ-HCH (and probably other pesticides and herbicides) to coastal waters in the recent past. EA survey data also suggests that the Weymouth long-sea outfall may result in increased bioaccumulation of some synthetic organics (PCBs, DDE), near to the discharge, though this is outside the cSAC,SPA. As most synthetic organic compounds analysed in tidal waters of the East Fleet Narrows and Portland Harbour are below detection limits, and appear to comply with EQS, we can speculate that risks to biota within the European Marine Site, from aqueous sources, are likely to be low.

Benthic muds can act as a sink for many of these compounds, but unfortunately there are no records of concentrations in Fleet sediments – only for one adjacent site in Portland Harbour near Ferrybridge, where most organic determinands were below detection. However, concentrations of γ-HCH in these sediments, measured in 1997, were above the PEL (and detection limits for dieldrin and the sum of DDT and DDE isomers were also above guidelines). Further monitoring of pesticides and herbicides in Fleet sediments is advisable to improve characterisation of possible sources, which may include diffuse agricultural inputs from the small streams entering the Fleet.

Body burdens of γ-HCH, dieldrin, HCB, DDT and PCBs in Fleet oysters are reported as being close to detection limits and are usually within OSPAR guidelines and food standards (and would therefore be anticipated to constitute little toxicological importance). For samples of Portland Harbour mussels, collected between 1985 and 1992, most of these compounds were also undetectable, apart from γ-HCH and PCBs (which sometimes exceeded lower JMP guidelines). These appear to be the only biological samples in, or adjacent to, the European Marine site that have been analysed for synthetic organics. More information on body burdens in infaunal species sampled along the length of the Fleet, in conjunction with sediments, would be useful to characterise distributions and threats. The possibility of endocrine disruption from synthetic organics has not been investigated in the European marine site and should, perhaps, also be addressed in future.

Despite being based on limited data, the review of toxic contaminants (metals and organic compounds) suggests that acute effects to biota are unlikely across most of the Fleet. The ecological divisions of the lagoon, described above, largely determine the distribution of the aquatic fauna and flora, though as indicated there are some preliminary indications that nutrients have a modifying effect on sensitive plant species.

A gradient of decreasing vegetation and invertebrate numbers, from mid lagoon to shore, has been described for all areas, with permanently submerged central areas supporting the highest densities of vegetation and associated invertebrates. Vegetation is strongly seasonal, generally, with seagrasses growing on the lagoon bed from late spring to autumn, accompanied by dense swards of green algae until mid-summer.

In common with other saline lagoons, biodiversity is somewhat limited in the Fleet compared with other marine habitats. Species diversity and abundance both peak in the Langton Hive area where the subtidal lagoon bed is dominated by soft mud and mixed stands of seagrass (*Zostera spp*.) and tassleweed (*Ruppia spp*). The fauna of the Fleet is characterised by brackish water species, including specialist lagoonal species (such as the starlet sea anemone *Nematostella vectensis*, lagoon sandworm *Armandia cirrhosa*, and lagoon sand shrimp *Gammarus insensibilis*). The specialised conditions in the link channel have led to an exceptional abundance of some of the more common marine species, notably snakelocks anemone *Anemonia viridis* and cushion star *Asterina gibbosa.*

Unfortunately, quantitative diversity indices, which are frequently used to assess the effects of environmental degradation on the biodiversity of natural assemblages of benthic organisms, have not been applied to the Fleet. To help in comparisons between sites, and in long-term assessment of condition, it may be useful to apply a selection of these quantitative techniques as part of any future monitoring strategy.

The recent BTO review of statistics for bird populations of Chesil and the Fleet has shown that numbers of the internationally important Dark-bellied Brent Goose increased during the 1970s and 1980s but have decreased in recent winters. This mirrors regional and national trends and therefore no alerts have been triggered; adverse factors such as pollution were not considered sufficient to warrant additional investigation. On current evidence, consumption of prey species, or accidental ingestion of sediment during feeding on mud-flats, appear to represent relatively negligible risks to birds within the Fleet. However, in common with other European marine sites, the potential for food chain transfer and bioconcentration of toxic contaminants is largely unknown. In view of the suspected sensitivity of the site to nutrients, and the largely unknown bioaccumulation status of many toxic contaminants, the acquisition of any further information which addresses possible links between environmental quality and biological consequences seems desirable.

7. CONCLUSIONS AND RECOMMENDATIONS

This summary report has provided an overview of existing knowledge on physical properties, uses and vulnerability for each of south west's European Marine Sites, together with an evaluation of current understanding on contaminant sources, exposure and biological impact. Specific gaps in knowledge brought to light in this synthesis are discussed in greater detail, along with others, in the individual site reports. It is appropriate here to highlight some of the more generic issues and recommendations.

Under the Habitats Directive, Member States must report on the progress towards Favourable Conservation Status (FCS) for all nominated sites. Favourable Conservation Status for a given habitat/species requires that the condition has to be characterised and, if considered necessary, brought up to a level where the habitat/species are sustainable in the long term. The information reviewed in the current project should contribute significantly towards establishing the condition for each of the nominated sites, albeit on a subjective basis. However, the requirement to fulfil FCS and other drivers on water and sediment quality (such as the 'standstill' provision under the Dangerous Substances Directive) may, on current evidence, be difficult to achieve with precision. Biological information is predominantly qualitative and is of restricted spatial or temporal coverage. Similarly, the fragmented nature of much of the available environmental quality data - much of which has been collected for compliance reasons rather than with process-oriented purposes in mind - prevents all but a first approximation of the status of the each of south west's European Marine Sites.

The current site characterisations therefore represent fairly rudimentary 'baselines' - highlighting the perceived threats to biota from point-source and diffuse pollutants and presenting available evidence of temporal change. Continuing statutory monitoring programmes, as a minimum requirement, will enable updates on the status of each site to be made at intervals. To some extent this may fulfil many regional, national and international policy requirements. For example revisions to the current series could be provided to coincide with DEFRA's second Marine Stewardship Report on the State of our Seas in late 2004, and also at regular intervals thereafter (three years seems an appropriate interval). Since the UK is firmly committed to the wider principle of ecosystem-based management, a comparable characterisation approach might be useful across all UK marine SACs, and would be amenable for adoption at other important marine sites, irrespective of whether they are designated under the Habitats and Birds Directives.

Unfortunately, maintaining the status quo with regard to statutory water quality monitoring programmes will not provide much-needed insights or re-appraisals of the functioning of these systems (and will obviously suffer from many of the drawbacks already encountered). This needs to be addressed if we are to progress our understanding of how environmental quality, and in particular anthropogenic inputs, are affecting the biota and, hence, the conservation status of the marine site. Better-integrated information on environmental chemistry, sub-lethal effects and biodiversity are generalised top-level needs to address the issue of 'quality' at each of the marine sites, just as rigorous monitoring of habitats will be needed to provide estimates of their 'quantity' and extent.

A major concern throughout the current project has been how to monitor the health of the environment within each of the sites i.e. to ensure that conditions are favourable for the survival of biota and, if they are not, to establish any cause and effect relationships. An obvious starting point is that, given the continual natural variation which occurs in ecological systems, critical assessments of human impacts (including consented discharges) can only be made against a time series of background data. The question is 'What data best serves this need'?

Some of the classes of contaminants and sample types which, in our opinion, should be prioritised in order to monitor, manage, and restore sites effectively, are discussed above, for each site. Since traditional compliance monitoring is not necessarily designed for the type of characterisation being undertaken here, future surveillance strategy should perhaps be reviewed in future to maximise the value of the information, taking as a starting point some of the following general requirements for contaminant data:

- Monitoring of nutrients (N, P and ammonia) in tidal waters appears to be important for most SACs and SPAs but was discontinued at a number of south west sites in the late 1990's. It is strongly recommended that targeted monitoring be continued (if not already reinstated) in order to maintain an up-to-date assessment of water quality, as results could highlight problem areas and expedite remediatory action when necessary. Further modelling exercises should be carried out, using the most recent data and estimates of flow, to determine distributions and loadings of P and N from different sources. Further research to evaluate sediments as sources or sinks for nitrogen, ammonia and phosphorus, and the significance of biological activity on nutrient behaviour in sediments, is also recommended.

- TBT legislation appears to have been effective in reducing levels in many small-boat dominated waters, although the persistence of TBT in sediments may have slowed down the recovery of benthic biota to some extent. Long-term studies in Poole Harbour should be continued to confirm the forecasts for improvement at this and other previously impacted sites. Selective coring of sediments would help to map out potential TBT hotspots and define the threat from remobilisation and bioavailability in areas likely to require dredging. At some SACs, assessments are limited due to a lack of detailed information. Remarkably, there are scarcely any published records of organotin in water, sediment or biota from the Severn pSAC, and only limited monitoring data, therefore the distribution and impact of butyl and phenyltins requires investigation. TBT contamination is probably of most concern in the Fal and Helford cSAC, where there is a need for targeted investigations into inputs to the system, environmental inventories and behaviour (particularly in sediment). Up-to-date information is needed on imposex levels, and population data for neogastropods (*Nucella, Nassarius)* at established sites here and elsewhere in the south west to ascertain the prognoses for re-colonisation. These studies are needed to judge both the effectiveness of current legislation, and as baselines for the impending IMO ban on TBT-based antifouling paint scheduled for 2003.

- Rigorous data on other endocrine disrupting substances in the south west European Marine Sites is needed, together with confirmation of the presence or absence of their effects. In comparison to freshwater environments there is a paucity of reliable information on the nature of these substances, or their effects, in the marine environment - other than in fish from industrialised estuaries such as the Tees and Mersey. With the exception of the effects of organotins in molluscs, knowledge of endocrine disruption in invertebrates is even more sparse.

- Radionuclides do not appear to be a generic concern but merit further consideration in parts of the Severn Estuary pSAC and Plymouth Sound and Estuaries cSAC. In the Severn, disposals of organic tritium at Cardiff have, in the recent past, resulted in anomalously high concentrations of tritium in sediments and benthic biota such as flounder and mussels. The consequences have, to date, not been considered a threat for humans. Clearly, however, this is an issue for further research since relatively little is known of the bioavailability, assimilation pathways and effects (e.g. genotoxicity) of organically-bound tritium on marine life. This may also be relevant to the Tamar Estuary (Plymouth Sound and Estuaries cSAC) where discharges of tritium from the Devonport Dockyard are expected to rise in the near future as a result of a recent substantial increase in the consent. Although the biological impact is predicted to be minimal, more data and fundamental studies on tritium behaviour, bioaccumulation and genotoxic effects on marine biota are recommended.

- Accurate, up-to-date chemical data on e.g. selected metals, PAHs, organotins and pesticides are needed across all sites, to give better impressions of fluxes from rivers and discharges, and to provide details of their current distribution, sources and sinks. It is particularly important that future sampling programmes incorporate more information on sediment contaminants and their role as diffuse sources. Furthermore, loadings in sediments consist of both anthropogenic and geogenic components, which have yet to be distinguished at most sites. Methods which help to separate these components (and the consequences for bioavailability and re-release) are now becoming practicable and it is recommended that these be applied. Biota should be collected, concurrently, to try to link contaminant loadings and 'speciation' in sediments with their biological consequences.

- Much of the data for bioaccumulation are now 10, or more, years old. The use of a validated suite of common indicator species, at a selection of reference sites, would a useful way of comparing and characterising bioavailability around these systems. Schemes should incorporate infaunal organisms, particularly bivalves and polychaetes, which are capable of reflecting sediment-bound contamination. Furthermore, many sediment-dwelling organisms are essential food items for the important bird species and assemblages for which the sites were designated: the threat posed by bioaccumulation and food chain transfer of, for example, PAHs, PCBs and metals, needs to be quantified in these species, requiring a much more extensive data set.

Alongside targeted chemical monitoring, it is essential to extend biological impacts studies, and to establish cause-effect linkages in the field. In the absence of extensive site-specific biological effects information, we are dependent on comparisons of water-monitoring results with Environmental Quality Standards (EQS) in order to gain a first-order approximation of possible impact on biota. Descriptions of 'risk' to the site, for individual contaminants, are scaled against the relevant EQS, assuming this to be an appropriate threshold for the protection of aquatic life. For a number of reasons, there are bound to be uncertainties surrounding such an empirical approach, particularly under complex environmental conditions: thus although acute biological and ecological effects are unlikely below the EQS, subtle sub-lethal effects are possible. EQS compliance should therefore be seen as an aid to prioritising those sites and conditions in need of closer investigation and does not necessarily assure Favourable Condition. Likewise, current sediment quality criteria are useful initial guidelines to impact, but have yet to be validated and may not necessarily be appropriate for all species or sediment types. Individual site conditions are likely to modify threats considerably, therefore accurate assessments need to be customised to the habitat in question and should be placed in context with chronic responses as well as the acute thresholds upon which many environmental standards are based.

In recent years, a wide range of techniques have been developed to assess sub-lethal biological impact and application of some of these techniques would allow targeted screening of sites, including consented discharges. The current site characterisations would be of obvious value in prioritising the strategy. By selection of an appropriate suite of indicators/biomarkers, sampling could be tailored to establish the causes and extent of damage, and hence to express the condition and vulnerability of the site on a more quantitative basis than is currently possible. Such a scheme would ideally include conventional quantitative ecological survey (for identifying changes in the abundance and diversity of species), together with biochemical, physiological and behavioural biomarkers which signal exposure to, and in some cases, adverse effects of, pollution (see Annex 5 for examples and further details). There are also strong arguments for more fundamental research into how contaminants impact on ecosystem function as a whole, rather than just individual components.

Provided that 'biological-effects' programmes are used in combination with appropriate chemical/biomonitoring procedures (for determining the concentrations and bioavailability of anthropogenic contaminants), in well-designed survey programmes, they would be expected to provide insights into which pollutants are likely to threaten condition, and to quantify the extent of any environmental degradation. They may also be useful in addressing the long-standing problem of additivity/ synergism.

A major criticism of many current statutory monitoring assessments, whether using comparisons with EQS values, sediment quality guidelines, or some other marker, is that they address only single contaminants at a time. Even if individual chemicals do comply with limit values (as most appear to do in each of the south west's marine sites), it does not necessarily mean the environment is healthy. Biological effects may occur if several contaminants act together. The majority of outfalls and sediments contain a particular cocktail of chemicals whose true impact can usually only be assessed through a site-specific evaluation, taking into consideration the interactions that occur between different components and also the local environment. By incorporating biological-effects monitoring, alongside chemical surveillance, it may be possible to make substantial progress towards understanding and managing these complex environmental issues and would provide for more reliable and objective site characterisations in the future (supplementing statutory monitoring). If such an integrated approach were put in place at an early stage, to provide baselines, it would also be amenable for measuring long-term trends in condition - i.e. one of the fundamental goals of the Habitats Directive. Furthermore it would be seen as an important contribution towards the practical application of ecosystem-style management of the marine environment.

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9. ANNEXES

Annex 1. Combined Bibliography

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* SEVERN ESTUARY DATA SET – reports based on data from Hinckley Point Power Station.

Annex 2. Conservation Features & Objectives

Fal and Helford cSAC: Summary of the interest (or qualifying) features, and conservation objectives, (adapted from English Nature, 2000)

Large shallow inlets and bays

Overall objective – Maintain in favourable condition re: extent, water clarity, nutrient status

Subfeatures

- Rocky shore communities
  - maintain extent and distribution
  - maintain species composition of low shore boulder community
  - maintain species composition of rock pools
- Subtidal rock and boulder community
  - maintain distribution
  - maintain composition
- Kelp forest communities
  - maintain algal species composition
  - characteristic species population size
    - *Laminaria spp.*
    - *Distomus* (tunicate)
- Subtidal mud communities
  - Maintain species composition of biotope

Subtidal sandbanks

General objectives – Maintain favourable condition re: extent; sediment character (granulometry); topography; water density

Subfeatures

- Eelgrass bed communities
  - maintain extent and density of beds
  - maintain epiphytic community
  - maintain nutrient status (extent of competing green algal bed)
- Maerl bed communities
  - maintain extent of maerl beds (live and dead)
  - maintain distribution of biotope
  - maintain species composition of communities
  - maintain nutrient status (extent of competing green algal mat)
- Gravel and sand communities
  - maintain species composition
  - maintain characteristic biotopes
- Mixed sediment communities
  - maintain species composition
  - maintain characteristic biotopes

Intertidal mudflats and sandflats

General objectives – Maintain in favourable condition re: extent (area), sediment character (granulometry and compaction), topography, nutrient status (algal mats).

Subfeatures

Mud communities
- maintain extent and distribution of characteristic biotopes

Sand and gravel communities
- maintain extent and distribution of characteristic biotopes

Muddy sand communities
- maintain extent and distribution of characteristic biotopes

Atlantic "Salt Meadows" (Saltmarsh)

General objectives – Maintain favourable condition re: extent; creek patterns, range and distribution of characteristic saltmarsh communities, vegetation structure (height, impact of grazing).

Subfeatures based on zonation

- Low marsh/low mid-marsh communities
  - maintain frequency/abundance of characteristic species
- Mid/mid-upper marsh
  - maintain frequency/abundance of characteristic species

(Annex 2 cont.)

Plymouth Sound and Estuaries cSAC: Summary of the interest (or qualifying) features, and conservation objectives (adapted from English Nature, 2000)

Large shallow inlets and bays

Conservation objective – Maintain in favourable condition re: extent (area), water clarity, density, temperature, salinity

Subfeatures

- Intertidal rock and boulder shore communities
  - maintain relative distribution of biotopes
  - maintain species composition of low shore boulder communities
  - maintain species composition of rock pool communities
- Subtidal rocky reef communities
  - maintain distribution of characteristic biotopes
  - maintain species composition of characteristic biotopes
- Kelp forest communities
  - maintain algal species composition
  - maintain characteristic species population size
  - *Laminari*a spp.
  - *Distomus* (tunicate)
- Subtidal mixed cobble and gravel communities
  - maintain species composition of characteristic biotopes
- Subtidal mud communities
  - maintain species composition of biotopes

Estuaries

Conservation objective – Maintain in favourable condition re: extent (area); "morphological equilibrium" * also of saltmarsh/mudflat, nutrient status

Subfeatures

- Intertidal mud communities
  - maintain extent
- Intertidal mixed muddy sediment communities
  -maintain extent
- Subtidal mud communities
  - maintain extent
- Subtidal mixed muddy sediment communities
  -maintain extent and distribution of biotopes
- Estuarine bedrock, boulder and cobble communities
  - maintain extent and distribution of biotopes
- Saltmarsh communities
  - maintain extent, creek patterns, range and distribution of reed bed and saltmarsh communities

* 'morphological equilibrium' = TP/CS ratio - hydrodynamic measurement
TP = m3 water crossing a given profile during flood tide
CS = area at HW springs

(Changes in TP/CS relationship indicate that anthropogenic factors are taking effect)

Subtidal sandbanks

Conservation objectives – maintain in favourable condition Re: extent (area), sediment character (granulometry), topography (depth and distribution)

Subfeatures

- Eelgrass bed communities
  - maintain extent
  - maintain water clarity
  - maintain characteristic species density (*Zostera marina,* epiphytic communities)
  - nutrient status(monitor extent of competing green algal mat)
- Gravel and sand communities
  - maintain species composition of characteristic biotopes
- Muddy sand communities
  - maintain species composition of characteristic biotopes

...cont.

(Annex 2. cont.)

Plymouth Sound And Estuaries cSAC, SPA: Summary Of The Interest Features

Nationally important Annex 1 bird populations (avocet *Recurcirostra avosetta*)

- Intertidal mudflat communities and mixed muddy sediment communities
  - maintain extent
  -maintain presence and abundance of prey species <15mm (insects, crustaceans small fish, worms)
- Saltmarch communities
  - maintain extent
  - minimise disturbance in feeding/roosting areas
  - maintain numbers of birds

Nationally important Annex 1 bird populations (little egret *Egretta garzetta*)

- Intertidal mudflat communities and mixed muddy sediment communities
  - maintain extent
  -maintain presence and abundance of prey species <15cm (fish, amphibians, large aquatic insects)
- Saltmarch communities
  - maintain extent
  - maintain numbers of birds
  - maintain presence and abundance of prey species <15cm (fish, amphibians, large aquatic insects)
  - minimise disturbance in feeding/roosting areas

Plymouth Sound and Estuaries cSAC, SPA: Summary of additional interest (or qualifying) features, and conservation objectives, proposed since those described in English Nature, 2000

Atlantic salt meadows (*Glauca-Puccinellietalia maritimae)*

- **For which the area is considered to be one of the best areas in the UK**

This habitat encompasses saltmarsh vegetation containing perennial flowering plants that are regularly inundated by the sea. The species found in these salt marshes vary according to duration and frequency of flooding with seawater, geographical location and grazing intensity. Salt-tolerant species, such as common salt marsh grass *Puccinellia maritima*, sea aster *Aster tripolium* and sea arrowgrass *Triglochin maritima*, are particularly characteristic of the habitat.

Reefs

- **For which the area is considered to be one of the best areas in the UK**

Defined as areas of rock or biological concretions formed by various invertebrate species. Reefs occur in the subtidal zone, but may extend onto the shore. They form the habitat for a variety of biological communities such as those characterised by encrusting animals and attached seaweeds.

…cont.

(Annex 2 cont.)

Plymouth Sound and Estuaries cSAC, SPA:Summary Of The Interest Features

Summary of additional interest (or qualifying) features, and conservation objectives, proposed since those described in English Nature, 2000

Mudflats and sandflats not covered by seawater at low tide

- **For which the area is considered to support a significant presence**

These are intertidal mud and sand sediments on a shore that are exposed at low tide but submerged at high tide. Many sites are important feeding areas for waders and wildfowl.

Alosa alosa **(Allis shad)**

- **For which the areais considered to support a significant presence**

The allis shad is a medium-sized fish of coastal waters and estuaries of the western Mediterranean and north-east Atlantic coasts. It spawns in rivers but has beconme rare due to over-fishing, pollution and and obstructions to migration

Rumex rupestris **(shore dock)**

- **For which this is considered to be one of the best areas in the United Kingdom**

Shore dock grows on rocky and sandy beaches, at the foot of cliffs and infrequently in dune slacks where there is a supply of fresh water. It is thought to be the world's rarest dock and is one of the most rare plants in Europe. In the UK it is found only on a small number of sites in south west England and Wales.

(Annex 2 cont.)

Severn Estuary SPA: Summary of the interest (or qualifying) features, and conservation objectives, (adapted from English Nature and Countryside Council for Wales, 2001)

Internationally important populations of regularly occurring Annex 1 bird species (Bewicks swan *Cygnus columbianus bewickii)*

- Maintain numbers as % of GB and NW European population

Habitat

- Intertidal mudflats and sandflats
  - maintain extent

- Saltmarsh
  - maintain extent
  - maintain >25% cover of soft leaved herbs and grasses (*Agrostis stolonifers, Glyceria fluitans, Alopecururs geniculatus*) during winter

Internationally important assemblage of waterfowl (the estuary supports over 20,000 wintering wildfowl)

- Maintain numbers

Habitat

- Intertidal mudflats and sandflats
  - maintain extent
  - maintain presence and abundance of prey species

- Saltmarsh
  - maintain extent
  - maintain abundance of soft leaved and seed bearing plants (*Puccinelli maritima, Saliicornia, Agrostis and Atriplex)*
  - maintain vegetation height of <10cm

- Shingle and rocky shores
  - maintain extent
  -maintain presence and abundance of intertidal invertebrates

Internationally important populations of regularly occurring migratory species (including shelduck, dunlin, redshank, European white-fronted goose, gadwall)

- Maintain numbers

Habitat

- Intertidal mudflats and sandflats
  - maintain extent
  - maintain presence and abundance of prey species

- Saltmarsh
  - maintain extent
  - maintain abundance of soft leaved and seed bearing plants (*Puccinelli maritima, Saliicornia, Agrostis and Atriplex)*
  - maintain vegetation height of <10cm

- Shingle and rocky shores
  - maintain extent
  -maintain presence and abundance of intertidal invertebrates

..cont.

Annex 2. (cont.)

Summary of the interest features for which the Severn Estuary has been recommended as a pSAC

Atlantic salt meadows (*Glauca-Puccinellietalia maritimae)*

- **For which the area is considered to be one of the best areas in the UK**

This habitat encompasses saltmarsh vegetation containing perennial flowering plants that are regularly inundated by the sea. The species found in these salt marshes vary according to duration and frequency of flooding with seawater, geographical location and grazing intensity. Salt-tolerant species, such as common salt marsh grass *Puccinellia maritima*, sea aster *Aster tripolium* and sea arrowgrass *Triglochin maritima*, are particularly characteristic of the habitat.

Mudflats and sandflats not covered by seawater at low tide

- **For which the area is considered to be one of the best areas in the United Kingdom**

These are intertidal mud and sand sediments on a shore that are exposed at low tide but submerged at high tide. Many sites are important feeding areas for waders and wildfowl.

Sandbanks which are slightly covered by seawater all the time

- **For which the area is considered to be one of the best areas in the United Kingdom**

Sandbanks permanently covered by seawater to depths of up to 20 metres below the low water can include muddy sands, clean sands, gravely sands, eelgrass *Zostera marina* beds, and maerl beds (carpets of small, unattached, calcareous seaweed).

Reefs

- **For which the area is considered to support a significant presence**

Defined as areas of rock or biological concretions formed by various invertebrate species. Reefs occur in the subtidal zone, but may extend onto the shore. They form the habitat for a variety of biological communities such as those characterised by encrusting animals and attached sea weeds

Estuaries

- **For which the area is considered to be one of the best areas in the United Kingdom**

Defined in the submission as semi-enclosed bodies of water which have a free connection with the open sea and within which the sea water is measurably diluted by freshwater from the surrounding land. They are usually large features containing a complex range of habitats that reflect the variations in tidal influence and substrate type.

……cont.

Annex 2. (cont.)

Severn Estuary pSAC: Summary of the interest features for which the Severn Estuary has been recommended as a pSAC.

Alosa alosa **(Allis shad)**

- **For which the area is considered to support a significant presence**

The allis shad is a medium-sized fish of coastal waters and estuaries of the western Mediterranean and north-east Atlantic coasts. It spawns in rivers but has become rare due to over-fishing, pollution and obstructions to migration.

Alosa fallax **(Twaite shad)**

- **For which the area is considered to be one of the best areas in the United Kingdom**

The twaite shad is a fish that occurs in western European coastal waters. It enters lower reaches of rivers to spawn It has beconme rare due to over-fishing, pollution and obstructions to migration

Lampetra fluviatilis **(River lamprey)**

- **For which the area is considered to be one of the best areas in the United Kingdom**

The river lamprey is a primitive jawless fish resembling an eel. Confined to western Europe, it migrates from the sea to spawn in silt beds of many rivers in the UK. One population in the UK is, however, known to live entirely in freshwater. The river lamprey is absent from some rivers because of pollution and barriers to migration.

Petromyzon marinus **(Sea lamprey)**

- **For which the area is considered to be one of the best areas in the United Kingdom**

The sea lamprey is a primitive jawless fish resembling an eel. It is the largest of the lampreys found in the UK. It inhabits north Atlantic coastal waters and migrates to spawn in rivers. It has widespread distribution within the UK, although populations have declined due to pollution and barriers to migration.

Annex 2. (cont.)

Poole Harbour Spa: Summary of the Interest Features and Conservation Objectives, (adapted from English Nature, 2001)

Internationally important populations of regularly occurring Annex 1 bird species (avocet, mediterranean gull, common tern*)*

- Maintain numbers by avoidance (no increase) in disturbance to feeding , roosting and nesting areas: maintain absence of obstructions to view lines

Habitats

- Shallow inshore waters
  - maintain extent and distribution of habitat and food avilability (avocets - marine insects, crustaceans, molluscs, fish and worms; common tern – sandeel, sprat, crustacea and annelids; Med.gull –crustaceans, nnelids, gobies, molluscs)
- Intertidal sediment communities
  - maintain extent and distribution and thus food for avocets and gulls
- Saltmarsh
  - maintain extent and distribution and thus food supply for avocets and gulls
  - maintain vegitation characteristics(<10cm height) for roosting avocets, terns and gulls

Internationally important assemblage of waterfowl (dunlin, cormorant, dark-bellied brent geese, teal, goldeneye, red-breasted merganse, curlew, spotted redshank, greenshank, redshank, black-headed gull) including the internationally important populations of regularly occurring migratory species (shelduck and black-tailed godwit). The estuary supports over 20,000 wintering wildfowl

- Maintain numbers by avoidance (no increase) in disturbance to feeding, roosting and nesting areas: maintain absence of obstructions to view lines

Habitats

- Shallow inshore waters including lagoons
  - maintain extent and distribution of habitat and food avilability (includes mussels, cockles, *Hydrobia, Carcinus*, small fish, *shrimps, nereis*)
- Intertidal sediment communities
  - maintain extent and distribution of habitat and food availability (including *Nereis, Hydrobia, Corophium, Macoma, Cardium,Crangon, Carcinus, Littorina, Gammarus, Arenicola*, small fish, *Zostera* and *Enteromorpha*)*.
  - maintain absence of obstructions to view lines
- Saltmarsh
  - maintain extent and distribution of habitat and food availability * (above species, together with *Salicornia, Atriple, Spegularia,Puccinellia, Triglochin, Aster, Plantego*)
  - maintain vegitation characteristics (<10cm height) i.e. absence of obstructions to view lines
- Reedbeds
  - maintain extent and distribution of habitat
  - maintain presence and abundance of intertidal invertebrates (e.g. *Nereis, Corophium, Hydrobia*).

Annex 2. (cont.)

Exe Estuary Spa: Summary of the Interest Features and Conservation Objectives, (adapted from English Nature, 2001)

Internationally important populations of regularly occurring Annex 1 bird species (avocet *Recurvirostra avosetta*), Slavonian Grebe (*Podiceps auritus*)

- Maintain numbers by avoidance (no increase) in disturbance to feeding , roosting and nesting areas: maintain extent/distribution of habitats (Avocets – mudflats, Slavonian Grebe - shallows)

Habitats

- Mudflat and sandflat communities
  - maintain absence of obstructions to view lines and food avilability (avocets – *Gammarus, Corophium, Hydrobia, Cerastoderma, Nereis,* fish i.e. Gobies)
- Saltmarsh communities
  - maintain absence of obstructions to view lines
- Shallow coastal waters
  - maintain food availability (Slavonian Grebe – marine/freshwater fish e.g. gobies, stickleback, scupins, aquatic invertebrates e.g molluscs, crustaceans, insects

Internationally important assemblage of waterfowl (Oystercatcher, Grey plover, Black-tailed godwit, Dunlin) including the internationally important population of regularly occurring migratory species (Dark-bellied brent goose) The estuary supports over 20,000 wintering wildfowl

- Maintain numbers by avoidance (no increase) in disturbance to feeding , roosting and nesting areas: Maintain extent and distribution of habitat (all require extensive mud/sandflats; Brent geese and wigeon require saltmarsh and seagrass; oystercatcher, dunlin and knot require large extent of intertidal and subtidal boulder and cobble scar)

Habitats

- Mudflat and sandflat communities
  - maintain food avilability (waders e.g. dunlin, black-tailed godwit, grey plover, oystercatcher require range e.g. *Gammarus, Corophium, Hydrobia, Cerastoderma, Nereis*) brent geese and wigeon require *Enteromorpha and Ulva*
- Saltmarsh communities
  - maintain food avilability (brent geese and wigeon need soft-leaved and seed-bearing-plants) waders (dunlin, black-tailed godwit, grey plover, oystercatcher) need invertebrates (as above)
  - maintain absence of obstructions to view lines
- Seagrass bed communities
  - (brent geese and wigeon require e.g. *Zostera*, waders prefer invertebrates – see above)
  - maintain absence of obstructions to view lines
- Intertidal and Subtidal boulder and cobble scar communities
  - maintain food avilability (oystercatcher, dunlin, knot feed on molluscs e.g *Mytilus*)
  - maintain absence of obstructions to view lines

Annex 2. (cont.)

Chesil And The Fleet cSAC, SPA: summary of the interest features and conservation Features, (adapted from English Nature, 1999)

Under the Habitats directive

Lagoons

For which the area is considered to be the largest and supporting the greatest diversity of habitats and species in the UK.

Conservation objectives focus on maintaining attributes such as extent, water clarity, salinity regime, nutrient status (no increase in algal mats), algal grazers (*Rissoa membranacea*), indicators of nutrient status -foxtail stonewort (*Lamprothamnium papulosum*), fish species assemblages.

Maintaing the extent and species composition of the following sub-featuresare an integral objective:

- seagrass bed communities (area and density of *Zostera* and *Ruppia*)
- Tide swept communities (nb species composition at the mouth)
- Sub-tidal coarse sediment communities; gravel, cobbles pebbles(nb *Anemonia viridis*).
- Inter-tidal sediment communities
- shingle springline communities)

Annual vegetation of drift lines

Selected of one of two representatives on the south coastis considered to be subject to little anthropogenic influence.

Conservation objectives focus on maintaining attributes such as extent and absence of landward constraints.

Maintaing the extent and species composition of the following sub-featuresare an integral objective:

- *Beta vulgaris maritima* (sea beet) - *Atriplex* (orache) community
- *Honkenya peploides* (sea sandwort) - *Cakile maritima* (sea rocket) community

Mediterranean and thermo-atlantic halophilious scrub

For which the area contains a major concentration and is the western limit in the United Kingdom

Conservation objectives focus on maintaining attributes such as extent and absence of landward constraints

Maintaing the extent of of the following sub-feature is the principle objective:

- *Suaeda vera* (sea blight) saltmarsh community. *S. vera,* together with *Atriplex portulacoides* (sea-purslane) lines much of the lagoon above the tidal limit and is in dynamic equilibrium with the sea beet dominated frift-line vegitation described above. The latter tends to replace the scrub community when disturbed by waves and erosion and is in turn displaced by scrub after disturbance ceases.

….cont.

Annex 2 (cont.)

Chesil and the Fleet cSAC, SPA: summary of the interest features and conservation features, (adapted from English Nature, 2000)

Perennial vegetation of stony banks

For which this is considered to be one of the best areas in the United Kingdom

Coastal shingle vegetation outside the reach of waves. This encompasses a widw range of vegetation found on coastal shingle outside the reach of waves. It includes the open pioneer stages cloe to the limit of the tide, in which there are a number of specialised flowering plants , such as yellow horned-poppy *Glaucium flavum*. It also includes the grasslands, heath, scrub and moss- and lichen dominated vegetation of very old, stable shingle further inland.

Additional proposed interest

European interest:

Atlantic salt meadows (*Glauca-Puccinellietalia maritimae)*

- **For which the area is considered to support a significant presence**

This habitat encompasses saltmarsh vegetation containing perennial flowering plants that are regularly inundated by the sea. The species found in these salt marshes vary according to duration and frequency of flooding with seawater, geographical location and grazing intensity. Salt-tolerant species, such as common salt marsh grass *Puccinellia maritima*, sea aster *Aster tripolium* and sea arrowgrass *Triglochin maritima*, are particularly characteristic of the habitat.

Annex 3. Water Quality Standards

List I substances

Parameter	Unit	Water quality standard		Standstill Provision [a]
		Estuary[b]	Marine	
Mercury	μg Hg/l	0.5 DAA	0.3 DAA	yes[c]
Cadmium	μg Cd/l	5 DAA	2.5 DAA	yes
Hexachlorocyclohexane[d]	μg HCH/l	0.02 TAA	0.02 TAA	yes
Carbon tetrachloride	μg CCl_4/l	12 TAA	12 TAA	no
Dichlorodiphenyltrichloroethane				
(all 4 isomers, total DDT)	μg DDT/l	0.025 TAA	0.025 TAA	yes
(para, para-DDT)	μg ppDDT/l	0.01 TAA	0.01 TAA	yes
Pentachlorophenol	μg PCP/l	2 TAA	2 TAA	yes
Total □drins□	μg/l	0.03 TAA	0.03 TAA	yes
Aldrin	μg/l	0.01 TAA	0.01 TAA	yes
Dieldrin	μg/l	0.01 TAA	0.01 TAA	yes
Endrin	μg/l	0.005 TAA	0.005 TAA	yes
Isodrin	μg/l	0.005TAA	0.005 TAA	yes
Hexachlorobenzene	μg HCB/l	0.03 TAA	0.03 TAA	yes
Hexachlorobutadiene	μg HCBD/l	0.1 TAA	0.1 TAA	yes
Chloroform	μg $CHCl_3$/l	12 TAA	12 TAA	no
1,2-Dichloroethane (ethylenedichloride)	μg EDC/l	10 TAA	10 TAA	no
Perchloroethylene (tetrachloroethylene)	μg PER/l	10 TAA	10 TAA	no
Trichlorobenzene (all isomers)	μg TCB/l	0.4 TAA	0.4 TAA	yes
Trichloroethylene	μg TRI/l	10 TAA	10 TAA	no

Notes
Substances are listed in the order of publication of Directives.
D dissolved concentration, ie usually involving filtration through a 0.45-μm membrane filter before analysis
T total concentration (ie without filtration).
AA standard defined as annual average

[a]Most directives include, in addition to the standards for inland, estuary and marine waters, a provision that the total concentration of the substance in question in sediments and/or shellfish and/or fish must not increase significantly with time (the "standstill" provision).
[b]In the UK the standards for estuaries are the same as for marine waters - The Surface Waters (Dangerous Substances) (Classification) Regulations 1989
[c]In addition to a standstill provision applying to sediments or shellfish there is a further environmental quality standard of 0.3 mg Hg/kg wet flesh "in a representative sample of fish flesh chosen as an indicator".
[d]All isomers, including lindane

continued….

Annex 3 (cont.) Water quality standards for the protection of saltwater life for List II substances

Parameter	Unit	Water Quality Standard (see footnotes)
Lead	µg Pb/l	25 AD[1,5]
Chromium	µg Cr/l	15 AD[1,5]
Zinc	µg Zn/l	40 AD[1,5]
Copper	µg Cu/l	5 AD[1]
Nickel	µg Ni/l	30AD[1]
Arsenic	µg As/l	25AD[2]
Boron	µg B/l	7000 AT[1]
Iron	µgFe/l	1000AD[1,5]
Vanadium	µgV/l	100 AT[1]
Tributyltin	µg/l	0.002 MT[2]
Triphenyltin (and its derivatives)	µg/l	0.008 MT[2]
PCSDs	µg/l	0.05 PT[1]
Cyfluthrin	µg /l	0.001 PT[1]
Sulcofuron	µg /l	25 PT[1]
Flucofuron	µg /l	1.0 PT[1]
Permethrin	µg /l	0.01 PT[1]
Atrazine and Simazine	µg /l	2 AA[2] ; 10 MAC[4]
Azinphos-methyl	µg /l	0.01AA[2] ; 0.04 MAC[4]
Dichlorvos	µg /l	0.04 AA and 0.6 MAC[2]
Endosulphan	µg /l	0.003 AA[2]
Fenitrothion	µg /l	0.01 AA[2]; 0.25 MAC[4]
Malathion	µg /l	0.02AA[2] ; 0.5MAC[4]
Trifluralin	µg /l	0.1AA[2]; 20 MAC[4]
4-chloro-3-methyl phenol	µg /l	40 AA[3]; 200 MAC[4]
2-chlorophenol	µg /l	50 AA[3] ; 250 MAC[4]
2,4-dichlorophenol	µg /l	20 AA[3]; 140 MAC[4]
2,4D (ester)	µg /l	1 AA[3]; 10 MAC[4]
2,4D	µg /l	40 AA[3]; 200 MAC[4]
1,1,1 trichloroethane	µg /l	100 AA[3]; 1000 MAC[4]
1,1,2-trichloroethane	µg /l	300 AA[3]; 3000 MAC[4]
Bentazone	µg /l	500 AA[3]; 5000 MAC[4]
Benzene	µg /l	30 AA[3]; 300 MAC[4]
Biphenyl	µg /l	25 AA[3]
Chloronitrotoluenes	µg /l	10 AA[3]; 100 MAC[4]
Demeton	µg /l	0.5 AA[3]; 5 MAC[4]
Dimethoate	µg /l	1 AA[3]
Linuron	µg /l	2 AA[3]
Mecoprop	µg /l	20 AA[3]; 200 MAC[4]
Naphthalene	µg /l	5 AA[3]; 80 MAC[4]
Toluene	µg /l	40 AA[3]; 400 MAC[4]
Triazophos	µg /l	0.005 AA[3]; 0.5 MAC[4]
Xylene	µg /l	30 AA[3]; 300 MAC[4]

Notes There are large uncertainties in the derivation of many of these standards especially for marine species (most values are extrapolated from freshwater studies : Details can be obtained from the relevant EQS derivation reports

A = annual ; **D**= dissolved concentration, ie usually involving filtration through a 0.45-µm membrane filter
T = total concentration (ie without filtration)**AA** = annual average ; **MAC** = maximum concentration
[1] DoE Circular in 1989 (Statutory standard)
[2] Statutory Instrument 1997 (Statutory standard)
[3] Statutory Instrument 1998 (Statutory standard)
[4] Non- statutory standard
[5] revised standards have been proposed but are not statutory

Annex 4. Sediment Quality Guidelines

Interim marine sediment quality guidelines (ISQGs) and probable effect levels (PELs; dry weight) [1]: metals and organics

Substance	ISQG	PEL
Inorganic (mgkg^{-1})		
Arsenic	7.24	41.6
Cadmium	0.7	4.2
Chromium	52.3	160
Copper	18.7	108
Lead	30.2	112
Mercury	0.13	0.70
Zinc	124	271
Organic (µgkg^{-1})		
Acenaphthene	6.71	88.9
Acenaphthylene	5.87	128
Anthracene	46.9	245
Aroclor 1254	63.3	709
Benz(a)anthracene	74.8	693
Benzo(a)pyrene	88.8	763
Chlordane	2.26	4.79
Chrysene	108	846
DDD[2]	1.22	7.81
DDE[2]	2.07	374
DDT[2]	1.19	4.77
Dibenz(a,h)anthracene	6.22	135
Dieldrin	0.71	4.30
Endrin	2.673	62.4[4]
Fluoranthene	113	1 494
Fluorene	21.2	144
Heptachlor epoxide	0.60[3]	2.74[4]
Lindane	0.32	0.99
2-Methylnaphthalene	20.2	201
Naphthalene	34.6	391
PCBs, Total	21.5	189
Phenanthrene	86.7	544
Pyrene	153	1 398
Toxaphene	1.5[3]	nd[5]

[1] from CCME, (1999)
[2] Sum of *p,p´* and *o,p´* isomers.
[3] Provisional; adoption of freshwater ISQG.
[4] Provisional; adoption of freshwater PEL.
[5] No PEL derived.

Annex 5. Examples Of Recommended Biomonitoring Techniques

Immunotoxicity Assays – these assays measure the immunocompetence of haemocytes from invertebrates, reflecting both the extent of exposure to immunotoxins and the general well-being of the test organism

EROD (ethoxyresorufin-O-deethylase) is a marker for the activity of the mixed function oxidase (MFO) system, whose induction is usually associated with exposure to, and the detoxification of xenobiotics such as PAHs and PCBs. Occasionally these transformations may produce deleterious side effects due to the formation of carcinogenic or genotoxic compounds (e.g. the formation of benzo(a) pyrene diol epoxide from benzo(a) pyrene).

Metallothionein (MT) induction and associated changes in metal metabolism are specifically induced by metals and are sufficiently sensitive to be used to detect elevated levels of bioavailable metal in the field or arising from metals in discharges.

Genotoxicity- - The single cell gel-electrophoresis (comet) assay is ideal for screening for possible genotoxicity associated with point-source and diffuse inputs to the system.

The CAPMON technique - Cardiac activity in bivalve molluscs and decapod crustaceans – Heart rate provides a general indication of the metabolic status of mussels and crabs. The CAPMON technique permits the non-invasive, continuous monitoring of cardiac activity using infra-red sensors attached to the shell.

Tolerance Studies - More widespread investigations of community tolerance to establish the extent of adaptation to contamination levels. Mapping the genetic composition of tolerant populations of individual species (*Hediste, Littorina* and others) in relation to induction of detoxification systems (such as EROD and metallothionein) should also be considered. Responses to anticipated improvements in environmental quality (arising from planned schemes) might be better predicted by testing this approach.

Toxicity Studies on sensitive species - Toxicity has been studied in a relatively small number of species to date. It would be useful to examine subtle sublethal-effects in some of the less well represented and perhaps sensitive species and communities of important conservation status. Also to include sediment bioassays in order to look at growth and survival of juvenile bivalves. Compare responses in biota from different sites to look for signs of adaptation.

Multivariate Statistical Analysis of biota and environmental variables in order to examine spatial and temporal trends in communities in relation to contaminants

It is stressed that the above procedures have been selected primarily with regard to their ease of use, low cost and relevance to known environmental problems. Ideally, any components used in monitoring schemes need to be synchronised and run in tandem to achieve best value and to provide the most useful information on causal links and mechanisms. Results should help to characterise, quantitatively, the health of marine sites and to identify those consents and activities which most require attention (or show signs of improvement). Hopefully may they may also help to formulate the best options for remedial action where this is shown to be needed.

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