Natural England Research Report NERR090

Condition review of Chichester Harbour sites: intertidal, subtidal and bird features

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J. Brooksbank, A. Giacomelli, Dr A. Marlow and E. Webster

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Lead surveyors: Janet Whitman (Field Unit), Sue Rees, Carole Mortimer, Rachael Mills (Field Unit), Vicky Gilson (Field Unit).

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Executive Summary (Non-technical)

Chichester Harbour is one of the most important sites for wildlife in the United Kingdom and is globally important for migratory birds. The harbour is designated as a Site of Special Scientific Interest (SSSI), Special Area of Conservation (SAC) and Special Protection Area (SPA) for birds. A combination of a desk-based evidence reviews and field survey for saltmarsh in 2019 were undertaken by Natural England to assess whether the harbour's special habitats and species (known as notified features) were flourishing – or as we describe features of designated sites: in favourable condition. The report reviews the historic trends in populations and condition of notified features, discusses whether the existing conservation actions are appropriate, and identifies what changes are required to improve the site and its features back to favourable condition.

A summary of the key findings and recommendations from the review (for further study, survey and conservation action) are provided below.

Saltmarsh

Aerial photographs from the two 2008 and 2016 were reviewed for extent of saltmarsh and compared to previous assessments to provide the trend in area of saltmarsh from 1946 to 2016. During this period, 58% of saltmarsh habitat area was lost overall, with loss of almost half (46%) of that present when the site first became legally protected (1970). The saltmarsh was in unfavourable condition at the time of first designation as the saltmarsh losses in the 1960's were approximately 18 hectares a year. The rate of loss has slowed, however, on average 2.54 hectares (the equivalent of more than 3 football pitches in area) of saltmarsh is still being lost every year across Chichester Harbour. At the current rate of decline the site could lose all its remaining saltmarsh habitat by the middle of the next century.

In 2019, field surveys of six transects were undertaken across the largest areas of remaining saltmarsh. Several rare species were still present and even locally abundant showing the continued ecological value of the remaining saltmarsh. However, all six sites that were surveyed on foot were experiencing impacts from inappropriate coastal management, including coastal squeeze, to some extent on their landward edge. Opportunistic macroalgae (a sign of nutrient enrichment) was observed at all the land-based survey locations. No transects met the requirement for favourable condition for flourishing saltmarsh habitat. As a result, all SSSI units with saltmarsh at designation were assigned to unfavourable declining condition, totalling 3,003 hectares.

Birds

The wintering populations of birds in Chichester Harbour vary in their trends over time but on average the assemblage is in unfavourable condition as numbers of many species have declined, some species dramatically so (>70% long term). Nevertheless, the site remains nationally important for nine wintering species and internationally important for dark-bellied brent geese and black-tailed godwit. The national populations of four of the notified wader species have shifted range in response to climatic factors, which explains part of the declines seen. However, there are additional site-specific factors affecting these and the other bird species, including disturbance, pressures on high tide roosts and poor quality of habitat (opportunistic macroalgae). Consequently, some of the birds whose populations are doing well are species which can switch their foraging habitats away from the main intertidal area such as brent geese.

Nesting terns are in unfavourable declining condition because nesting Sandwich tern numbers have declined to zero, little tern numbers have declined dramatically and the number of their chicks per nest successfully fledging is at or close to zero. A range of complex factors including predation (both mammalian and avian), habitat changes and climate change (sea level rise and increased stormininess) are the causes, despite concerted conservation action taken by the Chichester Harbour Conservancy (CHC) as site managers. However, there have been recent successes for common terns using artificial rafts deployed by CHC at Thorney Deeps, which if this continues will enable the population to recover.

Other intertidal habitats

Intertidal habitats – general and opportunistic macroalgae

The data on intertidal habitats' sediment type and the invertebrates that use it (biotopes) was reviewed based mainly on an analysis undertaken under contract in 2016. The data is of variable quality. For this reason, the current assessment should not replace the SAC wide assessment for overlapping features. Opportunistic macroalgae is an indicator of nutrient enrichment and high percentage coverage impacts bird prey and the habitat. Percentage coverage of opportunistic macroalgae was reviewed in 2011, 2014 and 2018, and assessed in each harbour arms and in the middle and outer harbour edges. Coverage varied from year to year and spatially but most of the harbour had too much opportunistic macroalgae in both 2011 and 2018. Only the outer harbour was not impacted by opportunistic macroalgae in all three years.

Intertidal and sub-tidal habitats – eelgrass

The historic data from a number of sources, including scientific literature on water quality impacts, was reviewed. There is no field survey of all the harbour's eelgrass in any one year. The review raised considerable doubt about the validity of previously used baseline data for the harbour. The SSSI baseline extent should be changed to at least between 130 and 220 hectares as a minimum for favourable condition for this sub-feature. This feature was assigned unfavourable as a provisional assessment, with a very low confidence due to the absence of reliable baseline data and was not used to change mapped condition of the SSSI. The current assessment should not replace but only supplement the SAC wide assessment for the overlapping features.

Water quality

Only the inorganic components of nitrogen; dissolved inorganic nitrogen (DIN) and orthophosphate were assessed. DIN and orthophosphate vary seasonally, yearly and spatially within the harbour. Most of the nutrients are taken-up in the harbour by the opportunistic macroalgae growth and by the wider catchment (in summer months) where both DIN and orthophosphate values drop, the former to below detectable limits in summers back to 1995. Winter peaks of DIN show no apparent overall trends across the harbour as a whole but increase during wet winters and springs. There are some localised declines in particular at Langstone Bridge where declines occur shortly after the removal of the Budds Farm wastewater treatment works (WwTW) discharge from the adjacent Langstone Harbour.

The winter DIN values do vary between areas of the harbour with a trend of increasing values from west to east and from the outer harbour towards the upper harbour arms. The highest mean winter value is from Fishbourne Channel, which has nearly six times higher (598%) values of nitrogen than the lowest value of $0.25 mgl^{-1}$ at Fisheries Buoy in the west of the main harbour. The conservation measures (such as Catchment Sensitive Farming and WwTWs improvements) that have occurred in the catchment may be reducing DIN values in parts of the harbour, but the picture is complex, and the localised reductions are not sufficient for the wildlife to recover. The best remaining saltmarsh habitat and the largest eelgrass beds are in areas with lower nitrogen.

Condition summary

Overall, the main intertidal habitats and bird features are assessed as unfavourable declining condition largely due to the continued loss of saltmarsh, the poor quality of saltmarsh and mudflat habitat, and the continued decline of several bird species (wintering and nesting). The summary condition following this review is:

Summary of the condition of Chichester Harbour SSSI (of all the saltmarsh and bird designated features within the SSSI)

Designated sites condition following 2019/20 review	Area in hectares (%)
Favourable	252.91 (6.77)
Unfavourable Recovering	115.83 (3.10)
Unfavourable No change	361.62 (9.69)
Unfavourable Declining	3003.17 (80.44)

Summarised recommendations for conservation action

- Restore saltmarsh habitat within Chichester Harbour to achieve at least the 552 hectares area at SSSI designation. This could begin with climate change safeguarding policies to help protect low lying land around the harbour for future saltmarsh restoration. Opportunities to recreate saltmarsh habitat should then be identified e.g. realigning sea defences. An additional 257 hectares of saltmarsh from the current level is initially needed to restore it back to recovering, and as the habitat structure evolves then to favourable condition.
- Remove barriers to coastal change caused from inappropriate coastal management including coastal squeeze, which are resulting in saltmarsh erosion and interrupting sediment supply.
- Identify low nutrient sources of sediment into the harbour, particularly mud sediment, if removing the structures does not restore the sediment supply.
- Maintain current actions and identify additional measures to reduce nitrogen into the harbour and the wider Solent including, depending on source apportionment, reducing nitrogen inputs from urban and rural diffuse (planning and farming), from atmospheric deposition and from point sources (mainly wastewater treatment works).
- Work with partners to understand the baseline condition of small fish (prey) populations in the harbour and whether this is influencing tern productivity.
- Significantly increase efforts to improve tern populations, e.g. creating more tern rafts (to improve nesting success rates) and predator management where necessary.
- In partnership investigate the feasibility of creating a network of sites that are less susceptible to tidal flooding by creating suitable raised shingle beaches at Stakes Island.
- Where feasible, include creation of islands for breeding terns and high tide roosts when designing coastal habitat creation schemes.
- Work with partners to continue to identify and manage sources of disturbance to birds.
- Improve monitoring and data collection, to include (if possible) assessing source apportionment at a smaller spatial scale related to the harbour's interest features and increase the frequency of saltmarsh assessment.
- In partnership, implement a second phase of the project, subject to resources, to address identified evidence gaps and provide simple clear messages for stakeholders and the general public on how to help restore the harbour's wildlife.

Contents

Appendices

List of tables

List of figures

1 Conservation designations, features and interests

The area of interest for this report, commonly known as Chichester Harbour, is located on the south coast of England and is the largest designated area within the National Character Area 126 the South coast plain[1]. The Solent and its harbours are unique in Britain and Europe for its double tide as well as the complexity of the marine and estuarine habitats in the area (Solent Maritime SAC Citation). Chichester Harbour is the largest of the eight estuaries designated within the Solent Maritime Special Area of Conservation (SAC), it is at the far eastern margin of the SAC, and, as such, it has a particularly important role to play with the Solent's wider ecology. The following nationally and internationally important and locally designated sites overlap with Chichester Harbour, demonstrating its importance both nationally and globally for its coastal ecosystems and the services they provide:

- Chichester Harbour Site of Special Scientific Interest (SSSI)
- Chichester and Langstone Harbours Special Protection Area (SPA)
- Chichester and Langstone Harbours Ramsar site
- Solent and Dorset Coast SPA
- Solent Maritime Special Area of Conservation (SAC)
- Chichester Harbour Area of Outstanding Natural Beauty (AONB)
- Chichester Harbour Amenity Area – designated under the 1971 Chichester Harbour Conservancy Act
- Nutbourne Marshes, Pilsey Island and Thorney Deeps Local Nature Reserves
- West Wittering Bathing Water
- Chichester Harbour Shellfish Waters (Chichester Channel, Thornham Channel and Emsworth Channel).

[1] Links work at the time of publication. References provided in links are not repeated in the refrence section.

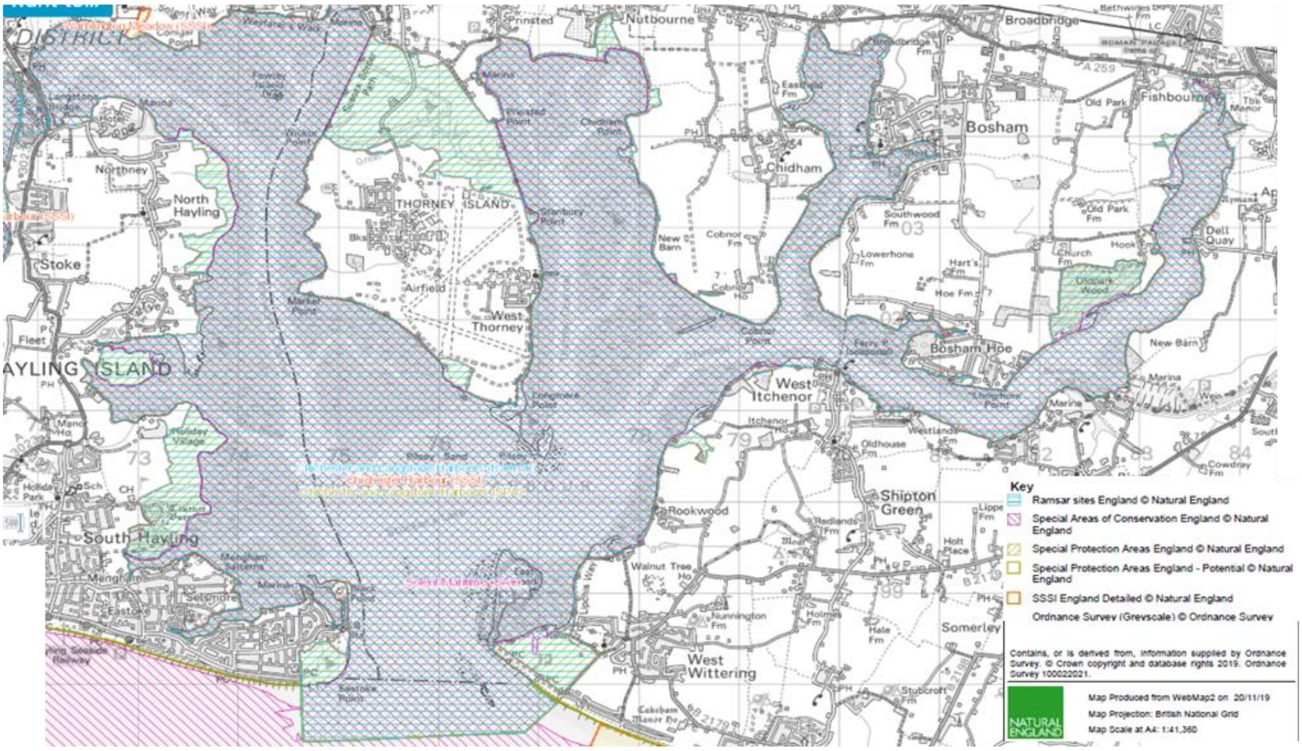


Figure 1.1 Chichester Harbour's ecological protected sites

A map of the landscape designations and other designations can be viewed online.

Natural England undertakes periodic monitoring of protected sites to assess whether the features of interest for which the site is notified are meeting their conservation objectives. If all the interest features are meeting their objectives, then a site is considered to be in favourable condition. The requirements for SACs and SPAs are set out in conservation objectives as prescribed in the Conservation of Habitats and Species Regulations 2017 (as amended). Links to these for the relevant designations are provided in table 1.1 which also sets out the designated site features and the current condition (**prior to this review**) of each site in more detail. Links to the citations, conservation objectives and favourable condition tables are also provided in table 1.1.

Site Improvement Plans (SIPs) have been developed for each Natura 2000 site (a network of nature protection areas with European designation; SACs and SPAs) in England. The plans provide a high-level overview of the issues (both current and predicted) affecting the condition of the Natura 2000 features on the site(s) and outlines the priority measures required to improve the condition of the features. The issues highlighted in the Solent SIP which apply to Chichester Harbour are listed below, with those that are focussed on in this report in bold:

- Public access and disturbance
- **Coastal squeeze**
- Fisheries commercial marine and estuarine
- **Water pollution**
- **Changes in species distribution**
- **Climate change**
- **Change to site conditions**
- Invasive species
- Direct land take from development
- Biological resource use
- Change in land management

- Inappropriate pest control
- Air pollution: impact of atmospheric nitrogen deposition
- Hydrological changes
- Direct impact from 3rd parties
- Extraction non-living resources
- Other (need to consider offsite habitat).

1.1 Objective of this report

The objective of this report is to review the evidence base for the intertidal (and some subtidal) features (including birds) of the Chichester Harbour designated sites:

- To assess their current condition.
- To assess the trend in condition (recovering, no change or declining).
- To identify significant evidence gaps that cannot be filled by available data and identify further study.
- To discuss the appropriateness of standards and or existing remedies and identify the likelihood that favourable condition will be achieved based on the current trajectory and in the light of climate change.
- Make recommendations for actions to reach favourable condition of the site features including recommendations for improving the evidence base (SIPs, Favourable Condition Tables (FCTs), and Supplementary Advice on Conservation Objectives (SACOs)), improving standards or changing available remedies where necessary. This will allow the site to make a significant contribution towards the favourable conservation status of these intertidal habitats, an objective for the Habitats Directive implemented in UK law by Conservation of Habitats and Species Regulations 2017 (as amended).

Table 1.1 Designated site condition and features

Designated site	Pre-review site condition and objectives[2] 31/01/2020	Summary of designated features
Chichester Harbour SSSI	Favourable (15.26%) 569.79 ha Unfavourable recovering (8.09%) 132.99 ha Unfavourable no change (74.64%) 3,030.75 ha Unfavourable declining (0%) 0 ha	The SSSI Citation shows the interest features which can be summarised as follows: • Aggregations of breeding terns • Aggregations of non-breeding birds • Assemblages of breeding birds - Mixed lowland damp grassland, scrub woodland species • Coastal vegetated shingle (SD1-3) • Lowland fens, including basin floodplain, open water transition and valley fens • Lowland and mixed deciduous woodland • Lowland and Neutral grassland (MG5) • Sand dune strand line, embryo and mobile dunes (SD1-6)

[2] The data was downloaded from various websites and Natural England's sites data base on 14/05/2019 any changes since then are not reflected in this table.

Designated site	Pre-review site condition and objectives[2] 31/01/2020	Summary of designated features
	Favourable condition tables (FCTs)[3]	• Saltmarsh (SM4 – 28) • Coastal Geomorphology.
Chichester and Langstone Harbours SPA	Conservation objectives Supplementary advice Site Improvement Plan	The SPA Citation shows the interest features which can be summarised as follows: • Waterbird assemblage • Non-breeding populations of A046a Dark-bellied brent goose, A048 Common shelduck, A052 Eurasian teal, A054 Northern pintail, A056 Northern shoveler, A069 Red-breasted merganser, A137 Ringed plover, A141 Grey plover, A144 Sanderling, A149 Dunlin, A157 Bar-tailed godwit, A160 Eurasian curlew, A162 Common redshank, A169 Ruddy turnstone, A050 Wigeon • Breeding populations of A191 Sandwich tern, A193 Common tern, A195 Little tern.
Chichester and Langstone Harbours Ramsar Site	Not available separately (combined with SPA)	The Ramsar site information sheet shows the interest features, which has not been updated since 1999: • Two large estuarine basins • Intertidal mudflats • Eelgrass • Saltmarsh • Sand and shingle spits • Dunes supporting reed beds and some grassland • Numbers of wintering waterbirds regularly exceed 20,000 individuals and include internationally and nationally important numbers of several species.
Solent Maritime SAC	Conservation objectives Supplementary advice Site Improvement Plan Marine condition	The Nature 2000 Standard data form, and the JNCC site description and SAC Citation provide the designation details. Features can be summarised below: • H1110 Sandbanks which are slightly covered by sea water all the time • H1130 Estuaries • H1140 Mudflats and sandflats not covered by seawater at low tide • H1150 Coastal lagoons • H1210 Annual vegetation of drift lines • H1220 Perennial vegetation of stony banks • H1310 Salicornia and other annuals colonising mud and sand • H1320 *Spartina* swards (*Spartinion maritimae*) • H1330 Atlantic salt meadows (*Glauco-Puccinelliletalia maritimae*)

[3] Now superseded by SACOs and out of date with regards to water quality guidance.

Designated site	Pre-review site condition and objectives[2] 31/01/2020	Summary of designated features
		• H2120 Shifting dunes along the shoreline with *Ammophila arenaria* ('White dunes') • S1016 Desmoulin's whorl snail *Vertigo moulinsiana* (NB thought to have gone from the harbour site).
Solent and Dorset Coast SPA	N/A	This SPA was classified in January 2020 so at present only the consultation package is available online. Confirmed interest features are: • Foraging habitat of breeding populations of common tern, little tern and Sandwich tern.
West Wittering bathing water	WFD standards Bathing Water Profile	Not in the harbour but just outside of harbour.
Chichester Harbour shellfish waters (x3)	Bacterialogical assessment	The shellfish waters sit in the Chichester Harbour water body (GB580705210000), with an overall water body status in the latest assessment (2016) of moderate.
WFD water body	Chichester Harbour Moderate	Transitional heavily modified water body. Overall water body status and the ecological status has been moderate since 2013. GB580705210000.

2 Policy context and Natural England condition assessments

The role of Natural England and the legislative drivers for protecting and restoring Chichester Harbour are described in Appendix 1. Natural England's Conservation 21 Strategy aims to create resilient landscape and seas, grow natural capital and put people at the heart of these environmental improvements. Protected sites, especially those on the coast, are critical for these three objectives as the coast is often the only place people regularly access marine wildlife. The UK Marine Strategy sets out how we will achieve the vision of clean, healthy, safe, productive and biologically diverse oceans and seas using a 3-stage framework for achieving good environmental status (GES) in our seas. Coastal protected sites such as Chichester Harbour are also critical to the delivery of the Marine Strategy. In addition, coastal protected sites are critical to deliver a number of the Defra 25 Year Environment Plan (25YEP) objectives including for the following:

- Increasing thriving plants and wildlife.
- Restoring 75% of our one million hectares of terrestrial and freshwater protected sites to favourable condition, securing their wildlife value for the long term[4].
- Reversing the loss of marine biodiversity and, where practicable, restoring it.
- Increasing the proportion of protected and well-managed seas, and better managing existing protected sites.
- Making sure populations of key species are sustainable with appropriate age structures.
- Enhancing beauty heritage and engagement with the natural environment.
- Mitigating and adapting to climate change.
- Reducing risk of harm from environmental hazards.

Understanding the current condition of the existing coastal sites, what the main pressures are, and what the long-term trends are is critical to ensuring these objectives are met.

2.1 Condition assessments

Under the EC Habitats Directive, which is relevant for Special Areas of Conservation (SACs), the United Kingdom was obliged to report on the conservation status of the habitats and species listed under Annexes I and II of the Directive every 6 years. There are similar reporting requirements under the Birds Directive, relevant for Special Protection Areas (SPAs). Now we have left the EU, the submission of these reports every six years will be to the Secretary of State, rather than the European Commission and there are specific targets being developed for the condition of protected sites in the Environment Bill. Under the Marine and Coastal Access Act, there is also a need to assess the achievement of conservation objectives for Marine Conservation Zones (MCZs). Alongside these reporting requirements, the ability to provide a current view of feature condition within protected sites is crucial to underpin advice on site management and casework.

Condition assessments are a statutory requirement for all SSSIs in the UK. They are undertaken to assess the condition of all notified features against the sites detailed FCTs. Overlapping European sites usually have site features that are underpinned by the relevant SSSI features for coastal and terrestrial sites. Conservation objectives and site supplementary advice set out the attributes that are important to site integrity and to achieve favourable condition. A site in favourable condition has all

[4] As a coastal designated site that has intertidal and subtidal features Chichester Harbour fits into both the terrestrial SSSI and the marine target categories in the Defra 25YEP.

the appropriate management measures in place, and all the notified features are meeting their conservation objectives and FCT attribute objectives. If a site is in unfavourable recovering condition this indicates that all the management measures are in place to facilitate recovery and enable the site features to achieve favourable condition in the future. Site condition for coastal and terrestrial SSSIs is currently reported at a SSSI unit level but that assessment should include as many of the features that occur on that unit as possible as Natural England is moving towards features based assessments for coastal and terrestrial features as this is already used for marine features. Some features or attributes are assessed at a much larger scale than unit level, including the water quality attribute of the intertidal features, the saltmarsh extent and bird population trends. Management measures required to address unfavourable condition are referred to as remedies on Natural England's recording system. Risks of deterioration or prevention of recovery are referred to as threats on the same system.

The SSSI FCTs are derived from an amalgamation and integration process from the relevant Common Standards Monitoring Guidance (CSMG) on the Joint Nature Conservation Committee (JNCC) website, and any national agreed information (such as SACOs). They are usually tailored to site-specific knowledge. Figure 2.1 provides a map of the site condition **prior to this condition review** and figure 10.1 provides an up-to-date map with the current site condition (following the findings of this review).

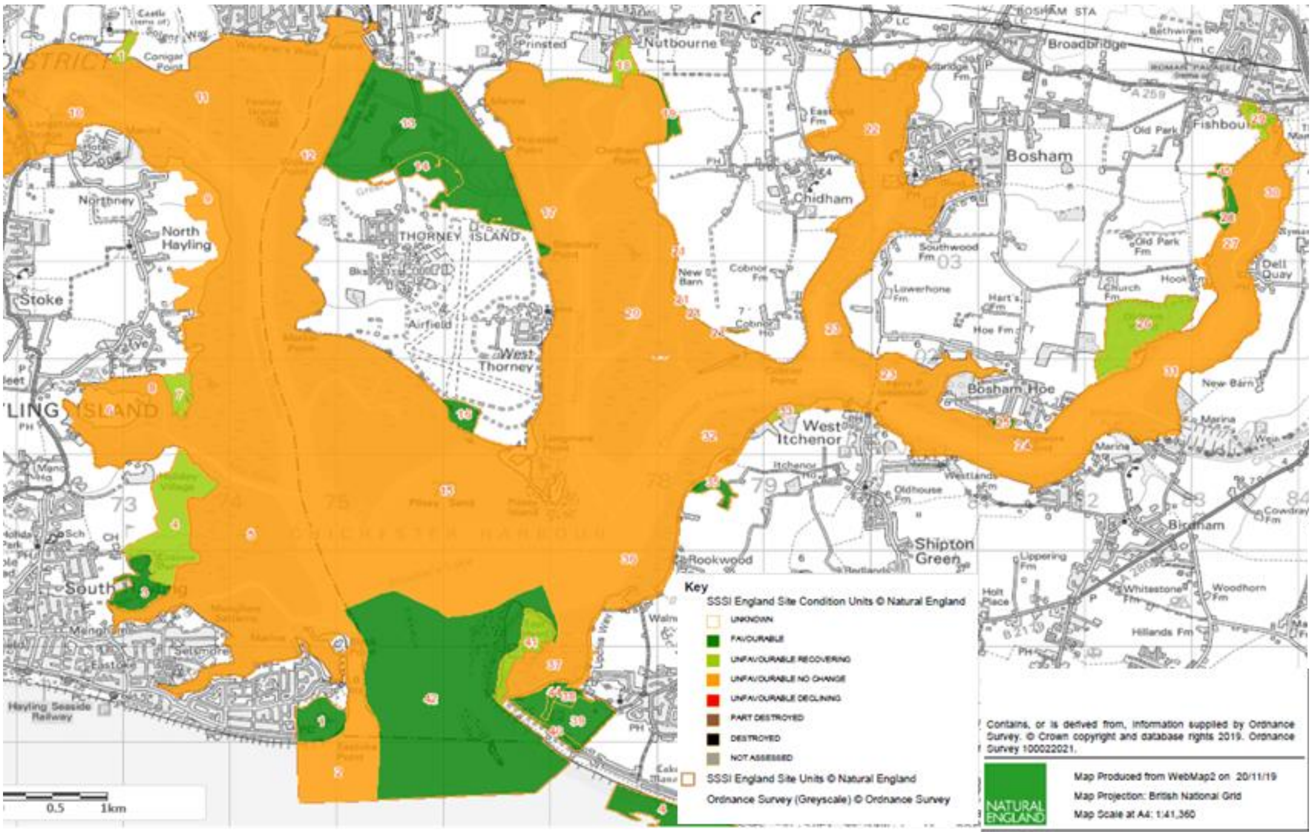


Figure 2.1 Condition of Chichester Harbour prior to this review (31 January 2020)

Marine Features Condition Assessment

In 2016, Natural England trialled and rolled out a new condition assessment methodology that provides information on the condition of marine features within Marine Protected Areas (MPAs). These assessments follow a standardised approach that assesses if features and site-specific attribute targets have been met. In the Solent, methodology is currently only applied to marine SAC features. This excludes saltmarsh, sand dunes, vegetated coastal shingle/driftlines and vegetated cliffs, but includes coastal and saline lagoons, intertidal reef and intertidal sediments. The Solent Maritime SAC marine condition assessment was published in 2018.

Table 1.1 lists the features of Chichester Harbour include overlapping SAC features that were assessed using the marine condition assessment method and other coastal features that were not assessed or are part of other European sites features. The focus of this report is to assess those features of the SSSI and features of SAC that were not part of the marine SAC assessment, as well as features of the SPA and Ramsar site that overlap with the SSSI. All will be assessed against the relevant criteria to their designation.

For features of the Chichester Harbour SSSI that overlap with the Marine SAC features assessed in 2018 some attempt has been made to gather data and assess the features against relevant attributes in the relevant CSMG guidance/ related to attributes in the marine advice guidance. The confidence level of the data was also stated in line with the marine condition assessment guidance. The purpose of looking at these data sets was to assess if at the SSSI level (which was designated significantly before the Solent Maritime SAC) these features are in favourable condition or if there is enough evidence to suggest a different condition for these features in terms of the SSSI than was published in the marine condition assessment for the whole SAC. For example, the extent at designation of the SSSI may have been different from the extent at designation of the SAC so restoration objective target may be different. These overlapping ‘marine’ features and sub features are covered in sections 7 and 8. Water quality is an attribute that supports many of the features and was explored in section 9 to provide a summary of the trends in this attribute and help support recommendations for conservation measures.

3 Objectives and standards on water quality

The locations of the SSSI units within Chichester Harbour SSSI are shown in figure 3.1. Figure 3.2 shows the extensive areas of mudflats and the significant difference between the exposed intertidal area of the mean low water and the lowest astronomical tide that is particularly relevant to units 15 and 42.

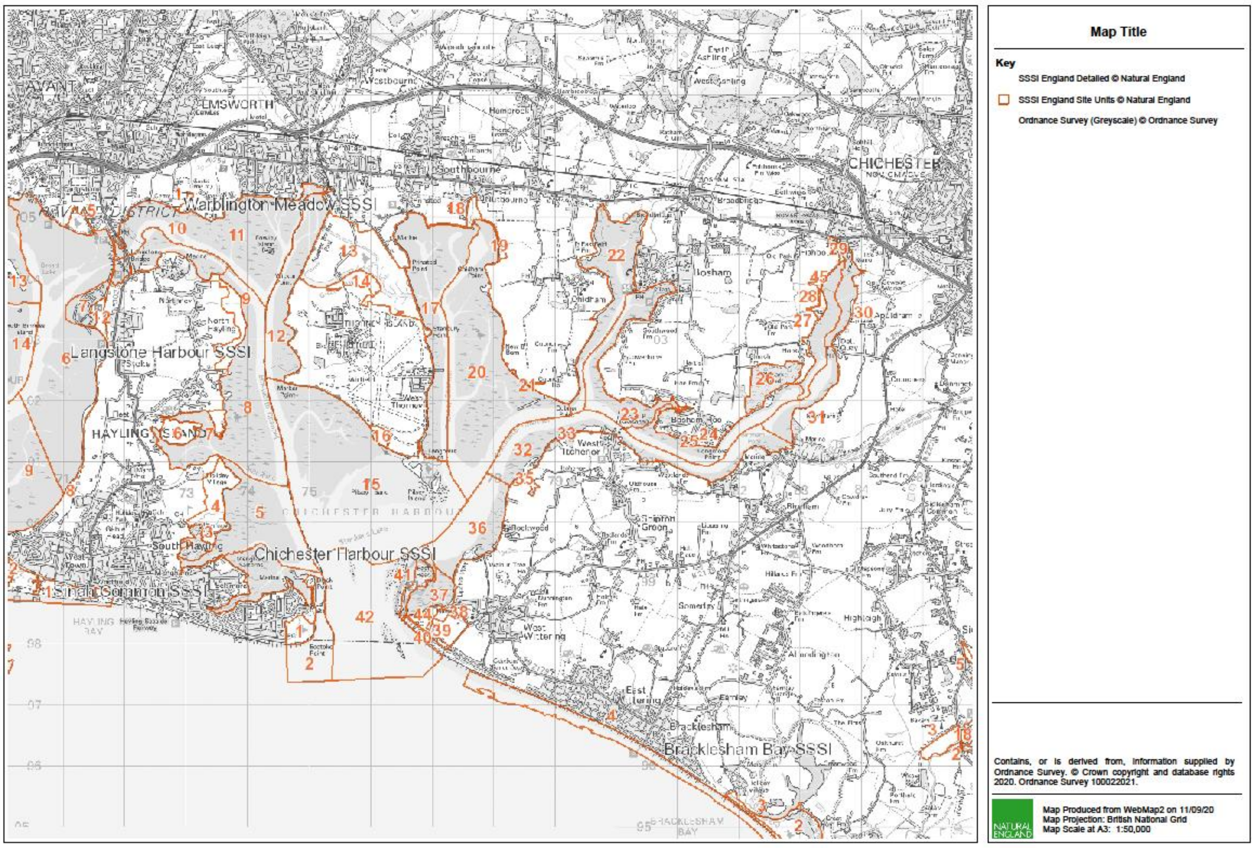


Figure 3.1 Location of the unit numbers within Chichester Harbour SSSI

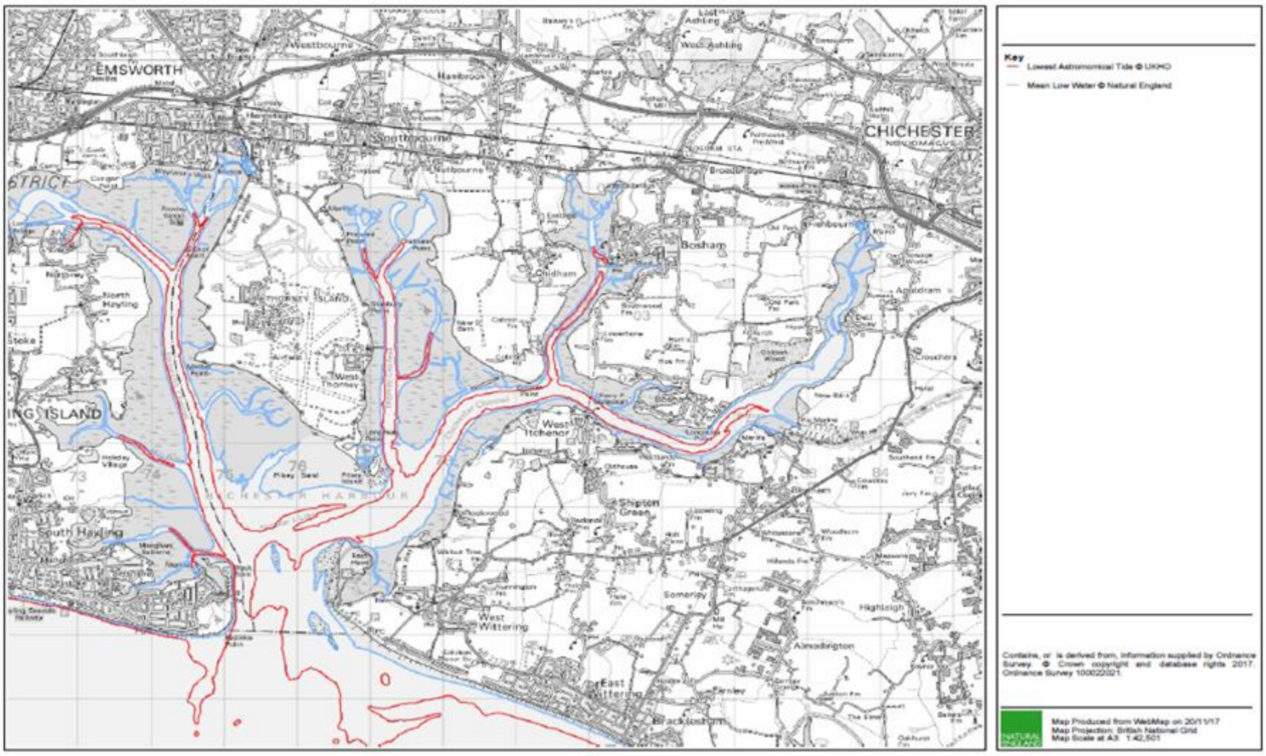


Figure 3.2 Difference between mean low water and lowest astronomical tide

Most features of the Solent Maritime SAC have nutrient standards in the published supplementary advice (see table 3.1 below for link), including the littoral habitats (eg saltmarsh and mudflats). The SPA supporting habitats also have minimum water quality standards which are summarised in table 3.1.

This report focuses largely on the SSSI features of the intertidal and subtidal habitats (marine habitats) within Chichester Harbour and the species that use them including birds. Though it should be noted that birds use a range of supralittoral and adjacent habitats as well. The Solent Maritime SAC encompasses ten Environment Agency estuarine and coastal water bodies, in which regular monitoring under the WFD is carried out. Chichester Harbour is currently encompassed by a single WFD water body (previously in River Basin Management Plan one cycle (RBMP1) it was split into two water bodies).

The whole of Chichester Harbour has been assessed as at risk of eutrophication, using the Environment Agency's Weight of Evidence (WoE) approach. This considers assessments of the WFD opportunistic macroalgae and phytoplankton quality elements using the respective assessment tools. This approach does not use an absolute nutrient standard but instead uses a range of weighted metrics. For example, the opportunistic macroalgae tool uses a multimeric index composed of five metrics:

- (i) Percentage cover of the Available Intertidal Habitat (AIH)
- (ii) Total extent of area covered by algal mats (Affected Area (AfA)) **or** affected area as a percentage of the AIH (AfA/AIH, %)
- (iii) Biomass of AIH (g m^2)
- (iv) Biomass of AfA (g m^2)
- (v) Presence of entrained algae (percentage of quadrats)

More detail on the development and application of the WFD water quality tools [are online](#).

Table 3.1 CSMG and examples of water quality standards as examples of attributes

<table>
<tr><th>SAC habitat
(SSSI habitat in brackets)</th><th>Guidance</th><th>Example targets for illustrative purposes
(water quality only)</th></tr>
<tr><td>1130 Estuaries (intertidal (littoral) sediment including Zostera communities but SAC only feature includes Saltmarsh in SAC only)</td><td rowspan="3">Common standards monitoring marine littoral sediment

Common standards monitoring for inshore marine sub-littoral sediment

Commons standards monitoring for estuaries

Solent Maritime SAC supplementary advice (SACO)</td><td rowspan="3">CSMG – to some extent superseded by SACOS for marine elements of water quality.

Extract from SACOs:
Restrict surface sediment contaminant levels to concentrations where they are not adversely impacting the infauna of the feature (or its sub-features).

Reduce aqueous contaminants to levels equating to high/good status (according to Annex VIII and X of the Water Framework Directive), avoiding deterioration from existing levels.

Maintain the dissolved oxygen (DO) concentration at levels equating to high ecological status (specifically ≥5.7 mg L-1 (at 35 salinity) for 95 % of year) avoiding deterioration from existing levels.

Restore water quality to mean winter dissolved inorganic nitrogen levels at which biological indicators of eutrophication (opportunistic macroalgal and phytoplankton blooms) do not affect the integrity of the site and features.
Maintain natural levels of turbidity (eg concentrations of suspended sediment, plankton and other material) across the habitat</td></tr>
<tr><td>1110 Sandbanks which are slightly covered by seawater at all time (SAC only feature but includes Zostera communities)</td></tr>
<tr><td>1140 Mudflats and sandflats not covered by seawater at low tide (sheltered muddy shores including estuarine mud), (intertidal sediment including seagrass beds Zostera communities and large shallow inlets and bays)</td></tr>
<tr><td>1330 Atlantic Salt meadows, Saltmarsh SM6: Spartina anglica, SM14: Atriplex portulacoides saltmarsh, including: SM4, SM7, SM8, SM9, SM13, SM16, SM22, SM23, SM24</td><td rowspan="3">Common standards monitoring for saltmarsh

Solent Maritime SAC supplementary advice</td><td rowspan="3">No water quality standards in the common standards monitoring and therefore this element is superseded by the SACOs.

Extract from SACOs:
Maintain both the sediment nutrient status to within typical values for the habitat and the processes that sustain effective nutrient cycling by the saltmarsh feature.

Water quality should be restored to mean winter dissolved inorganic nitrogen levels at which biological indicators of eutrophication do not affect the integrity of the site and features.</td></tr>
<tr><td>1320 Spartina swards (SM6: Spartina anglica Saltmarsh)</td></tr>
<tr><td>1310 Salicornia and other annuals colonizing mud and sand (see various saltmarsh communities)</td></tr>
<tr><td>Birds – all designations</td><td>Common standards monitoring for birds

Chichester and Langstone Harbours SPA supplementary advice</td><td>No specific water quality standards for birds in the published guidance – but refers to habitat quality – now fully superseded by the SACOs.

SACOs – see supporting habitat requirements of estuaries above as the water quality requirements for the birds are identical in the SACOs.</td></tr>
</table>

Following national discussions on alignment of WFD and CSMG water quality targets, the WFD elements were incorporated into the SACOs for the Solent Maritime SAC including Chichester Harbour. The SACO requires the following standards for the intertidal units plus other water quality attributes listed in table 3.1:

Table 3.2 Water quality targets (incorporating WFD and CSMG) in the SACOs for the Solent Maritime SAC, which includes Chichester Harbour

Factor	Target	Notes
Algal cover	<15% of assessment area	Accounting for seasonal variations and fluctuations in growth
Algal biomass	<500gm^2	
Algal entrainment in sediment	(<5%)	
Phytoplankton levels	Above WFD 0.6 which includes only a) minor decline in species richness b) Disturbance to diatom-dinoflagellate succession in spring bloom is minor	Compared to reference condition

These targets are currently applied at the whole water body level by the Environment Agency though the spatial scale of the assessment is not given in the supplementary advice, it refers to the assessment of the features or sub-features and is clear that the targets should not be applied without reference to relevance of the surveys to the integrity of features and sub-features. The Environment Agency use their assessment tools in the Solent for transitional water bodies at a spatial scale ranging from approximately 23 hectares to more than 3000 hectares (see Appendix 2 for the breakdown of Solent water body sizes). Previous Environment Agency work shows that application of the weight of evidence approach at a smaller than water body spatial scale is possible (eg former water body Chichester Harbour East). Changes in the spatial scale of the assessment can affect the source apportionment and potentially the impact assessment, which in turn will affect the remedies that are included in the condition assessment reporting. Assessment of spatial scale will be covered in sections 9 and 10.

The Environment Agency have a number of other WFD metrics that relate to interest features of marine and coastal sites. Of most relevance in Chichester Harbour are the saltmarsh metric, Infaunal Quality Index (both in the WFD estuaries and coastal guidance) and coastal opportunistic macroalgae/ angiosperms (WFD coastal guidance) – including eelgrass. The saltmarsh tool is covered further in section 5 and the remaining metrics are covered in more detail in sections 7, 8 and 9. It is important to note that although these metrics apply to Chichester Harbour designated site features they are **not** all routinely measured in Chichester Harbour WFD water body.

4 Coastal processes and climate change

4.1 Coastal processes

Unimpacted coastal systems, in particular saltmarshes and mudflats, are dynamic systems, with areas naturally accreting (gaining sediment/organic matter) and eroding, in response to coastal processes. Such systems are defined as being in morphological equilibrium. The Healthy Estuaries Project utilises this dynamic equilibrium principle, where the coastal ecosystem and corresponding habitats do not show a particular trend over time but change dynamically around an 'average form'. This is used to identify how far a contemporary estuary form may be from equilibrium, particularly as a result of anthropogenic interventions.

Estuaries are complex systems and can include a wide range of habitats of principal importance for conservation, termed 'Priority Habitats' under the Natural Environment and Rural Communities Act 2006 (NERC Act). The saltmarsh, littoral and sublittoral sediments within Chichester Harbour estuary are all features in their own right and are covered separately in this document but they all form part of the estuary feature of the Harbour. There is a gradient of salinity from freshwater (at the head of estuaries) to marine conditions (in outer estuaries generally), where sediment from the freshwater systems, plus shelter from wave action often lead to extensive mud and sandflats. Though Chichester Harbour has extensive mud and sandflats it is unusual in the UK series as the input of freshwater into Chichester Harbour is from several small, sometimes seasonally dry, largely groundwater fed streams rather than larger lowland rivers.

The structure of estuaries is largely determined by geomorphological and hydrographic factors. There are four main sub-types of estuary of which two are found within the Solent Maritime SAC:

1) *Coastal plain estuaries*. These estuaries have formed where pre-existing valleys were flooded at the end of the last glaciation. They are usually less than 30m deep, with a large width-to-depth ratio. This is the main sub-type of estuary, by area, in the UK.
2) *Bar-built estuaries*. These characteristically have a sediment bar across their mouths and are partially drowned river valleys that have subsequently been inundated. Bar-built estuaries tend to be small but are widespread around the UK coast (JNCC 1130 Estuaries).

Chichester Harbour is a bar-built estuary and like most such estuaries has soft sediments in the upper parts of the estuary. Chichester Harbour's coastline, along with the rest of the southeast of England, is undergoing post-glacial isostatic readjustment. This results in the coast in the north of England rebounding from the depression caused by the weight of ice in the last ice age and an equivalent sinking on the south coast. Added to this natural coastal change is climate change and interaction of these forces with land use of the coast.

Coastal risk management is the term used to describe the reduction and prevention of flooding and erosion (and sometimes accretion) to protect people, property and economic activities in the coastal zone. Coastal risk management has become more integrated, working with the natural environment and coastal processes, as our understanding of coastal ecosystems function improves and how these contribute both positively and negatively to risk management. The contribution that the natural environment makes to coastal management, often identified as ecosystem services, now recognises the importance of the natural environment particularly in response to sea level rise and climate change (European Commission 2002, 2004, Defra 2008 and Coastal Management Theme and Improvement Programme for England's Natura 2000 sites (IPENS)).

Flood and Coastal Erosion Risk Management (FCERM) is managed by the Environment Agency, who also have a strategic role to oversee the work of local authorities and coastal management authorities. In general, local authorities are responsible for managing erosion risk and the Environment Agency manages flood risk. Chichester Harbour is a ‘heavily modified water body’ (HMWB) as defined by the Water Framework Directive (WFD), due to the extensive areas of coastal defences around the harbour affecting its natural geomorphology and ability to respond to coastal processes. However, being a HMWB as defined under WFD, does not influence the targets for protected areas such as SAC and SPA as these systems still need to meet conservation objectives.

There is a strategic approach to coastal management governed by a process known as Shoreline Management Plans (SMP). In general, SMP cover the open coast and there are separate estuary strategies. SMP’s are developed by coastal groups with members from local councils, the Environment Agency, Natural England and others. SMP’s identify the best approach or approaches to managing risks over the next 100 years from flooding and coastal erosion (including cliff instability). They are high level, non-statutory documents. SMP’s were established in circa 1999 (SMP 1), subsequently updated and improved in 2005/06 (SMP 2) and are being refreshed (*a fit for purpose check*) in 2020.

Chichester Harbour is covered by the North Solent SMP, which includes the coastline between Selsey Bill, in the east, and Hurst Spit, in the west. Much of this SMP coastline is designated internationally due to important natural habitats and the large number of species, particularly birds, it supports.

There are four strategic coastal management policy options:

[NAI]	No active intervention	- no current plans to build any defences
[HTL]	Hold the existing defence line	- maintaining current defences
[MR]	Managed realignment	- allowing the shoreline to move to an agreed position
[AL]	Advance the line	- new defences planned extend the land area out to sea

A non-standard policy of adaptive management has been taken where the option is to monitor changes and act in a flexible way. Most of Chichester Harbour is ‘hold the line’ though many of the defences are privately owned. SMP’s are non-statutory documents and their role is to carry out a strategic assessment of the risks associated with coastal processes (flooding and coastal erosion), so set the framework for managing these risks, taking account of climate change and environmental considerations. Many of the privately owned defences around Chichester Harbour are coming to the end of their design life at the end of the first epoch in 2025. There is a legal requirement to assess future strategies and schemes against protected site legislation. This provides an opportunity to manage the coastline to a more sustainable location and/or alignment, both in terms of managing flood risk and to create and restore habitat.

The SMP’s are currently undergoing a ‘refresh’. Whilst this is not intended to be a complete review, the current study should feed into advice that Natural England will provide in future.

As a result of coastal risk management, losses to designated habitat have been recognised. The Environment Agency have a strategic role to ensure that losses that occur as a result of inappropriate coastal management, particularly those covered under European legislation are compensated. In addition, nationally designated sites (SSSIs) underpin these European sites and therefore it is critical that these sites are also maintained.

The SMP's undergo a Habitat Regulation Assessment to identify future losses of intertidal habitats from coastal squeeze impacts, as a result of future coastal risk management. The Environment Agency's Habitat Compensation Programme (HCP), ensures that habitat is (re)created, generally through managed realignment or regulated tidal exchange, to address these losses. Historic losses that have occurred on designated coastal sites also need to be addressed to maintain or restore favourable conservation status of these sites. As part of the HCP for the Environment Agency's Solent and South Downs area, potential opportunities for managed realignment around Chichester Harbour for intertidal habitat creation have been identified.

4.2 Climate change and coastal processes

The changing climate is having a significant impact on the coastal processes in a number of ways including:

- Sea level rise (SLR), which can result in coastal squeeze when combined with coastal development (see below for definition).
- Increase in extreme events with SLR meaning impacts of storms are a greater risk, bringing wave energy closer to shore, increasing coastal erosion, altering sediment transport, habitat loss and saline intrusion into brackish and freshwater systems.
- Increased intensity of rainfall events increasing the nutrient peaks for the same land management and affecting sediment transport.
- Increased periods of hot dry weather making some coastal habitats vulnerable to erosion by cessation of growth/interruption of soil processes.
- Increased total winter rainfall which raises groundwater peaks into formerly unsaturated zones flushing out any nutrient from historic land use.
- Thermal changes influencing species distribution as well as sea level rise.
- Coastal acidification from increased absorption of atmospheric CO2.

The 2019 Intergovernmental Panel on Climate Change (IPCC) *special report on ocean and cryosphere in a changing climate* confirms the global mean sea level is rising and shows the rate of rise is accelerating from 1.4mm yr^{-1} (1901-1990) to 3.6mm yr^{-1} (2005-2015). The dominant cause of sea level rise is changing with thermal expansion being overtaken by sum of glacier and ice sheet contributions as the dominant source of sea level rise globally.

The Natural England Healthy Estuaries Project attempted to evaluate the morphological 'health' of an estuary and thus inform measures needed to restore and then sustain a healthy form. This project defined coastal squeeze as "*narrowing of intertidal zone due to the prevention of its natural landward migration in response to sea-level rise; [...] where this is a response to defences such as sea walls preventing migration and causing intertidal erosion"*. Coastal squeeze is therefore a response to climate change, however coastal management must address the combined influence of many factors acting synergistically to determine the health of systems.

The 2019 IPCC report (referred to above) notes that "*non-climatic anthropogenic drivers including recent and historical demographic and settlement trends and anthropogenic subsidence, have played an important role in increasing low-lying coastal communities exposure and vulnerability to sea level rise and extreme sea level events (very high confidence). In coastal deltas, for example, these drivers have altered freshwater and sediment availability (high confidence). In low-lying coastal areas more broadly, human-induced changes can be rapid and modify coastlines over short periods of time, outpacing the effects of SLR (high confidence). Adaptation can be undertaken in the short- to medium-term by targeting local drivers of exposure and vulnerability about local SLR impacts in coming decades and beyond (high confidence)."*

The Marine Climate Change Impacts Report Card 2020 highlights four key emerging issues for climate change impacts on coastal habitats and communities, one of which is that multiple stressors from changing climate coupled with human activities, which reduce the resistance and resilience of natural systems. The report raises the need to understand, quantify and mitigate cumulative or synergistic impacts demonstrating the UK is following the global picture.

This recognition of the synergistic impacts of coastal management, development and agriculture with climate change is particularly relevant to the Chichester Harbour condition review and will be addressed further in the following sections.

5 Trends in saltmarsh habitat extent and condition

Saltmarsh is a critical part of the coastal ecosystem as it provides a range of ecosystem services such as shoreline stabilization, flood and storm surge protection, maintenance of coastal water quality and grazing for food production in addition to its inherent value for biodiversity (eg ENRR 2006; Zedler, 2003; Costanza and others, 2008; Gedan and others, 2011; IPPC 2019). Understanding the long-term trends and health of saltmarsh to improve its resilience is critical for the health and economic well-being of coastal communities worldwide (eg Millennium Ecosystem Assessment 2005, Raposa and others, 2016).

The importance of the saltmarsh in the Solent within the national series is emphasized by the SAC citation and the conservation advice site description. The Solent saltmarshes are described as the second largest aggregation of saltmarshes in the south and south-west England, representing 33% of saltmarsh in this region and 3% of the national resource. Chichester Harbour was noted by the Chichester Harbour Conservancy as having the 7th largest area of saltmarsh in England.

The development of saltmarsh from sand and mudflats requires shelter from strong wave action and a consistent supply of sediment to enable accretion to offset the erosion. The extent depends on other factors such as tidal range and elevation.

The decline in saltmarsh extent in Chichester Harbour has been a cause for concern for some decades; in his seminal book on the Solent, Colin Tubbs (1999) estimated at least 1090 hectares of intertidal habitat had been lost from 1930 across the Solent. In 2006 English Nature published a report with maps showing the loss of extent of saltmarsh at a range of SPAs including Chichester and Langstone Harbours between 1976 and 2001. The English Nature report showed the rate of historic loss per year for the Chichester and Langstone Harbours SPA was just over six hectares a year on average. The Solent SACOs give 1,095 hectares as the extent objective for favourable condition across the SAC for saltmarsh and this has a restore objective. Coastal Habitat Management Plans (CHaMPs) were produced in 2003 as part of the LIFE-funded partnership project ‘Living with the Sea’. The Solent CHaMP (Bray and Cottle 2003) included Chichester Harbour, providing the first truly long-term evaluation of the implications of sea level rise for the Natura 2000 sites around the Solent. The science-based forecast it made for up to 100 years of coastal change resulting from sea level rise, and the habitat compensation requirements to address this change, were incorporated into coastal management planning, as required by Defra to meet the requirements of European legislation. Bailey and Pearson (2007) summarise the CHaMPs, showing rapid loss of more than half the Solent estuary saltmarsh between 1971 and 2001. This was also reflected in the 2006 English Nature report.

As well as historic loss, the future loss to rising sea level and coastal defences has been predicted in the Solent Dynamic Coast Project. This project is discussed later in this section.

The features considered in this section are summarised as follows:

Table 5.1 The saltmarsh features within the Solent Maritime SAC

1330 Atlantic Salt meadows, Saltmarsh **(SM6: *Spartina anglica,* SM14: *Atriplex portulacoides* saltmarsh, including: SM4, SM7, SM8, SM9, SM13, SM16, SM22, SM23, SM24)**
1320 Spartina swards **(SM6: *Spartina anglica* Saltmarsh)**
1310 Salicornia and other annuals colonizing mud and sand **(see various saltmarsh communities)**

In this section the trends in Chichester Harbour saltmarsh over time and the current condition of the remaining saltmarsh are examined and factors which may have contributed to observed declines are discussed. This section focusses on factors that are observable on site related to structures and indicators of water quality impacts. Attempts have been made to identify the extent of restoration required to achieve favourable condition for the SSSI and the contribution this would make to favourable conservation status of the above features of the Solent Maritime SAC.

5.1 What do Natural England normally measure?

Condition assessment of saltmarsh usually follows CSM coastal saltmarsh guidance. This should be translated into the FCT for the site and tailored where necessary.

The mandatory features of condition for saltmarsh are:

- Habitat extent
- Physical structure: creeks and pans
- Vegetation structure: zonation; sward structure
- Vegetation composition: characteristic species; indicator of negative trend (*Spartina anglica*)
- Other negative indicators.

For Chichester Harbour the following discretionary attributes are also important:

- Presence of notable species (vascular plants)
- Other important features eg transitions to other habitats, is considered to be a discretionary attribute (indicators of local distinctiveness).

5.2 WFD saltmarsh metric

The Environment Agency have a number of WFD metrics that relate to interest features including saltmarsh. The Environment Agency saltmarsh tool is a multimeric index composed of six individual components known as metrics, these are:

- Saltmarsh extent as proportion of ‘historic saltmarsh’
- Saltmarsh extent as proportion of the intertidal
- Change in saltmarsh extent over two or more time periods
- Proportion of saltmarsh zones present (out of five)
- Proportion of saltmarsh area covered by the dominant saltmarsh zone
- Proportion of observed taxa to historical reference value or proportion of observed taxa to15 taxa

To calculate the saltmarsh tool the following information is required:

- Aerial extent of the saltmarsh (usually obtained from aerial imagery with ground truthing),
- The area of each of the six saltmarsh zones, and
- A taxa list for the marsh.

Further data on the Environment Agency’s saltmarsh tool can be found online.

This metric is **not** currently measured routinely within Chichester Harbour as part of the waterbody status assessment so was not available to inform this review.

5.3 Review of historic saltmarsh extent 2019

1) Saltmarsh extent - methodology

The Channel Coastal Observatory (CCO) carried out extensive analysis as part of the Solent Dynamic Coast Project (SDCP) in order to quantify inter-tidal losses and identify potential areas for re-creation at a strategic level across the north Solent. The report and the aerial photography report looked at the following data to estimate loss of intertidal (specifically saltmarsh) from 1946, 1965, 1971, 1991, and 2002:

- Historical aerial photographic interpretation
- LIDAR (coastal elevation) data.

Natural England extended this historical aerial photography with two new datasets, the first from 2008 Chris Blair Myers Saltmarsh Inventory Dataset and the second from the Environment Agency's Geomatics 2016 aerial survey.

These two additional extent datasets (2008, 2016) were added to the series that CCO had already examined (1946-2002), to identify the ongoing trend in saltmarsh extent, to see if the losses were still occurring, and whether the rate of loss had changed. Comparisions between the two most recent datasets were considered to understand the rate of recent losses. Natural England also compared the 1971 extent data with the 2016 data to estimate the losses and gains, since SSSI designation, to this most recent dataset, to understand the remaining saltmarsh resource within the SSSI up until 2016. The trend since 1946 was used to determine if the saltmarsh extent was stable, accreting or eroding at SSSI designation, giving an indication of whether saltmarsh features were at favourable condition at the time of the SSSI designation.

2) Saltmarsh historic trend - results

Maps of the historic extent losses from 1946 to 2002 can be viewed in the Chichester aerial photography report figures 2a to 2d of that report. Maps of the 2008 and 2016 saltmarsh extent and comparison with the extent at 1971 (close to SSSI designation date) and 1991 data are shown in figures 5.1 to 5.2. Table 5.2 shows the extent data and the percentage net loss within the time period. The total cumulative loss since SSSI designation and the annual rate of loss are also shown (estimated by dividing the loss in a time period by total loss over the time period). Figure 5.3 shows a graph of the loss since SSSI designation.

Natural England's analysis included area lost due to reclamation, however you can see from the table 5.2 in the figures quoted from the CCO Solent Dynamic Coast Project study (below), that losses due to reclamation during the study period, only occurred between 1965-1971 within Chichester Harbour (see table 5.2 comparing the total loss with the loss excluding reclamation). These losses were comparatively small between 1940 and 2002 - reclamation accounted for 1% of the saltmarsh lost at Langstone and Chichester Harbour.

Net loss of saltmarsh is extensive over the time period and continues through to the latest data sets. The data is patchy with a clear evidence gap in the 1980s. The results overall show a continued but slowing loss of saltmarsh extent. As with all assessments there are potential errors inherent in the assessment of aerial imagery in particular older images which need to be geo-rectified. Angle of photography and seasonality of photographs can also affect precise details the CCO estimate a +/-5m tolerance for older aerials up to 1991 with +/-0.2m for 2002. The errors are small in relation to the losses and not sufficient to affect the overall conclusions.

Table 5.2 Historic extent of saltmarsh Chichester Harbour

Year	Area (ha)	Data source*	Period	Length of time (years)	Loss (ha)	Rate of loss (ha/yr)	% loss in time period (ha)	Cumulative loss (ha) from 1946 (from SSSI designation in brackets)	% Cumulative loss from 1946 (from SSSI designation in brackets)
1946	717.3	CCO							
1965	659.1	CCO	1946-1965	19	58.2	3.1	8.1	58.2	8.11
1971	552.1	CHaMPS	1965-1971	6	107	17.8	16.2 (15.3) +	165.2	23.03
1991	346.4	CCO	1971-1991	20	205.7	10.3	37.3	370.9 (205.7)	51.71 (37.26)
2002	334.8	CCO	1991-2002	11	11.6	1.1	3.4	382.5 (217.3)	53.32 (39.36)
2008	315.8	Chris Blair	2002-2008	6	19	3.2	5.7	401.5 (236.3)	55.97 (42.80)
2016	295.5	EA geomatics	2008-2016	8	20.3	2.54	6.43	421.8 (256.6)	58.80 (46.48)
Total Loss		**1946-2016**		**70**	**421.8**	**6.03**	**58.8** (57.9) +		

*CCO – Channel Coast Observatory. CHaMPS – Coastal Habitat Management Plans.
+this figure is the percentage loss since excluding reclamation after (Cope and others, 2015)

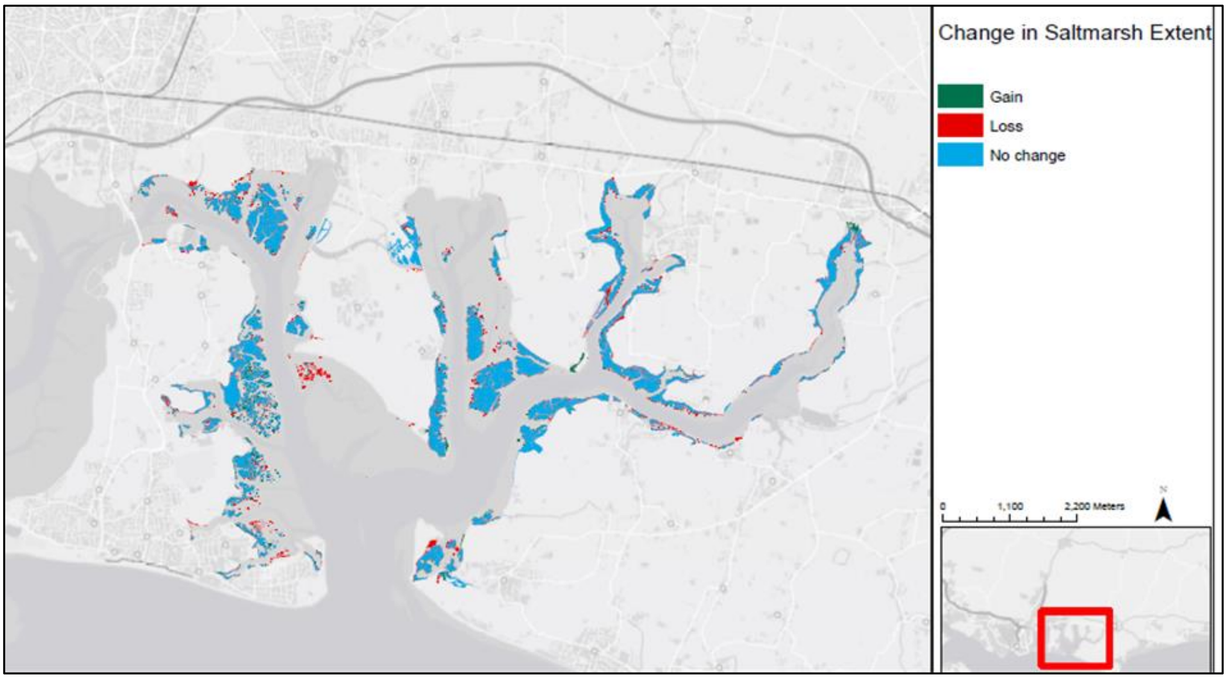


Figure 5.1 Saltmarsh extent gains and losses from 2008 to 2016

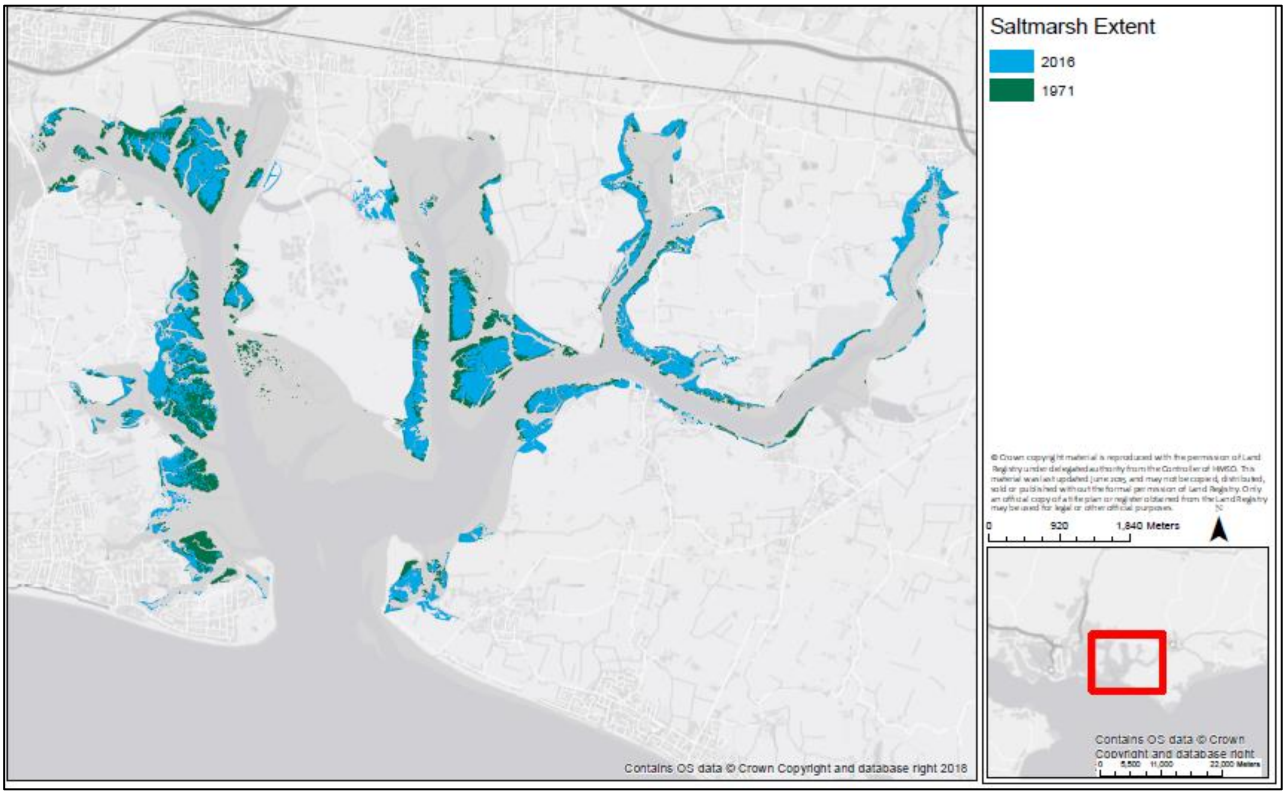


Figure 5.2 Saltmarsh extent difference 1971 to 2016

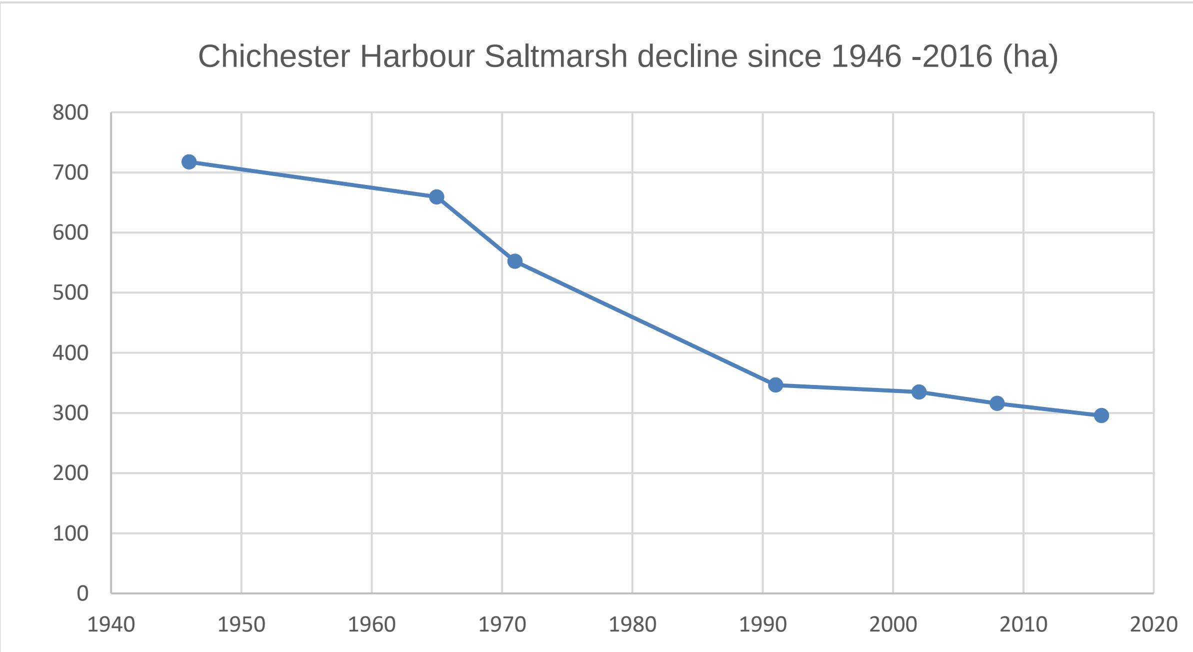


Figure 5.3 Chichester Harbour saltmarsh decline 1946 to 2016

Based on the current annual rate of loss assuming a linear continuation, the harbour will have lost all its remaining saltmarsh by the mid 2100's (estimated at 2142). The rate of loss from 2008 to 2016 was predicted by the Solent Dynamic Coast Project (2008) to be in the region of five hectares a year from 2008 onwards for the whole of the Solent including Pagham Harbour. The rate of loss observed in the 2008 and 2016 data sets for Chichester Harbour is in the same range as this figure and it is therefore likely losses in the Solent as a whole will exceed those that were predicted by the Solent Dynamic Coast Project (2008). This apparent difference is most likely as a result of the inherent difficulties in predicting saltmarsh loss from historic data across an area the size of the Solent in face of climate change and other pressures. There are some small localised areas of net gain shown on figure 5.1 most of these are at the fronts of the larger areas of remaining marsh.

Current units identified as having saltmarsh at designation from aerial photos and/or in subsequent surveys: 2, 5, 7, 8, 10, 11, 12, 15, 17, 20, 22, 23, 24, 27, 28, 30, 31, 32, 33, 36, 37, 38, and 44.

Current units identified as possibly or definitely having important fringing or transitions to saltmarsh at designation: 3, 6, 13, 16, 19, 21, 26, 35, 39, and 26.

Unit 29 is a reedbed which is often considered an important transition zone from saltmarsh and in some surveys is included in the saltmarsh but has not been included in this assessment as saltmarsh.

3) 2019 Rogers MSc study

An MSc study by Rogers (2019) from the University of Portsmouth reviewed the same aerial photographs in more depth for specific areas of the harbour, to better understand amongst other variables, saltmarsh extent and fragmentation in Chichester Harbour between 2002 and 2016. The four specific locations within the harbour were; East Hayling Island, East Head Spit, Fowley Head and East Thorney Island. Rogers highlighted that the extent of saltmarsh increased in Chichester Harbour at these locations from 2002 to 2008 and then started to decline in extent through to 2016, with a very small overall net accretion. This appears to contradict the results in table 5.2 above which shows a continued net loss between 2002 to the current day. This apparent difference is explained by greater losses elsewhere in the harbour, offsetting these small overall net gains identified by the discrete areas of saltmarsh assessed by Roberts. The small areas of net gains shown in figure 5.1 are also included as the main focus in Roberts study and are identified by the current study as the best remaining areas of stable or 'core' saltmarsh and have been included in the condition surveys described in the next sub-section. The Roberts study is useful in identifying the short-term localised changes in saltmarsh and highlighting how important long-term studies are. The Roberts study also looked at abiotic factors such as wave height, nitrate and dissolved oxygen - these interactions are discussed in sub-section 5.5.

5.4 Review of saltmarsh condition – 2019

In addition to saltmarsh extent (quantity), the quality of the saltmarsh is also fundamental to the condition of the habitat and its resilience to climate change. To assess the quality and other condition measurements of the saltmarsh on site surveys were conducted. In addition, this survey work also helps to verify the aerial photography used to estimate the extent.

1) Saltmarsh survey methodology

The survey methodology used in the current study was a combination of CSMG and WFD Environment Agency style transects. To ensure all surveyors applied the methodology consistently, a saltmarsh training day was held for all the surveyors on the 10th of August 2019 at Dell Quay Education Centre, Chichester Harbour led by Natural England's field unit staff. This event was well attended and offered a chance for surveyors from all participating organisations to meet and learn about the survey methodology including a saltmarsh plant identification refresher. The survey techniques were then used in the field to develop surveyor's capacity and offer an opportunity to refine the methodology.

The transect locations were selected in advance to select the best areas of saltmarsh remaining in the harbour. It is recognised that this is not a random sampling of the remaining saltmarsh and therefore the condition will be a "*best current case scenario condition*" of saltmarsh. Any obvious changes within the wider saltmarsh area were also noted in 'Target Notes' (similar to a walkover site check). A summary of the main methodological attributes is outlined below, and a more comprehensive methodology can be found in Appendix A3.1.

- Transects: used for assessing saltmarsh zonation ie one 2m x 2m quadrat in each main zone along the transect, and an adjoining second quadrat 5m distant.
- GPS coordinates[5] were noted for the beginning and end of each community zone; the aim being to detect long-term trends in communities and zonation that may be occurring on site. The grid references, target notes and photographs from these transects are given in Appendix 3.
- The start and end points of these transects have been mapped to form a baseline for future monitoring.
- Where resource allowed, a CSM structured walk was also carried out ie a W-shaped walk: to assess vegetation structure, species composition and negative indicators, with up to 10 stops within each assessment unit representing the different saltmarsh zones present. Quadrats (2m x 2m) were undertaken to assess species composition and sward height. The exact locations of each quadrat were recorded in the field using GPS. Any quadrats recorded for the purposes of undertaking the transect survey also counted towards the 10 stops within the unit.

The saltmarsh surveys were carried out on the 9th and 10th September 2019 at six locations across Chichester Harbour, West Sussex. An additional boat-based survey at Hayling Island was carried out on Monday 16th September 2019. The sites were chosen using aerial maps to include sites across the whole harbour that had an expanse of saltmarsh that was accessible on foot from the shore. The transect at Hayling Island was carried out on foot from the shore and by boat, selected to replicate the Solent Maritime SAC monitoring transect carried out in 2016. Surveyors were specifically asked to record any observed opportunistic macroalgae on the muds and the saltmarsh, and signs of eutrophication. Surveyors were also specifically asked to record any observed structures or barriers to landward migration in particular if compression of transitions was observed in the surveys. Please refer to table 5.3 and figure 5.4 showing the Chichester Harbour SSSI saltmarsh survey transects.

Table 5.3 Chichester Harbour SSSI survey locations

	Location	SSSI Unit
Monday 9th September 2019	Hayling Island	8
	Thorney Island	15
	Colner Creek	22
	Bosham	23
Tuesday 10th September 2019	Fishbourne	27
	West Itchenor (Horse Ferry pond)	32
Monday 16th September 2019	Hayling Island (boat survey)	8

On Monday 9th September high tide was at 8.53am and low tide was at 2.35pm. There was persistent rain for most of the survey period on Monday and warm, dry sunshine on Tuesday. On Tuesday 10th

[5] OS 1:25,0000 grid references from Viewranger app for Apple platforms and Offline OS Maps APP also for Apple platform accuracy variable from 5 to 10m accuracy in most cases

September high tide was at 10.02am and low tide was at 3.26pm. All foot-based surveying started late morning at all sites. The boat-based survey started at 1pm on Monday 16th September, high tide was at 1:26pm and low tide was at 6.59pm. The surveys were carried out by colleagues from the Natural England's field unit; a national coastal specialist and area team staff. In addition to Natural England staff, a range of local stakeholders also attended the training day (one or both survey days) including Environment Agency staff, an ecologist from the Ministry of Defence and a representative from Chichester Harbour Conservancy.

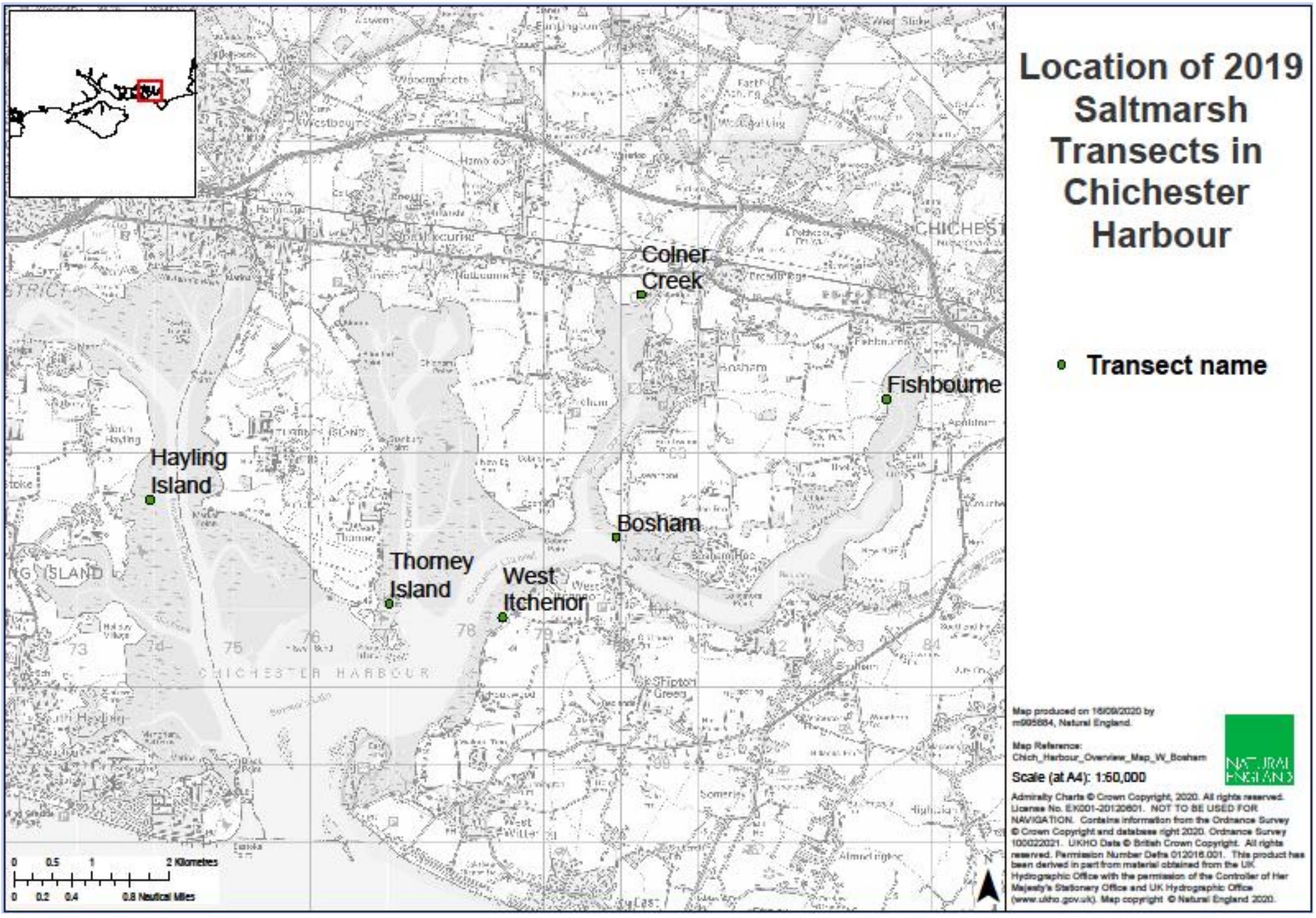


Figure 5.4 Location of the Chichester Harbour SSSI saltmarsh survey transects

2) Summary of results

All six sites that were surveyed on foot were experiencing coastal squeeze to some extent on their landward edge where sea defences or raised ground were preventing landward transgression of the saltmarsh and in some cases causing wave reflection affecting upper saltmarsh communities.

Opportunistic macroalgae was observed at most of the survey locations and was particularly prevalent at Fishbourne, Colner Creek and Bosham trapped in the pioneer marsh and on the surrounding mudflats on the eastern arm of the harbour. The main large channel to the east of unit 23 is covered in a bloom of green filamentous algae, this continues around the coast and worsens at Bosham Hoe. Bare areas of mud are present, but the surveys noted they suspected this indicates pollution/water quality issues due to the anoxic nature of the muds seen. At West Itchenor and Hayling Island a large amount of decaying brown algae was observed on the strand line.

Several of the transects had indicators of local distinctiveness. Golden samphire, a rare saltmarsh plant, was observed at Hayling Island, West Itchenor, Bosham, and Thorney Island. The Lax variant of sea lavender was also noted at West Itchenor, Hayling Island and Fishbourne. The pioneer zone on all sites contained *Spartina anglica*. At Fishbourne *Spartina* dominates the northern part of the unit 27. The judgement on whether this is evidence of eutrophication or compression of transition zones by structures or process interruption (if observable) is summarised in table 5.4. The target notes from the transects are provided in Appendix A3.2 with sample photographs in A3.3.

Table 5.4 Summary of key impacts seen at sites (officer judgement)

Location	SSSI Unit	Coastal squeeze / compressed transition zones	Green macroalgae present
Monday 9th September 2019			
Hayling Island	8	Uncertain	In pioneer marsh and on mudflats
Thorney Island	15	Minimal	Minimal
Colner Creek	22	Yes	In pioneer marsh and on mudflats
Bosham	23	Yes	In pioneer marsh and on mudflats and round to Bosham Hoe
Tuesday 10th September 2019			
Fishbourne	27	Yes	In pioneer marsh and on mudflats
West Itchenor (Horse Ferry pond)	23	Yes	In low / pioneer marsh and on probably mudflats
Monday 16th September 2019			
Hayling Island (boat survey)	8	Not applicable	Fucoids present but not much green algae

Table 5.5 gives a summary of the attributes assessed in transects and walkover for each transect and whether the relevant common standards monitoring targets for those attributes are passed or failed. Further details of the saltmarsh quality criteria per unit are provided in Appendix 3.3, table A3.2.

Table 5.5 Littoral sediment – saltmarsh quality criteria from CSMG and FCT. Summary of transect data from 2019 surveys

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
Vegetation structure – zonation of vegetation	Maintain characteristic range of zones for Chichester Harbour: **Pioneer saltmarsh** SM4, SM5, SM6, SM7 SM8, SM9, SM11, SM12 **Low-mid marsh** SM13, SM14 **Mid-upper marsh** SM16, SM22, SM23 **Drift line** SM24								
Vegetation structure – sward height	<10cm in some areas in bird areas No indicators of excessive grazing								
Vegetation composition characteristic species	**Pioneer** Maintain at least one characteristic species frequent and another occasional **Mid marsh** At least one of the following dominant *Puccinella maritima Atriplex portulacoides or Salicornia species* dominant, and at least two other species frequent **Mid-upper marsh** At least one listed species abundant and three frequent								
Indicators of local distinctiveness	Maintain SM22 (*units 15 Pilsey only*) and lax flowered sea lavender and perennial glasswort (required at specific locations only - *unit 15 Pilsey only not surveyed*)								

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
Negative indicator species *Spartina anglica*	<10% expansion of *Spartina* into pioneer saltmarsh in last 10 years *(Baseline CASI 2002 data)*								
Physical structure – creeks and pans	Realignment of creeks absent or rare.								
Other negative indicators	No increase in trampling, no obvious signs of pollution, no turf cutting No poaching and artificial channels or drainage affecting the drainage absent (or rare)								
	Other signs of coastal squeeze/physical issues noted on target notes								
Summary saltmarsh condition for transect/unit		All units unfavourable							

Key		
Meets target for attribute	Does not meet target for attribute	Attribute not assessed or not relevant in this transect

5.5 Saltmarsh condition discussion

1) Fragmentation of saltmarsh

The current study shows that saltmarsh is losing extent both in front of coastal defences as well as on the seaward edges of the remaining areas of saltmarsh. Many of the small localised gains observed in the extent study are in similar areas to the losses. This suggests some defences may have reflective energy that moves sediment away from the defences which becomes trapped by the existing saltmarsh, and in less energetic conditions settles and accretes. However, in areas exposed to higher wave energy conditions there is likely to be a net loss. This is supported by the findings of the Rogers study (2019) that show a correlation of years with losses of saltmarsh to years with highest wave action (in the study's four areas of 'core' saltmarsh in Chichester Harbour). Rogers (2019) also showed areas of accretion and erosion with a very small net accretion over the 2002 to 2016 period (across the chosen four areas within the harbour). However, the Rogers report showed an increase from 2002 to 2008 with erosion from 2013 to 2016 for the specific areas considered, against the wider overall decline in the entire harbour as shown by this report eg 2002, 334.8 hectares; 2008, 315.8 hectares; 2016, 295.5 hectares.

The fragmentation of marsh resulting in net erosion as demonstrated by Bailey and Pearson (2007), and see figure 5.2, appears to be resulting in areas of ongoing loss. Rogers MSc (2019) shows an increase in the number of polygons, representing fragmentation in 2016 compared with 2013. The fragmentation is happening both in front of sea defences and from the front of the pioneer marshes, with large losses occurring around larger creeks, ie creek widening is occurring contributing to the loss. The number of polygons in the Rogers study (and therefore the fragmentation of the saltmarsh) was highly variable, with relatively rapid changes between each of the five dates studied despite only three years between most photographs. Accretion and erosion are natural parts of dynamic habitats such as saltmarsh. However, this recorded change resulting from erosion with rapid fragmentation is indicative of the vulnerability of the remaining Chichester Harbour 'core' marshes to changes in environmental factors and a lack of environmental resilience, particularly to the effects of climate change. There is also some anecdotal evidence of the estuary depth being extended due to erosion of sediment, following loss of eelgrass to wasting disease in the 1920's and 1930's (Tubbs 1999) and this is compounded by regular dredging of the channels.

2) 1320 *Spartina* swards (*Spartinion maritimae*)

Spartina (cord-grass) swards are an interest feature of the SAC and can form part of the pioneer community of 1330 Atlantic Salt meadow SAC feature. The national vegetation classification communities associated with *Spartina* are:

- SM4 *Spartina maritima* salt-marsh community
- SM5 *Spartina alterniflora* salt-marsh community
- SM6 *Spartina anglica* salt-marsh community

Though these are recognised in the National Vegetation Classification (NVC) and the SAC designation, of the four cord-grass taxa which occur in the UK (small cord-grass *Spartina maritima*, smooth cord-grass *S. alterniflora*, Townsend's cord-grass *S.* x *townsendii* and common cord-grass *S. anglica*) the only original native species is *S. maritima*. All four taxa occur in the Solent Maritime SAC and form part of its interest feature. All non-*Spartina anglica* records were reported in the Solent and re-visited about 2012 (Natural England, 2015).

Though Townsend's cord-grass is of interest to scientists, extensive stands of monoculture *Spartina anglica* are thought to be of limited value to wildlife. They can be considered a threat to feeding waders (SPA features) if it is extending extensively out from the saltmarsh edge across the mudflats on which many SPA bird species feed. The IPENS report on *Spartina anglica* shows there is a major lack of research on impacts to waders, wader declines are correlated with *S. anglica* increase, but no proven causal effect (Natural England, 2016).

Conversely *S. anglica* has been known to help restoration of saltmarsh and form part of pioneer saltmarsh in the Dee Estuary (Dargie, 2001). *S. anglica* evolved naturally in the Solent from a doubling of the chromosomes in the Townsend's cord-grass hybrid and is known to have reached Chichester Harbour by the end of the 19th Century and occupied a significant part of the mudflats in the 1920s where it is likely to have filled the niche being vacated by the first wave of eelgrass dieback (Tubbs 1999). Unlike other parts of Europe and some parts of the UK, *Spartina* was not widely planted in the Solent where its spread has been largely natural (except for the Beaulieu) (Tubbs 1999). Historic descriptions show that *Spartina* marshes were largely on the seaward side of the existing marshes in the Solent though it later expanded into the upper marshes as these eroded and became damaged. Tubbs states in the Solent "*Accretion has been insufficient to elevate the marsh surface to the point where mixed marsh usually develops*".

In Budd and Coulson 1981, the area of diverse upper marsh in Chichester Harbour is quoted as only 40 hectares with 610 hectares of "*Spartina* marshes", however they give no source for these figures and note the methodology they used was poor at identifying *Spartina*. Ground truth surveys in the Budd and Coulson study showed that what was described as *Spartina* marsh was often dominated by other saltmarsh plants or in areas of *Spartina* 'dieback' it was associated with *Enteromorpha* and *Ulva* which resulted in difficult interpretation of the aerial photographic and infrared imagery.

Though *Spartina* is extensive in Chichester Harbour, there is no evidence that it is extending out at the expense of intertidal mudflats and therefore its extent is not a reason alone for unfavourable condition in Chichester Harbour where it has naturally colonised. The extensive marshes in some parts to the Solent (such as Langstone Harbour) were subject to rapid 'dieback' throughout the 20th Century especially where colonisation of intertidal mud had occurred. This pattern of saltmarsh loss due to *Spartina* dieback is characterised by loss of seaward margin of large areas of intertidal mud where it appeared to have occupied a niche vacated by eelgrass due to wasting disease (Tubbs 1999).

Spartina is found in all areas of the remaining saltmarsh surveyed in 2019 and is seen extensively in the Hayling Island transect on the seaward side and in the areas adjacent to transects. However as can be seen in figures 5.1, 5.2 and 5.3, the loss of marsh both historic and continued is happening at both the seaward and landward side in front of defences and indicates *Spartina* dieback is not the dominant cause of marsh loss. Indeed Tubbs 1999 estimates that of the intertidal area across the Solent lost to development since 1930 to 1999, at least 273 hectares were high level mixed-species saltmarshes and about 400 hectares were *Spartina* marshes, much of the latter in Langstone Harbour.

3) Impacts of water quality

The direct impacts of nutrient loading on saltmarsh has been the subject of much empirical study, mainly in the USA (eg Ryan and Boyer 2012; Bertness and others, 2007). Some researchers have demonstrated saltmarsh destabilisation due to excess of nitrogen (eg Turner 2011), whilst others have suggested long term experimental addition of nitrogen does not alter saltmarsh stability (eg Graham and Mendelssohn 2014) or is unrealistic for upper marshes (eg Johnson and others, 2016). However, the Graham and Mendelssohn study is of a system that is otherwise relatively pristine and subject to few other pressures so is not a realistic corollary for the UK saltmarsh.

One mechanism suggested for destabilisation of saltmarsh is thought to be a reduction in the root biomass or at least a reduction in the below ground to above ground plant biomass ratio (eg Deegan and others, 2012). The precise effects of excess nitrogen vary as so many other factors influence nitrogen uptake, saltmarsh growth and ecosystem responses vary to the precise combination of determinants. For example, Alldred and others (2017) found that below ground biomass increased with increasing salinity and decreased with nitrogen content in sediments. Boyer and Fong (2005) used radio isotopes to show that opportunistic macroalgae mediated the increase of nitrogen to saltmarsh plants. This mechanism could be occurring in Chichester Harbour due to the large volumes of opportunistic macroalgae on the marsh.

Rogers (2019) assessment, though more limited in time period and geographic scope than the current study, was more detailed in data analysis and found a relationship between the localised erosion of saltmarsh in years there were higher nitrate values in Chichester Harbour. She also demonstrated an overall slight but statistically significant rise in nitrate values in the harbour. The Rogers work was based on data from 2002 to 2016 at only three water quality monitoring sites. It does not include the areas with highest nitrogen values shown in the current study and only covers four of the most extensive areas of remaining saltmarsh, so does not include those areas arguably most likely to be impacted by water quality. However, the Rogers study does find a statistically significant relationship whereby higher nitrogen (nitrate) can result in greater annual saltmarsh losses at a local level when combined with other factors likely to correlate with high nitrogen such as increased wave action (as they are related to increased wind and rainfall). Though all attributes correlated to saltmarsh, wave action and nitrate levels had the strongest correlation to losses of saltmarsh with the correlation to winter nitrate stronger than summer nitrate (however both were statistically significant). The relationship between environmental variables and saltmarsh will be discussed further in section 9 along with discussion of more indirect mechanisms of nutrient impact on saltmarsh such as smothering by opportunistic macroalgae.

4) Synergistic and additive interactions

In order to stay stable in the face of sea-level rise, coastal systems in general, and salt marsh in particular, must accumulate sediment/organic matter and resist erosion from increased wave action and storm surges. Both features of resilient marshes depend on healthy root systems (good below ground biomass) (eg Perillo and others, 2018). Saltmarshes adapt to sea level rise by vertical accretion and inadequate accretion can result from insufficient sedimentation but also insufficient organic matter accumulation (eg Nyman and others, 2006). As early as 1999 in Tubbs it was postulated that the increased urbanisation of the coastal fringe around the Solent combined with coastal flood defences which stablise the coast had reduced the sediment supply to the Solent marshes contributing to their net loss.

The English Nature Research Report 710 (2006) (ENRR) emerged from studies of the impacts of coastal flood defences on saltmarsh, predicting the future saltmarsh extent by 2054 based on the saltmarsh loss between designation (circa 1976) and 2004, although as noted above there are difficulties predicting future losses. By 2054 the ENRR report predicted there to be only 44.4 hectares across Chichester and Langstone Harbours but noted this assumes a constant rate of loss which is unlikely to be the case. The current study shows the rate of loss has varied over the years but appears to be slowing, though net saltmarsh loss across Chichester Harbour is still significant (approximately 2.5 hectares a year).

The work of Rogers (2019) on the more stable remaining saltmarsh in the harbour also shows that as well as spatial variation in saltmarsh accretion/ losses there is inter-annual variation in saltmarsh loss and accretion. This correlated to inter-annual variation in wave action, nutrients and sea temperature all of which are also correlated to each other. The influence of the weather on nutrients is discussed in section 9. Nutrients also increase with increased rainfall particularly during high rainfall events. Since climate change increases sea temperature, wave action and the intensity of rainfall events, also increasing nutrient release into the harbour, the effects of climate change on these other factors (not just sea level) is likely to exacerbate the loss of saltmarsh in the harbour. The recognition of multiple stressors on saltmarsh was provided by Duarte and others (2017) who suggested that biological monitoring of saltmarsh characteristics would form a useful indicator of estuarine ecosystem health.

The synergistic impacts of climate change with other factors, such has high nutrients and coastal process interruption, is highlighted in the 2019 IPCC report on impacts in coastal habitats and as one of the top four biggest issues facing UK coastal habitats in the 2020 Marine Climate Change Impacts Partnership (MCCIP) report card.

In order for UK ecosystems to be resilient and to enhance their natural capital as required by the 25 Year Environment Plan and a range of statutory drivers, we need to understand their response to a range of impacts that vary simultaneously over space and time (eg MICCP, 2020; Staudt and others, 2013). The conceptual understanding of ecosystems and conservation decision making needs to account for concurrent impacts of all stressors. Assessing activities separately as is currently the case in the UK, is likely to grossly underestimate the impacts and lead to insufficiently precautionary standards and decisions, leading to long term ecosystem degradation and failure to restore sites.

This is especially true for coastal ecosystems such as salt marshes that will face multiple spatially and temporarily varied impacts going forward, including coastal stabilisation, sediment input change, sea level rise and warming, coastal eutrophication and changes in rainfall patterns affecting salinity (eg Natural England and RSPB 2020, and Crain and others, 2008). All of which have been observed in Chichester Harbour by this report and/or by Roberts MSc 2019. The current approach of setting targets separately for impacts and needing to prove that each factor is alone a causal issue before acting is inadequate and cannot continue. A clear case for more stringent standards is required if ecosystems are to become resilient to and adapt to climate change.

5) Climate change adaptation

Climate adaptation strategies for coastal wetlands are required for all wetlands in the south of England. These can include enhancing resilience of the existing marshes to remove other stressors that may act to reduce resilience (such as high nutrient levels or overgrazing) through to the more drastic measures such as removing barriers to migration of marshes or creating new marshes through sediment addition (Wigand and others, 2016).

The type of measure chosen to help climate change adaptation for saltmarsh has been assessed for 16 saltmarshes in the USA (Roposa and others, 2018). Those most vulnerable to loss are described as those with low sediment input, subject to other anthropogenic impacts and those with low elevation. Based on UK sites, sediment flux is by far the strongest indicator of long-term lateral changes in saltmarsh extent (Ladd and others, 2019).

Chichester Harbour saltmarsh fits into this description of high-risk saltmarsh in general terms. Though the mathematical model used by Roposa and others cannot be extrapolated from the studies for use in the UK, the conceptualisation and types of resilience are likely to be universal and are corroborated by the evidence of continued loss of the saltmarsh in Chichester Harbour (shown by the current study, by the ENRR in 2006 and by the Roberts (2019)). The forecast of loss of Chichester Harbour saltmarsh by mid-2100’s is also consistent with the Raposa and others model that predicts such marshes (of low elevation and low sediment) are unlikely to survive a century.

The importance of climate change with other factors is indicated by the current study and the Rogers (2019) MSc, the latter showing the increased wave action correlated strongly with years where erosion occurred. Since on average wave action is set to increase with climate change the erosion of Chichester Harbour saltmarsh is likely to increase over time and exacerbate the impacts of coastal defences.

Raposa and others recommend that the only long-term solution in these areas is to:

- Turn low lying coastal areas above the marsh into conservation land for recreating marshes.
- Removing barriers to landward migration.
- Creating new marshes in the existing tidal footprint (through addition of low nutrient sediment in appropriate areas).

The 2019 IPPC report is clear that coastal ecosystems including saltmarsh are able to help coasts adapt to climate change impacts as they can build vertically and expand laterally. However, the ability to do this varies and can be limited by other anthropogenic stressors such as habitat degradation and coastal development (activities that prevent sediment movement, reduce sediment availability and prevent landward migration).

The 2019 IPPC report states that decision makers need to take "*long term perspective when making short term decisions*". Considering this and supported by the continued loss of saltmarsh the recommendations section gives views for planning and policy as well as condition of the designated sites.

The Natural England and RSPB climate Change Adaptation Manual (2020) gives lists of adaptation approaches for saltmarsh and the most appropriate for Chichester Harbour are:

- Anticipate and develop approaches to developing landward movement of marshes by identifying and protecting priority sites for realignment projects.
- Develop and implement management plans that respond to predicted changes along the whole coast, not individual sites in isolation.
- Ensure adequate space and promote policies that allow a continued supply of sediment [..] for replenishing saltmarsh through strategic coastal planning.
- Adjust boundaries and interest features of sites as coasts evolve and aim to enlarge functional units.
- Act to eliminate or reduce non-climate associated erosion for example caused by altered drainage flows, contamination, removal of sediment by dredging or wash from shipping.
- Ensure that adaptation through use of hard defences does not adversely affect coastal dynamics and increase the threat of coastal squeeze.
- Manage recreational pressure to minimise erosion and damage to saltmarsh vegetation.
- Consider using sediment re-charge to reduce the rate of erosion of vulnerable areas of saltmarsh, where supply of sediment has been disrupted by human activity.

5.6 Saltmarsh condition summary

Prior to this report, coastal squeeze impacts were considered as being addressed through the Environment Agency's Habitats Creation Programme (HCP), therefore the saltmarsh was in unfavourable recovering condition, although this habitat creation was delivered off site. In 2010 the Public Service Agreement (PSA) target for biodiversity required the delivery of a minimum of 100 hectares of intertidal habitat, which was delivered through the Lymington Water Level Management Plan and managed realignment at Medmerry to address historic losses across the wider Solent including Chichester Harbour. At the time, as agreed with the Environment Agency, Natural England moved the SSSI condition status to unfavourable recovering for coastal squeeze. The initial phase of the Solent and South Downs RHCP (Regional Habitat Compensation Programme) was identified as the remedy for this impact, whilst recognising that more habitat creation would be needed in later epochs. Subsequently as part of the IPENS Programme, it was agreed that estuaries and their habitats such as saltmarsh would only remain in recovering condition after 2010 if significant additional habitat was created. Medmerry in West Sussex (breached in 2013) was designed to create a total of 183 hectares of intertidal habitat which only a portion will evolve to be saltmarsh (Environment Agency 2018). Medmerry addresses losses for the whole Solent due to coastal squeeze, not just Chichester Harbour and contributes in part to the first epoch for the shoreline management plans. Further habitat creation schemes have been identified to address the epoch 1 losses. The following weblink takes you to the HCP that covers the Solent and South Downs RHCP.

Clearly with loss of extent in Chichester Harbour at circa 257 hectares since first SSSI designation (1970), 421 hectares since 1946, and the continued net loss likely to be exacerbated by climate change, additional habitat will be required to compensate the historic losses at Chichester Harbour and to enable favourable condition to be achieved. A similar issue will exist for the whole Solent. Careful consideration is also required whether the site was in favourable condition at designation and therefore whether additional habitat is required to achieve favourable condition.

Currently the HCP focus is on addressing future losses predicted by the SMP, however, it is clear from this study, that the favourable condition for the SSSI will not be achieved if restoration of historic losses is not undertaken. The habitat extent loss due to coastal management underpins the condition of the internationally designated sites. Losses should be addressed in the order they occur, historic, current and future in order to conserve and enhance our designated sites and contribute to the designated sites targets in the 25 Year Environment Plan.

The continued loss of extent, lack of transitional zones and limited extent of both upper and middle marsh are failures of condition and the continued extent loss and quality factors indicates a declining condition. Therefore, all units that had saltmarsh at designation but have subsequently lost marsh and those that continue to have saltmarsh will be recorded as unfavourable declining condition based on this report.

5.7 Recommendations summary

- Assign condition of all units with saltmarsh currently or historically to unfavourable declining condition and apply appropriate adverse condition reasons (see section 10).
- Investigate sources of sediment that are low in nutrients, and/or other pollutants that might be used to stabilise the marshes. Ensure any beneficial use of sediment does not impact existing biodiversity saltmarsh, through smothering etc.
- Management of physical barriers/defences to ensure that use of sediment is placed in sustainable locations where it can accrete.
- Using available data (such as LIDAR) to identify areas of low-lying land around Chichester Harbour. Safeguard all land outside of settlement boundaries for climate change adaptation in local plan and identify areas for saltmarsh creation as compensatory habitat in all other relevant statutory plans. Consider using the coastal change management area mechanism in the NPPF to achieve this.
- As a matter of urgency begin restoration of saltmarsh in Chichester Harbour to at least the figure at 1970 (SSSI designation) and potentially to 1949 figures in order to achieve favourable condition in extent terms for the SSSI and at least back to the 1992 figures to restore conservation status for the SAC (552.1 hectares and ideally 717 hectares of saltmarsh in Chichester Harbour). This requires at least an additional 257 hectares of realigned saltmarsh creation in order to address historic losses and meet the favourable condition of the site. This would not address future losses due to climate change interacting with coastal management. If coastal processes and water quality issues can be addressed, the system may become more resilient and not need additional measures (once historic losses are addressed).
- Discuss and identify with partners, potential funding options for saltmarsh recreation for example through the Environment Agency Capital Improvement Programme and using any other appropriate sources.
- Implement recommendations of section 9 on nitrogen reduction.
- Saltmarsh surveys should be undertaken every 3 to 5 years due to rate of decline.

6 Review of ornithological interest feature condition

6.1 Chichester Harbour SSSI – ornithological interest features

1) Chichester Harbour SSSI – ornithological interest features

As described elsewhere in this report, both Chichester and Langstone Harbours contain extensive intertidal mudflats and sandflats with areas of seagrass beds, saltmarsh, shallow coastal waters, coastal lagoons, coastal grazing marsh, shingle ridges and islands. Figure 3.2 shows the extensive area of habitats exposed by the lowest astronomical tide. The size and diversity of habitats and sheltered nature ensure these habitats support internationally and nationally important numbers of overwintering and breeding bird species. Table 6.1 lists the ornithological features of the SSSI, SPA and Ramsar site. Alongside the Chichester and Langstone Harbours SPA, the Solent and Dorset Coast SPA was recently classified for foraging tern species.

2) What do Natural England measure?

Assessment of SSSI condition for designated sites' ornithological features is undertaken following CSMG for birds (JNCC, 2004). Some site specific elements of the ornithological condition assessment are undertaken following the Chichester Harbour FCTs.

The common standards approach to SSSI condition monitoring does not refer to low tide counts for wintering birds or their distribution. However, maintaining the distribution of supporting habitats and wintering birds is an important element of the SPA condition, as described in the SACOs. In this study, low tide counts and the distribution of foraging birds is assessed. Consideration is also given to the influence that broad-scale climatic factors are having on wintering bird distribution.

6.2 Data collection and limitations

1) Wetland Bird Survey (WeBS)

The WeBS is the UK national non-breeding waterbird monitoring scheme. The aim is to monitor all non-breeding waterbirds in the UK in order to provide the principal data on which the conservation of their populations is based. WeBS core counts are conducted once per month, particularly from September to March. Chichester Harbour is divided into 13 different count sectors, which are counted on synchronised dates, at high tide.

Whilst counts are only undertaken once a month, the value in the dataset is its long-term nature and consistency. Therefore, WeBS core count data can be used to assess trends in site, regional and national populations. The British Trust for Ornithology (BTO) recently published updated WeBS alerts, assessing the change in populations for SPA qualifying features, and comparing these to regional and national population changes.

The WeBS low tide counts scheme was launched in the winter of 1992/93 and provides information on the numbers of waterbirds feeding on subdivisions of the inter-tidal habitat within estuaries. Coordinated counts of waterbirds are made by volunteers each month between November and February on pre-established subdivisions of the inter-tidal habitat in the period two hours either side of low tide.

Table 6.1 The ornithological interest features of the SSSI

Species/assemblage feature	SSSI	SPA	Ramsar
Common tern (br) (foraging)	Y	Y	Y
Little tern (br) (foraging)	Y	Y	Y
Sandwich tern (br) (foraging)	Y	Y	
Bar-tailed godwit (nb)	Y	Y	
Black-tailed godwit (nb)	Y		Y
Brent goose (dark-bellied) (nb)	Y	Y	Y
Curlew (nb)	Y	Y	
Dunlin (nb)	Y	Y	Y
Greenshank (nb)	Y		
Grey plover (nb)	Y	Y	Y
Redshank (nb)	Y	Y	Y
Ringed plover (nb)	Y	Y	Y
Sanderling (nb)	Y	Y	
Shelduck (nb)	Y	Y	Y
Shoveler (nb)		Y	
Teal (nb)	Y	Y	
Turnstone (nb)		Y	
Red-breasted merganser (nb)		Y	
Wigeon (nb)		Y	
Pintail (nb)		Y	
Assemblages of breeding birds - mixed: lowland damp grassland, scrub, woodland	Y		
Assemblage of wintering waterbirds		Y	Y

Given the extra work that low tide counts entail, often by the same counters that carry out the core counts, WeBS aims to cover most individual estuaries about once every six years. Chichester Harbour is divided into 70 low tide count sectors, resulting in a significant workload in terms of organising and carrying out the survey. Low tide counts were undertaken in Chichester Harbour in 1992/93, 1993/94, 1996/97, 1997/98, 1998/99, 2001/02, 2005/06, 2010/11 and 2017/18. This data series gives a good picture of how numbers and distribution of foraging birds have changed over time.

However, the sporadic nature of the survey means that it is not possible to directly compare with other datasets to determine potential reasons for changes in number or distribution of birds. For example, we were unable to compare the amount of opportunistic macroalgae in an area with the number of foraging birds, as the surveys were not undertaken in the same year and there is significant weather dependant inter-annual variation in the opportunistic macroalgae.

2) Solent Wader and Brent Goose Strategy (SWBGS)

WeBS count sectors are focused on the designated sites and intertidal area. However, some SPA qualifying features make extensive use of terrestrial habitats either for foraging and/or at high tide. Therefore, the SWBGS was set up to identify these important sites and then maintain a network of sites through better management and protection from development and recreational pressure. The first strategy was published in 2002, and updated in 2010 (King, 2010). A further update, incorporating new survey data and the results of a three-year bird movement study (undertaken between 2016/17 and 2018/19) is due to be published in 2020.

Although the final version of the updated strategy is not yet published, a new suite of maps and bird records have been produced, and have been used to inform this report. The SWBGS sites have been classified according to a newly developed metric scoring system. Guidance has been produced on the levels of mitigation necessary for the different classifications of sites.

3) Breeding birds

Breeding terns within the SPA are monitored every year by the RSPB (in Langstone Harbour) and Chichester Harbour Conservancy (in Chichester Harbour), as part of the Seabird Monitoring Programme. The EU LIFE Little Tern project ran from 2014 to 2019 and established productivity monitoring in order to give a better picture of the health of the population.

The SSSI is also notified for its breeding bird assemblage of lowland damp grassland, scrub and woodland. As these habitats are terrestrial, an assessment of this feature is outside the scope of this current project.

6.3 Condition assessment of wintering waterbirds

1) Aggregations of non-breeding birds

The favourable condition table for Chichester Harbour SSSI states that the population should be maintained above the lowest annual peak WeBS count in the five years prior to designation for that species to be in favourable condition. The Birds CSMG is that the feature should be considered unfavourable no change if the average population is within 25% of the previous assessment population, or unfavourable declining if it is >25% less than the previous assessment population (JNCC, 2004). The last assessment recorded on HP Content Manager (Natural England's records keeping system (TRIM)) was 5 years ago, and corresponds to the short-term WeBS alert, therefore, this has been used to derive the trend in condition. However, combining the SSSI condition assessment with the medium- and long-term WeBS alerts and associated commentary (table 6.2) and the trends presented in figure 6.1, below, give a comprehensive picture of the status of the SSSI bird features.

Table 6.2 Condition assessment and WeBS alerts for birds wintering in Chichester Harbour SSSI

Species	5-year peak mean at designation SSSI: 1980-85 SPA: 1991-96	Known natural fluctuations baseline (minimum count 1980/81 – 85/86)	Current 5-year peak mean (13/14-17/18)	WeBS alerts for SSSI species[6]					Commentary on changes in population
				First winter[7]	Ref winter[8]	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	
Dark-bellied brent goose	9524	7088	14265^ Favourable	91/92	16/17	21	-4	25	Proportion of the regional population held by the site is stable, suggesting conditions remain relatively favourable for the species.
Shelduck	2938	2007	486 Unfavourable no change	91/92	16/17	1	-16	-71	Decline since designation but levelled off over the short- to medium-term. This follows the regional trend, though the proportion of the regional population present on the site has declined, suggesting site specific factors in the decline.
Teal	2392	1724	1235 Unfavourable declining	91/92	16/17	-25	-2	-10	Population has fluctuated with a general downward trend. Whilst the proportion of the regional population on site has recently remained stable, the differing trend between site and national populations may indicate site- or region-specific reasons for the population change.

*Shoveler are a feature of Chichester and Langstone SPA but are only found in low numbers in Chichester Harbour (the peak count was 9 individuals in the period 2013/14 to 2017/18). Therefore, a meaningful favourable condition target cannot be generated, and WeBS Alerts have not been produced for this species in Chichester Harbour, hence not included in this table.

[6] Wetland Bird Survey Alerts 2016/2017 (Woodward and others, 2019).
[7] The first winter is defined as the earliest winter available in time-series for long-term assessment (nominally 25 years prior to ref winter unless a shorter time series dictates otherwise).
[8] Reference winter is defined as the winter for which alerts status is assessed (nominally the penultimate winter of the available time series).

Table 6.2 (cont) Condition assessment and WeBS alerts for birds wintering in Chichester Harbour SSSI

Species	5-year peak mean at designation SSSI: 1980-85 SPA: 1991-96	Known natural fluctuations baseline (minimum count 1980/81 – 85/86)	Current 5-year peak mean (13/14-17/18)	WeBS alerts for SSSI species[9]					Commentary on changes in population
				First winter[10]	Ref winter[11]	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	
Grey plover	2056	1541	1444* Unfavourable no change	91/92	16/17	-11	-17	-49	The trend on the site appears to be tracking the regional and British trends. The slightly increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and suggests broad scale reasons for the declines.
Ringed plover	520	413	506* Favourable	91/92	16/17	0	-36	-66	Population increased after designation, then declined back to the levels found at designation. This pattern follows regional and British trends, and therefore changes on the site are likely to be due to broad-scale population changes.
Curlew	1836	1223	1489* Favourable	91/92	16/17	-9	-26	14	The proportion of the regional population held by the site remains stable, indicating that conditions remain relatively favourable.
Bar-tailed godwit	988	732	715* Unfavourable no change	91/92	16/17	-22	-28	-30	Declines in population on site are greater than British declines but track regional declines.

[9] Wetland Bird Survey Alerts 2016/2017 (Woodward and others, 2019).
[10] The first winter is defined as the earliest winter available in time-series for long-term assessment (nominally 25 years prior to ref winter unless a shorter time series dictates otherwise).
[11] Reference winter is defined as the winter for which alerts status is assessed (nominally the penultimate winter of the available time series).

Table 6.2 (cont) Condition assessment and WeBS alerts for birds wintering in Chichester Harbour SSSI

Species	5-year peak mean at designation SSSI: 1980-85 SPA: 1991-96	Known natural fluctuations baseline (minimum count 1980/81 – 85/86)	Current 5-year peak mean (13/14-17/18)	WeBS alerts for SSSI species[12]					Commentary on changes in population
				First winter [13]	Ref winter [14]	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	
Black-tailed godwit	892	716	643^ Unfavourable no change	91/92	16/17	-21	4	6	Whilst alerts are not triggered, the proportion of the regional population held by the site has declined, suggesting some site-specific issues.
Sanderling	409	330	304* Unfavourable declining	91/92	16/17	-31	-38	-49	Site trend appears to be tracking the regional trend (but not national). Proportion of the regional population held by the site is stable.
Dunlin	25544	21036	11853* Unfavourable declining	91/92	16/17	-34	-34	-45	Site trend is tracking regional and national trend over the long term. Therefore, changes on the site are likely to largely be due to broad-scale population changes.
Redshank	2603	2160	1854* Unfavourable no change	91/92	16/17	0	-10	14	Site trends appear to be tracking regional trends. The proportion of the regional population held by the site has increased, indicating conditions remain relatively favourable.

[12] Wetland Bird Survey Alerts 2016/2017 (Woodward and others, 2019).
[13] The first winter is defined as the earliest winter available in time-series for long-term assessment (nominally 25 years prior to ref winter unless a shorter time series dictates otherwise).
[14] Reference winter is defined as the winter for which alerts status is assessed (nominally the penultimate winter of the available time series).

Table 6.2 (cont) Condition assessment and WeBS alerts for birds wintering in Chichester Harbour SSSI

Species	5-year peak mean at designation SSSI: 1980-85 SPA: 1991-96	Known natural fluctuations baseline (minimum count 1980/81 – 85/86)	Current 5-year peak mean (13/14-17/18)	WeBS alerts for SSSI species[15]					Commentary on changes in population
				First winter [16]	Ref winter [17]	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	
Greenshank	92	60	90* Favourable	91/92	16/17	3	24	139	Site trend is tracking the regional and national trends. Proportion of the regional population held by site is stable, indicating conditions remain relatively favourable.
Turnstone (SPA only)	296	193	226 Favourable	91/92	16/17	12	-17	35	The proportion of the regional population held by the site has increased, suggesting conditions on the site are relatively favourable for the species.
Red breasted merganser (SPA only)	139	120	153* Favourable	91/92	16/17	-31	-25	12	Site appears to be following regional trend. The proportion of the regional population held by the site has increased, suggesting broad-scale reasons for population changes.
Pintail (SPA only)	212	91	201 Favourable	91/92	16/17	-13	-42	-31	Site trend is tracking the regional trend, and the proportion of the population held by the site is stable.
Wigeon (SPA only)	1466	988	2922	91/92	16/17	-16	21	151	The proportion of the regional population held by the site increased since

[15] Wetland Bird Survey Alerts 2016/2017 (Woodward and others, 2019).
[16] The first winter is defined as the earliest winter available in time-series for long-term assessment (nominally 25 years prior to ref winter unless a shorter time series dictates otherwise).
[17] Reference winter is defined as the winter for which alerts status is assessed (nominally the penultimate winter of the available time series).

			Favourable						designation, but has declined more recently, suggesting redistribution of birds.

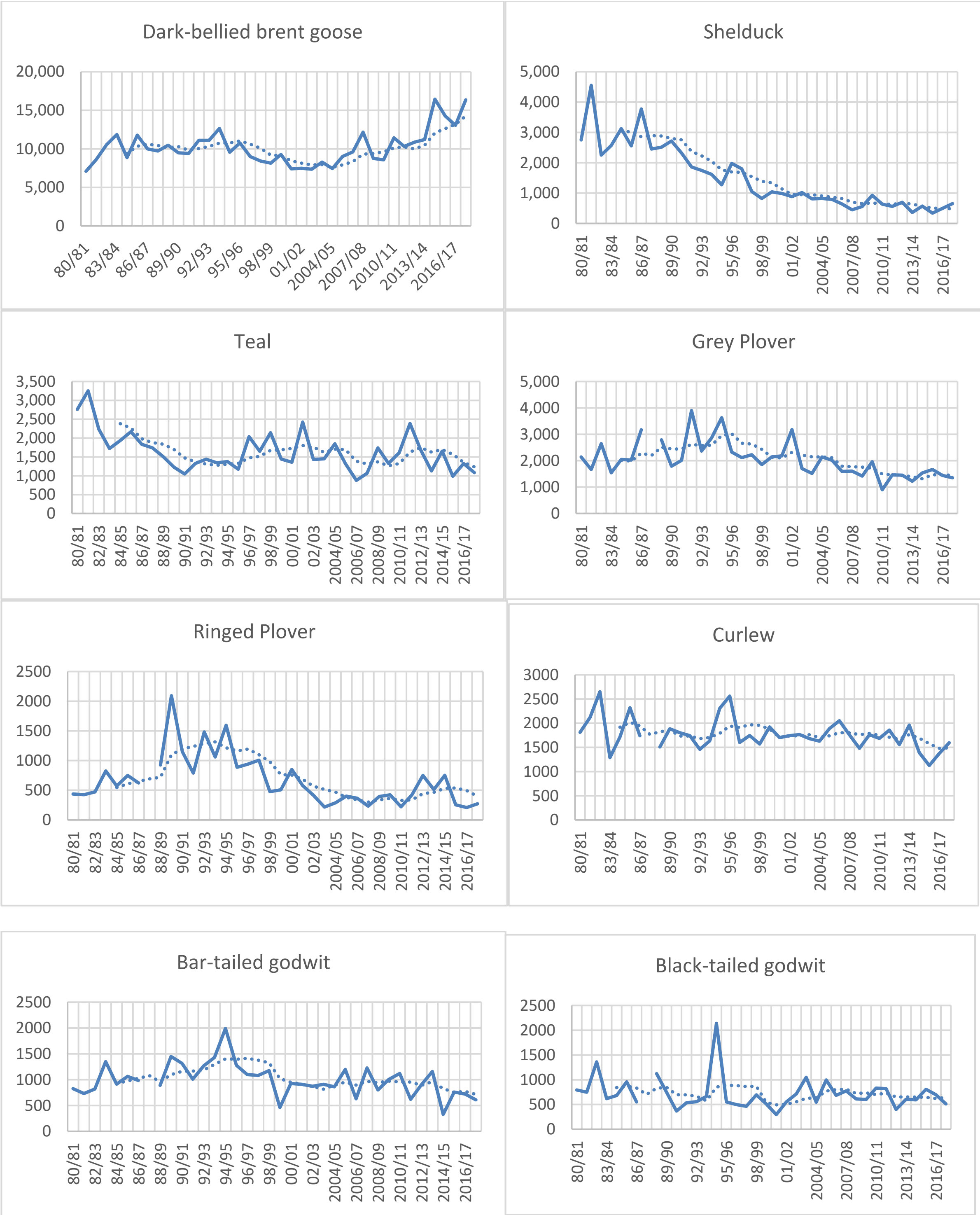


Figure 6.1 Changes in peak WeBS core count since designation for Chichester Harbour SSSI

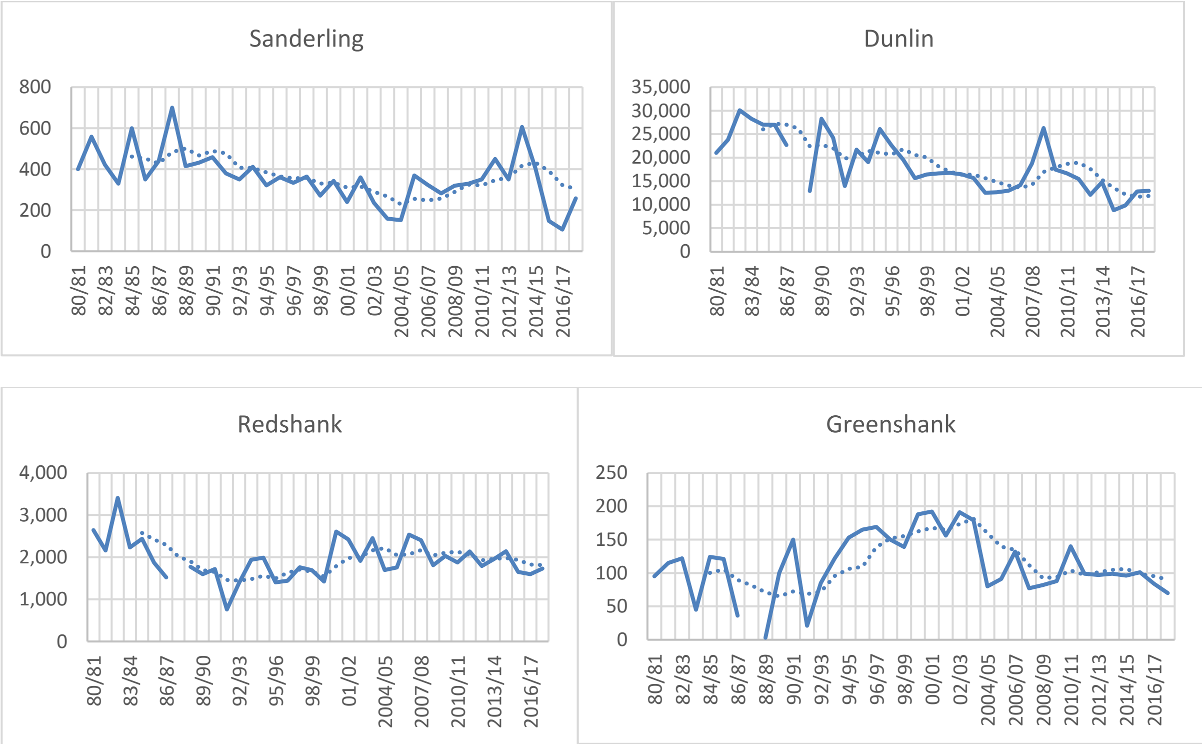


Figure 6.1 (cont.) Changes in peak WeBS core count since designation for Chichester Harbour SSSI

The long-term trends of peak WeBS counts are shown in figure 6.1. Based on the current 5-year peak means from WeBS (2013/14 – 2017/18), dark-bellied brent goose, ringed plover, curlew and greenshank wintering populations are in favourable condition. Shelduck, teal, grey plover, bar-tailed godwit, black-tailed godwit, sanderling, dunlin and redshank are in unfavourable condition at the SSSI level. However, based on the BTO's assessment of waterbirds in the UK 2017/18 (Frost and others, 2019), the SSSI remains nationally important for shelduck, grey plover, ringed plover, curlew, bar-tailed godwit, sanderling, dunlin, redshank, greenshank and red-breasted merganser, and is internationally important for black-tailed godwit and dark-bellied brent goose.

The WeBS alerts and comparison with regional trends and populations suggest that there are site specific reasons for the declines in shelduck and black-tailed godwit. Comparison with national trends suggests regional or site-specific reasons for declines in teal.

2) Taking account of wider flyway-scale influences on population change

Over the past 15 years, evidence has emerged that factors operating across different parts of certain migratory birds' breeding and wintering range are affecting the population abundance and distribution. These factors include climate change: for example, milder winters encouraging certain migratory waterbirds to winter closer to their breeding grounds, with a consequent shift in range to the North West, away from the UK.

Natural England has, therefore, produced internal guidance to accompany the CSMG for birds on how to take account of wider flyway scale influences on population change (Baylis and Barker, 2016). Reviews have been produced for wintering waterbirds, which examine the evidence for climate related shifts in distribution. Where there is good evidence that a species range distribution is being affected by climate change, and where examination of the WeBS alerts indicates that site trends are in line with national trends, it may be possible to 'switch off' the population abundance attribute when assessing condition. The guidance also advises that area teams consider whether the population baseline needs to be amended to consider a natural change reflected in a decreasing national trend.

This report, therefore, now considers each of the species that are not meeting the favourable condition target, as identified in table 6.2 above.

Shelduck

After increasing in the UK between the early 1970s and mid-1990s, shelduck have since declined (Frost and others, 2019). Declines on the site have been greater than that seen nationally. This, and the fact that the proportion of the regional population held by the site has declined, indicate site specific reasons for the trends seen on site. Therefore, it is not appropriate to switch off the population abundance attribute, and hence the condition should remain as unfavourable no change. As site specific reasons are implicated in the declines, it is not appropriate to amend the baseline population for favourable condition.

Teal

The population has fluctuated on site with a general downward trend. This is different to the national picture, in which teal have increased, although the rate of increase has slowed in recent years. Whilst the proportion of the regional population on site has recently remained stable, the differing trend between site and national populations may indicate site- or region-specific reasons for the population change. Guidance (Baylis & Barker, 2016) is that as it is unknown whether climate-related broad scale influences across the flyway are playing a role in a non-breeding teal site decline, it is not recommended to temporarily ‘switch off’ the population abundance attribute during any CSM assessment. Therefore, the condition assessment remains as unfavourable declining.

Grey plover

The trend on site follows the declining national trend, although the rate of decline is larger in the long-term on the site. The proportion of the regional population held by the site has increased slightly. Warmer winter temperatures have been associated with a significant shift in the wintering range for grey plover in a north-easterly direction. The inference is that a lower proportion or lower numbers of the breeding birds from western Siberia are using British sites for wintering purposes and this is reflected in decreasing abundance at individual site level. Therefore, guidance (Baylis & Barker, 2016) is that it is likely that off-site influences, either from breeding areas or via shifts in wintering range will be playing an important role in the non-breeding grey plover site declines. As such, it may be appropriate to temporarily ‘switch off’ the population abundance attribute. However, Massimino and others 2012, identifies that the changes within the Chichester and Langstone SPA are performing worse than climate predictions, and hence does not recommend amending the baseline population. Therefore, whilst climatic changes are clearly an important factor in grey plover declines on site, there may also be site level influences. Therefore, it is proposed that the assessment of unfavourable no change remains, but with a note that climate-based range shifts are likely to be a major cause of the condition.

Bar-tailed godwit

The declines at a SPA and SSSI site level are greater than national declines. However, they are similar to regional declines, and the proportion of the regional population held by the site has remained relatively stable. Therefore, the WeBS alert commentary suggests that as the trends at the SPA level are similar to regional trends, the reasons for declines are due to broad-scale population changes.

Warmer winter temperatures have been associated with a significant shift in the wintering range for bar-tailed godwit in a north-easterly direction. Therefore guidance (Baylis & Barker, 2016) is that it is likely that off-site influences, ie shifts in wintering range, will be playing an important role in the non-breeding site declines. As such, if the site declines match national declines, then it may be appropriate to ‘switch off’ the population abundance attribute.

In this case, site declines are greater than national declines, and site-specific reasons for the difference cannot be ruled out (for example recreational disturbance and water quality changes). Therefore, it is proposed that the assessment of unfavourable no change remains, but with a note that climate-based range shifts are likely to be a major cause of the condition.

Black-tailed godwit

The national population has seen a large increase in the long term, which is not seen at the SSSI level. The increasing national populations are thought to be due to climatic factors – both on their breeding grounds and wintering, with a shift in wintering range towards the UK. The proportion of the regional population held by the site has declined over time, suggesting site-specific issues. Therefore, the assessment of unfavourable no change remains.

Sanderling

Population trends at SSSI and SPA-level follow regional trends. However, they do not follow the national picture, which has seen increases in estuary sites covered by WeBS. There is evidence for a shift in distribution within the UK, away from the South West, in response to milder winters. Therefore, guidance (Baylis & Barker, 2016) is that the population abundance attribute should only be 'switched off' for South West estuarine sites. Therefore, the assessment of unfavourable declining remains.

Dunlin

The scale of wintering dunlin declines has been the same at SSSI, SPA and British levels over the long term. However, in the short- and medium-terms, the declines at the site and SPA level have been greater than national declines.
As with other small waders, there has been a shift in wintering range away from the UK in a north-westerly direction, which is associated with warmer winters. Therefore, guidance (Baylis & Barker, 2016) is that it is likely that off-site influences, ie shifts in wintering range, will be playing a role in the non-breeding site declines. In this case, the long-term scale of decline on the site is the same as at the regional and national scale, indicating broad-scale factors for the decline, and suggesting that the population abundance attribute should be 'switched off' for this species. When assigning a condition to a feature, the guidance also states that where a 'population is being negatively affected by an influence that is occurring primarily off-site and there is no conservation measure or action that can reasonably be taken to rectify or ameliorate this pressure' then it can be recorded as unfavourable recovering. This is to account for factors such as 'short-stopping' where wintering birds are not arriving in the UK due to climatic shifts on their migratory pathways. Whilst broad-scale factors are likely playing a major role in the decline seen on site, dunlin are susceptible to water quality changes and disturbance. Therefore, whilst site specific factors cannot be entirely ruled out, the assessment of unfavourable declining should remain.

Redshank

The site trend is tracking the British trend but is not following the regional trend. The regional population has declined more than on the site, and the proportion of the regional population held by the site has increased, indicating that conditions remain relatively favourable compared to other sites. There is evidence that there have been shifts in the range of wintering redshank in response to warmer winters, resulting in both a decline at the UK scale, and a shift from west to east within the UK. Therefore guidance (Baylis & Barker, 2016) is that for sites in the South East and South West, it is likely that broad-scale influences across the flyway are playing a role in the non-breeding site declines. In this case, as the site is tracking the national trend, and is doing better than the regional trend, it may be appropriate to 'switch off' the population abundance target. However, whilst broad-scale factors are likely playing a major role in the decline seen on site, redshank are susceptible to water quality changes (see section 6.2) in relation to low tide counts and disturbance. Therefore, as site specific factors cannot be entirely ruled out, the assessment of unfavourable no change should remain.

Ringed plover

Warrants a special mention as it is classed as in favourable condition, but still triggers a high alert (66% decline) over the last 25 years. As noted in table 6.2 above, this is because the population increased after designation and has since declined. Compared to SPA-level trends, the declines at the SSSI level have not been so great, suggesting that conditions are relatively favourable in Chichester Harbour compared to the whole SPA. The range of wintering ringed plovers has shifted north and west due to milder winters. Therefore, the declines on the site, and at the UK-level are likely due to broad-scale climatic factors. Hence it is appropriate to assess the condition as favourable, despite the high WeBS alert.

Summary

Eight species are in favourable condition: dark-bellied brent goose, curlew, ringed plover, greenshank, turnstone, red-breasted merganser, pintail and wigeon (the latter four are SPA species only). Shoveler are a feature of Chichester and Langstone SPA but are only found in low numbers in Chichester Harbour (the peak count was 9 individuals in the period 2013/14 to 2017/18), therefore a meaningful favourable condition target cannot be generated.

Eight species are in unfavourable condition. Of these, four are not deemed to be affected at a national scale by climatic changes, and/or are being affected by site specific factors: shelduck and black-tailed godwit (unfavourable no change), teal and sanderling (unfavourable declining).
Two further species (grey plover and bar-tailed godwit) are proposed to remain at unfavourable no change, but with a note that broad-scale climatic factors are likely to be a major cause of declines, but site-specific reasons cannot be ruled out.

The final two species (dunlin and redshank) are likely to be primarily affected by broad-scale climatic factors, so it may be appropriate to 'switch off' the population abundance target and revise the condition assessment. However, as site specific factors cannot be entirely ruled out, the assessment of unfavourable condition should remain.

3) WeBS alerts for Chichester and Langstone Harbours SPA[18]

BTO have also produced WeBS alerts at the SPA level, with alerts triggered for 10 out of the 15 species assessed, and also for the waterbird assemblage. For the seven wader species for which alerts have been triggered, comparison of the site and regional trends suggests that the alerts may be driven by broad scale changes in distribution. However, for the three wildfowl species (shelduck, shoveler and teal) the comparison suggests that the alerts may be driven by site-specific pressures. Note that in the case of teal, high numbers were sustained at the site for several years during the baseline period, but these levels have not been achieved subsequently in spite of increases elsewhere.

[18] Wetland Bird Survey Alerts 2016/2017 (Woodward and others, 2019).

Table 6.3 WeBS alerts for Chichester and Langstone Harbours SPA

Species	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	% Δ since designation [19]	Comparison to regional and British trends for the species and conclusions regarding site suitability
Brent goose (dark-bellied - bernicla)	22	-11	3	6	The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and also indicates that this site is becoming increasingly important on a regional scale for this species.
Shelduck	-5	-18	-67	-73	The trend on the site appears to be tracking that of the region although not the British trend. The declining proportion of the regional numbers supported by this site suggest that site-specific pressures may be affecting this species.
Shoveler	-23	-39	-34	-48	The trend on the site does not appear to be tracking that of either the region or the British trend. The declining proportion of the regional numbers supported by this site suggest that site-specific pressures may be affecting this species.
Wigeon	-20	15	73	58	The stable proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable for this species.
Pintail	12	-23	-13	2	The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and that this site is becoming increasingly important on a regional scale for this species.
Teal	-20	1	-16	-44	The declining proportion of the regional numbers supported by this site suggest site-specific pressures may be affecting this species. Although alerts have been triggered, they are difficult to interpret, therefore it would be prudent to continue to closely monitor populations on this site in coming winters to assess whether these alerts are due to ongoing fluctuations or other pressures.
Red-breasted Merganser	-26	-13	-6	39	The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and that this site is becoming increasingly important on a regional scale for this species. The similarity between the site- and regional-trend suggests that the declining numbers result from broad-scale population trends.
Grey plover	-8	-13	-47	-38	The trend on the site appears to be tracking that of the region and British trends. The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and that this site is becoming increasingly important on a regional scale for this species.

19 Change since the baseline winter (84/85). For further details see the BTO web alerts.

Species	Short-term (5 year) % Δ	Med-term (10 year) % Δ	Long-term (25 year) % Δ	% Δ since designation [19]	Comparison to regional and British trends for the species and conclusions regarding site suitability
Ringed plover	-8	-41	-74	-71	The trend on the site appears to be tracking that of the region and British trends. The stable proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable for this species.
Curlew	-12	-26	-2	-31	The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and that this site is becoming increasingly important on a regional scale for this species. The similarity between the declining site trend and the regional and British trends suggests that the declining numbers underpinning these alerts result from broad-scale population trends.
Bar-tailed godwit	-19	-21	-40	-51	The proportion of regional numbers supported by this site is decreasing, suggesting the site is becoming less attractive relative to others in the region. However, the similarity between the site trend and the regional trend suggests that the declining numbers underpinning these alerts result from broad-scale population trends.
Turnstone	7	-10	18	12	The increasing proportion of regional and even country-wide numbers supported by this site suggest the environmental conditions remain relatively favourable and that this site is becoming increasingly important for this species.
Sanderling	-31	-38	-49	-69	The stable proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable for this species. The similarity between the site trend and the regional trend suggests that the declining numbers underpinning these alerts result from broad-scale population trends.
Dunlin	-20	-16	-47	-49	The stable proportion of both regional and country-wide numbers supported by this site suggest the environmental conditions remain relatively favourable for this species. The similarity between the declining site trend and the regional and British trends suggests that the declining numbers underpinning these alerts result from broad-scale population trends.
Redshank	3	-3	17	-19	The increasing proportion of regional numbers supported by this site suggest the environmental conditions remain relatively favourable and also indicates that this site is becoming increasingly important on a regional scale for this species.
Waterbird assemblage	-9	-5	-26	-31	

4) WeBS low tide count data

Six species were chosen to investigate for potential changes in foraging numbers that might be linked to changes in water quality:

- Shelduck: WeBS alert species (see table 6.2) showing large long-term declines in numbers, and a declining proportion of the regional population found within Chichester Harbour, suggesting site-specific reasons for the declines. The species feeds on invertebrates in the intertidal. It may be able to continue to feed in areas of algal mats by feeding on invertebrates sustained by the mats (Pringle & Burton, 2017). But increased nutrients have been suggested as a cause of shelduck declines in Langstone Harbour (Tubbs, 1977).
- Black-tailed godwit: have shown declines in the short-term which do not follow the regional trend, suggesting site-specific reasons. The species is susceptible to declines in water quality: in Clonakilty Bay, Ireland, black-tailed godwit distribution and foraging was negatively associated with algal mats, which affect food resources and accessibility (Pringle & Burton, 2017).
- Bar-tailed godwit: WeBS alerts have been triggered in the medium-and long-term. The species feed mainly on worms and shellfish found in sandy habitats, but also uses mudflat.
- Grey plover: Declines over all timescales, though WeBS alert only triggered in the long-term. The proportion of the regional population held by the site remains stable. They are a shallow probing wader. Where increased nutrient levels are moderate and do not lead to depletion of oxygen, increase in productivity may benefit the species. However, high nutrient levels can cause declines in prey species, particularly when mudflats are turned anoxic beneath algal mats.
- Redshank: WeBS counts have fluctuated with increases in the long-term but declines in the medium-term. Increased nutrients in Langstone have been suggested as a reason for decline in redshank there (Tubbs, 1977). In Clonakilty Bay, Ireland, redshank densities increased as algal mats receded, and foraging success rate was higher on clear sediment (Pringle & Burton, 2017).
- Dunlin: WeBS Alerts triggered over all timescales. Dunlin feed on invertebrates on- or just beneath the surface of the mudflat, and as such may be susceptible to changes in water quality that affect invertebrate abundance in this zone.

Low-tide count sectors were grouped into larger sectors to allow comparison between each of the harbour arms, the central harbour (south of Thorney Island) and the outer harbour, east and west sections. These sections are shown in figure 6.2, below. The trend in mean density of foraging birds in each of the sectors was then compared with the trend across the harbour as a whole.

If foraging birds are being negatively affected by water quality, it might be expected that a widespread generalist, with cosmopolitan habitat preferences, would be found at a greater density in the outer harbour or Emsworth Channel, where nutrients levels are lower. See other sections of this report which demonstrate that nutrient levels are highest in Fishbourne Channel, with a gradient towards lower levels in the west and outer harbour.

In carrying out this analysis, differing trends in the different sectors could only be discerned for two out of the six species: bar-tailed godwit and redshank.

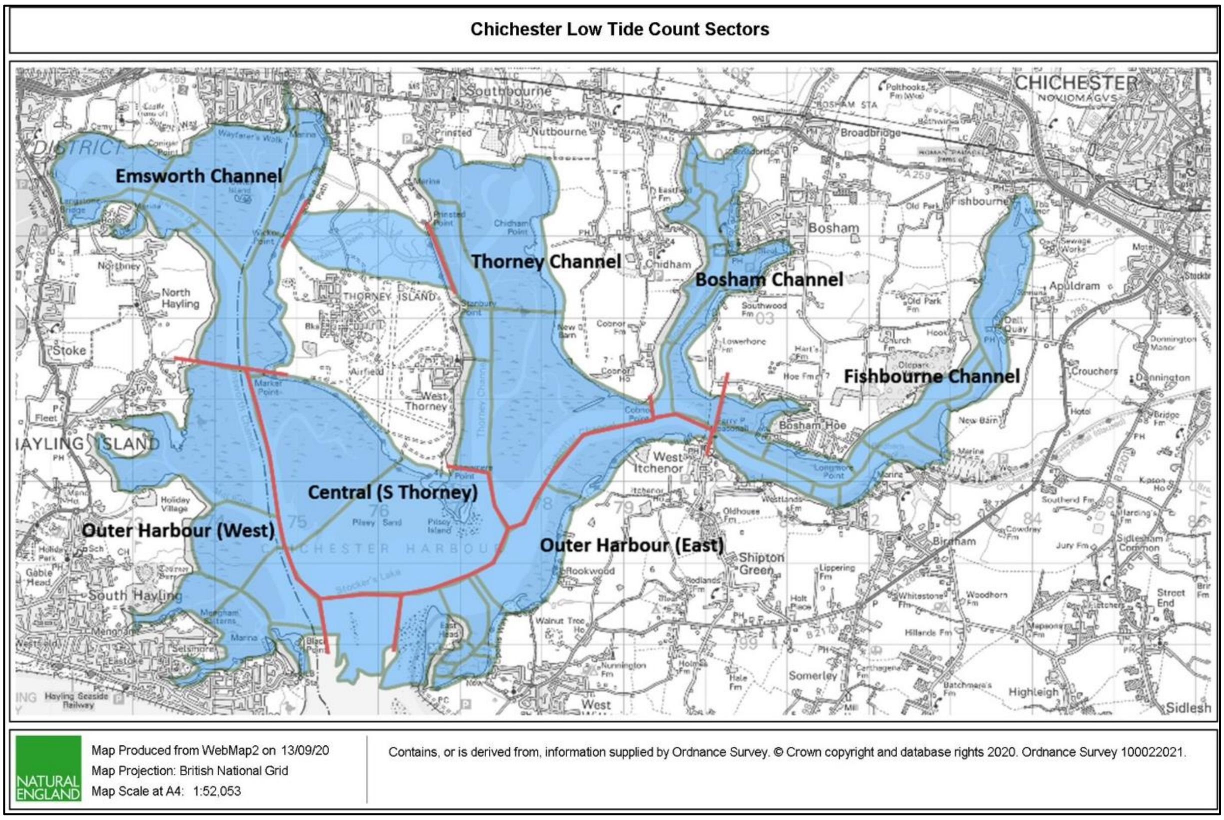


Figure 6.2 Low tide count sectors and groupings into larger sectors in Chichester Harbour

Figure 6.3 shows that the mean density of bar-tailed godwits over the whole site has increased slightly over the 25 years of the low tide counts. There does seem to have been a shift in distribution over time. Bar tailed godwits favour sandy habitat though also make use of more muddy substrates. Sandy habitat is found in the centre of the harbour (south of Thorney Island), and this is the key area for bar-tailed godwits, which also roost on Pilsey Island. Density in the central sector (south of Thorney) has increased, however there has been a decrease in density in the Bosham Channel, Outer Harbour (east) and Outer Harbour (west). There has been a slight increase in density in Fishbourne Channel - similar to that seen for the whole site.

Figure 6.4 shows that the mean density of redshanks over the whole site has stayed the same over the 25 years of low tide surveys. However, there seems to have been a shift in distribution. Density in Fishbourne Channel has declined, also a slight decline in density in Bosham Channel. Density in Emsworth Channel has increased, and a slight increase in Thorney Channel.

Low-tide count spatial variation plots for other species tested did not show differences in trends in the different sectors.

- Dunlin show similar declines in mean density across all sectors, except central (south of Thorney) which appears to show an increase. However, this is due to one exceptionally high-density year in 2010, which has not been recorded before or since.
- Black-tailed godwits have shown increases in mean density over time in all sectors. Though the increase in Bosham Channel is greater than the other sectors.
- Grey plovers and shelducks have shown similar declines across all sectors over time.

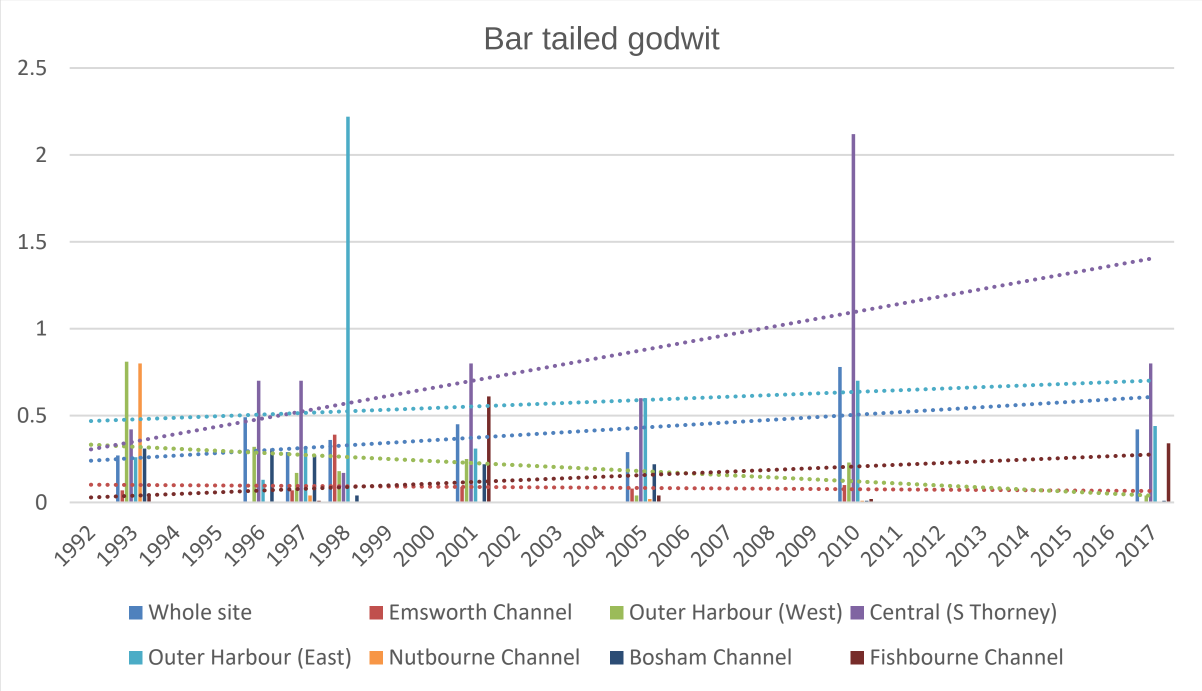


Figure 6.3 Mean density of bar-tailed godwits in Chichester Harbour

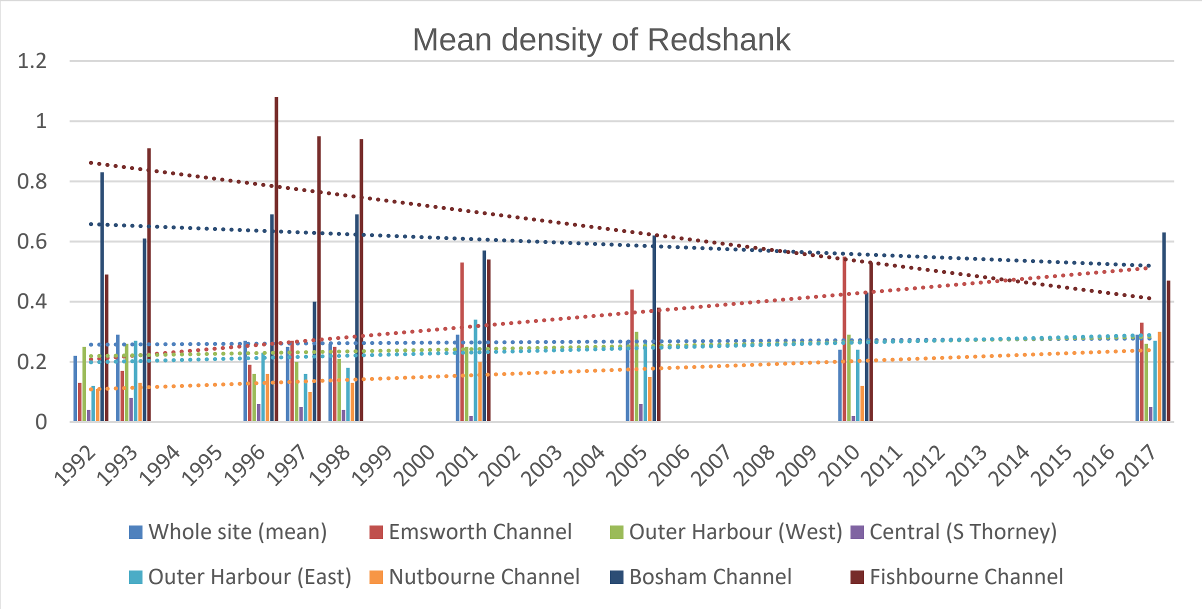


Figure 6.4 Mean density of redshanks in Chichester Harbour

6.4 Discussion relating to wintering birds

High tide core WeBS counts are influenced by a range of factors, including availability of suitable high tide roosts and proximity to favoured feeding areas. Sea level rise and loss of higher saltmarsh is affecting availability of sites. Birds at high tide roosts are more vulnerable to disturbance as there are a limited number of suitable areas, and the locations bring them closer to people. For example, the Bird Aware Solent project has identified particular issues with recreational disturbance in Fishbourne Channel and at East Head, though all the main high tide roosts within the harbour are under significant pressure.

The high tide roost that is least affected by recreational disturbance is at Thorney Deeps, though as it is predominantly wet grassland and reedbed, it does not support the more marine bird species. Thorney Deeps are covered by units 13 and 14 of the SSSI and are assessed in favourable condition for the bird populations they support. In contrast, based on its habitats East Head should support significant numbers of bar-tailed godwit, ringed plover and sanderling in the winter and breeding terns in the summer; but instead only supports relatively low numbers of sanderling (a peak of 63 birds was recorded by the SWBGS in 2008). The principle reason for this is recreational disturbance: the car park at West Wittering estate receives around 150,000 car visits a year (Chichester Harbour Conservancy and Urban Edge Environmental Consulting Ltd., 2009).

The Bird Aware Solent project is addressing the recreational disturbance issue, using financial contributions from developers to fund mitigation, mainly in the form of rangers to encourage responsible recreation, focusing on walkers and dog walkers, and monitoring is demonstrating positive results (Liley and Panter, 2017). However, water-based and other shore-based recreational uses are becoming more of an issue. For example, Pilsey Sands is less accessible by foot as it is some distance from main urban areas and car parks, but CHC report that it is under pressure from increases in water sports and different types of craft (kiteboarders, paddleboarders, etc).

Other forms of recreational pursuits are also present in the harbour, including wildfowling, light aircraft, model aircraft and bait digging. Therefore, there is probably no part of the SSSI that is unaffected by disturbance.

Chichester Harbour has a greater availability of undeveloped terrestrial habitat (both designated and un-designated) than either Langstone, or particularly, Portsmouth Harbours. This means that species that make use of grassland or cropped habitat tend to be doing better than other species. For example, brent geese have increased in the short- and long-term and the SSSI remains favourable for the species. Traditionally, brent geese would have fed on eelgrass at the beginning of the season, before moving on to saltmarsh grasses and wet grassland. However, they have now made the switch to feeding on winter cereals, and will also feed on opportunistic macroalgae, which has ensured they have not suffered from the fluctuations/declines in eelgrass availability.

Similarly, although there have been declines in the short- and medium-term, the site remains in favourable condition for curlew, which is a wader that makes use of both intertidal and terrestrial foraging habitat. Clearly, this foraging pattern is only possible if suitable sites are not developed, and this is the aim of identifying land through the Solent wader and brent goose strategy. It should be noted that any recommendation of this report for realignment of sea defences to create intertidal habitat is not necessarily in conflict with continued foraging opportunities for these species that use terrestrial habitat. However, any proposals for realignment over areas that are identified in the Solent wader and brent goose strategy would have to be assessed under the Habitats Regulations to ensure that there is no loss of foraging opportunity overall and realign foraging habitats alongside others.

Moderate increases in nutrient status of a water body can lead to increases in invertebrate biomass and consequent increases in wintering wader populations. However, once algal mats are formed, and particularly where these persist, and the mud underneath becomes anoxic, detrimental impacts are seen. For example, in Clonakilty Bay, Ireland, redshank densities increased as algal mats receded, and foraging success rate was higher on clear sediment (Pringle and Burton, 2017). Further, increases in nutrients have been suggested as a cause of shelduck declines in Langston Harbour (Tubbs, 1999).

It has only been possible to detect differences in low-tide count sector data that may be attributable to water quality changes in two species. This may be due to a number of reasons:

- Only a small subset of species on site were chosen for analysis – other species may have shown differences

- Statistical analysis of the species chosen may reveal patterns not revealed by the simple analysis undertaken for this report
- There are many variables that affect the distribution of feeding birds, and which may have a greater or lesser effect than water quality changes. For example, habitat type and disturbance
- The sectors chosen may have been too large to show small scale changes in distribution due to presence of opportunistic macroalgae or pockets of anoxic mud.

Caution should also be exercised in attributing water quality to the changes in mean density, given the confounding variables. For example, Fishbourne Channel has the highest nutrient levels, but it is also subject to high recreational pressure, and is narrow, meaning that both roosting and foraging birds are close to people using the terrestrial habitat for recreation. Therefore, declines in Fishbourne Channel may be either due to water quality or disturbance, or most likely, both issues. In addition, there are other issues that may be affecting foraging birds, for example bait digging, which can displace birds from an area and deplete food resources.

Furthermore, a suite of the wintering birds are being affected at the flyway scale by climate change. Therefore, for grey plover, dunlin, redshank and bar-tailed godwit, range shift caused by climatic factors are likely to be a (major) cause of site-based declines. In this situation, the national condition assessment guidance is that it may be appropriate to ‘switch off’ the population abundance target. However, the recommendation of this report is not to do this for species in Chichester Harbour, all the while site-specific reasons for declines cannot be ruled out.

Overall, the recommendation is that the wintering bird assemblage is recorded as unfavourable no change as there has been a decline in the WeBS core count of 23% over the short-term.

6.5 Condition assessment of breeding terns

1) Little terns

Table 6.4 Numbers of pairs and productivity of little terns in Chichester and Langstone Harbours

Year	Number of pairs		Productivity	
	Chichester	Langstone	Chichester	Langstone
2013	2	19	0	0
2014	10	31	0	0.9
2015	13	41	1.31	0.1
2016	15	11	0.06	0
2017	6	36	0	0.75
2018	0	36	-	0.03
2019	3	32	0	0.02
5-year mean (2015-19)	7	31		

The five year mean number of little terns in Chichester Harbour SSSI at designation was 16 pairs (1980-84). The lowest count during this time was 0 pairs, with the next lowest at 17 pairs, which is the threshold for favourable condition. Therefore, Chichester Harbour is in unfavourable condition for little terns. The last assessment recorded on TRIM recorded a 5-year mean (2009-2013) of 10 pairs.

As this means there has been a 30% change in the breeding population, the condition of the feature is unfavourable declining.

As table 6.4 shows, little terns have struggled in Chichester Harbour in recent years. There are three sites in the harbour where little terns have attempted to nest: Pilsey Island, Stakes Island and Ellanore Spit. Nesting attempts on Pilsey and Ellanore suffer particularly from mammalian predation as both sites are connected to the mainland. Chichester Harbour Conservancy (CHC) has installed electric fencing at Ellanore in attempt to combat this issue. However, in 2017 three nesting attempts at Ellanore failed due to presumed fox predation, despite the electric fence, as a fox was picked up on a trail camera on one of the nest failures. There have been no recorded nesting attempts at Pilsey since 2014 (LIFE Little Tern Project Newsletters).

Little terns attempt to nest on Stakes Island regularly. However, this site is very low, and nests tend to get flooded out and fail. As shown in table 6.4, there has only been one year in the last seven where the productivity has been above the 0.7 chicks per pair needed to sustain the population. In 2015, 13 nests on Stakes Island produced a good number of fledged young. However, since then any nesting attempts have been flooded by high tides, and so the site is acting as an ecological sink. This is despite best efforts by the CHC. In 2016, eight nests were artificially raised onto boxes with the nests recreated but were still flooded. In 2017, nest patches were created using material sourced on site, which were used, but again flooded out.

Little terns in Langstone Harbour have not fared much better. The RSPB have improved the habitat on the islands within the harbour by shingle recharge (supported by the EU LIFE Little Tern project). However, the nests are still vulnerable to storm surges, and also suffer predation from gulls. Therefore, the SPA cannot be said to be in favourable condition for little terns, despite concerted conservation effort by a range of partners.
The recently published (Rowell, 2020), *definition of favourable conservation status for little tern*, states that in recent decades, there has been a reduction in the number of colonies, a loss of range and, in general, poor levels of productivity such that the species is considered to have unfavourable conservation status in England. In order to restore the conservation status of the species in England, the population size should be increased to that in the mid to late 1980s (around 2,000 pairs). Therefore, by increasing the productivity of Chichester Harbour's little tern population and restoring the numbers to that seen at designation, the site will be restored to favourable condition and will contribute to favourable conservation status at the national level.

2) Common Terns

The five year mean number of common terns in Chichester Harbour at the time of the SSSI designation was 61 pairs (1980-84). The lowest count during this time was 34 pairs, which is the threshold for favourable condition. Therefore, the SSSI is currently in unfavourable condition for common terns. The last assessment recorded on TRIM recorded a 5-year mean (2009-2013) of 14 pairs. As this means there has been a less than 25% change in the breeding population, the condition of the feature is unfavourable no change. However, as noted in the discussion below, the tern raft installed at Thorney Deeps by CHC in 2019 was very successful in terms of productivity. Therefore, the feature could be turned to unfavourable recovering, if the pattern seen in 2019 continues. The 2020 breeding season looks promising: whilst productivity figures are not yet available, the CHC report 35 pairs on two rafts at Thorney Deeps. Given that the tern rafts at the Hayling Oyster beds in Langstone Harbour have been very successful in driving common tern population recovery, there is no reason that success should not be repeated in Chichester Harbour.

Table 6.5 Numbers of pairs and productivity of common terns in Chichester and Langstone Harbours

Year	Number of pairs		Productivity	
	Chichester	Langstone	Chichester	Langstone
2013	12	85	0	0.68
2014	0	117	-	0
2015	24	118	0.63	0.02
2016	13	111	0	
2017		154		0.34
2018	8	149	0	0.65
2019	19	107	1.37	0.71
5-year mean	16	128		

3) Sandwich Terns

Table 6.6 Numbers of pairs and productivity of Sandwich terns in Chichester and Langstone Harbours

Year	Number of pairs		Productivity	
	Chichester	Langstone	Chichester	Langstone
2013	71	6		0.17
2014	8	66	0	0.41
2015	0	93		0.75
2016	0	122		
2017	0	73		0.6
2018	0	113		
2019	0	59		0.34
5-year mean	0	92		

The 5 year mean number of Sandwich terns in the SSSI at designation was 52 pairs (1980-84). The lowest count during this time was 17 pairs, which gives the threshold for favourable condition. Therefore, Chichester Harbour is in unfavourable condition for Sandwich terns. The last assessment recorded on TRIM recorded a 5-year mean (2009-2013) of 3 pairs. On the basis that there has been a less than 25% change in the breeding population since the last assessment, the condition of the feature is unfavourable no change. However, as the species has effectively been lost from the site, the condition should be recorded as unfavourable declining.

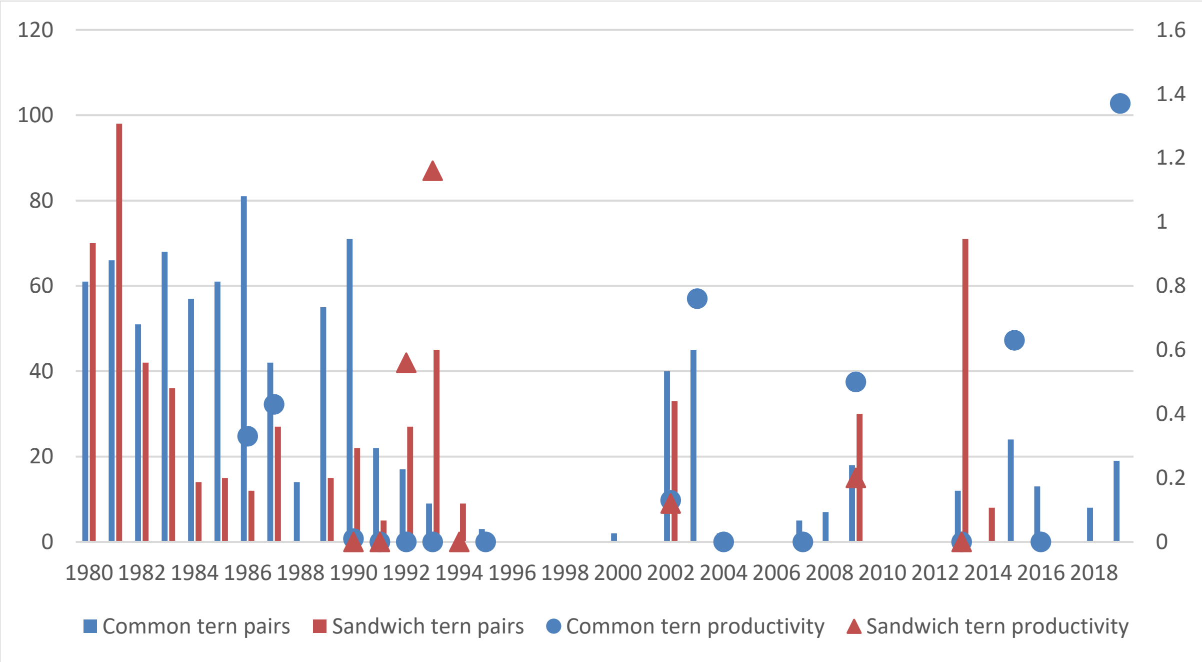


Figure 6.5 Common and Sandwich tern numbers and productivity since designation of Chichester Harbour SSSI

6.6 Discussion regarding breeding terns

Chichester Harbour has always supported fewer breeding terns than Langstone Harbour; simply because the latter has a greater area of suitable habitat in the form of extensive islands with shingle. However, Chichester is important in adding to the network of sites within the SPA. This is important so that if one site fails, then birds can move to others for a second breeding attempt.

A network of suitable sites is particularly important for little terns. This species is known to shift colonies from one year to the next in response to predation, disturbance and habitat change. Therefore, it is important to maintain the Chichester Harbour nesting sites in favourable condition for terns. However, all sites in Chichester suffer from tidal flooding and/or predation, and despite breeding attempts in most years, productivity has been zero or close to zero in all but one of the last seven years. This means the SSSI is acting as an ecological sink for the species. CHC have attempted to reduce mammalian predation at Ellanore spit, though this has had only limited success. Nesting attempts on Stakes Island are usually flooded by high tides, which is a situation that will worsen with sea level rise and increased wave action due to climate change. CHC are investigating the possibility of using shingle recharge to raise parts of the island to address this issue.

Like little terns, the distribution of Sandwich tern colonies can vary from year to year as birds respond to changing conditions. In addition, colony sizes are renowned for wide fluctuations as the proportion of adults nesting varies annually (JNCC, 2016). Even in this context, the species has declined in the SSSI since designation, and since the late 1990s has only nested sporadically (see figure 6.5).

The national population of common terns has remained relatively stable over the last 30 years (JNCC, 2016), although there has been a shift in distribution to use of man-made water bodies, with considerable effort focused on the provision of nesting platforms. This approach shows great promise in Chichester Harbour. In 2019, CHC installed a tern raft at Thorney Deeps, which was very successful with 9 pairs fledging 20 chicks. This is double the productivity needed to sustain the population, and therefore sufficient to lead to an increase. 2019 was also a good year for common terns on Stakes Island, with around 10 pairs fledging 6 young at the second attempt. This is unusual as in recent years tidal flooding normally causes complete failure. In 2020, two rafts were installed at Thorney Deeps and CHC report them being used by 35 pairs. Therefore, if the provision of rafts continues to be successful, there appears to be a viable solution for the recovery of common terns in the SSSI.

In order to improve the habitat on Stakes Island and increase resilience of the nesting sites to flooding and increased storminess, shingle recharge could be considered. However, in Langstone, mixed gull colonies have formed with consequent predation on terns. Therefore, there is a likelihood that the same would happen in Chichester. To mitigate this, the area of recharge has to be large so that there is space on the edge for little terns, and chick shelters provided to reduce predation risk. Alternatively, several smaller areas could be provided. However, the impacts of shingle recharge on other habitats would also have to be assessed.

1) Conclusions

- Overall, the SSSI is in unfavourable condition for wintering birds and nesting terns. In terms of wintering birds, some species are in favourable condition, and some in unfavourable declining condition, however overall, the assemblage is considered to be in unfavourable no change condition.
- Breeding terns are in unfavourable declining condition overall due to the declines in little terns, loss of Sandwich terns from the site, and extremely poor productivity for all three species. However, if the rafts at Thorney Deeps continue to be successful, common terns could be considered to be in recovering condition.
- The translation of the ornithological features into unit condition is discussed in Section 10.

2) Recommendations

- Further detailed analysis of WeBS low tide count data would be beneficial. Consider approaching universities as a Masters Project proposal.
- An assessment of the condition of Chichester Harbour for foraging terns has not been undertaken. Work with CHC and Sussex IFCA to understand the baseline condition of small fish populations in the harbour and whether this is influencing tern productivity.
- Additional support should be provided to efforts such as those by CHC to improve tern productivity, including supporting the provision of tern rafts and predator management as necessary.
- In partnership with CHC, investigate the feasibility of using shingle recharge to create suitable raised beaches at Stakes Island, with the aim of creating a network of sites that are less susceptible to tidal flooding.
- Implement other recommendations made in this report, in particular on habitat improvements, climate change adaptation and nutrient reduction, all of which are likely to benefit both wintering and breeding birds.
- When designing managed realignment proposals, alongside the creation of intertidal habitat, the function of that habitat for wintering and breeding birds should be considered. Where feasible, high tide roosts and islands for breeding terns should be created.

7 Sublittoral and littoral sediments – habitat and infaunal trends

7.1 Ecological importance of estuary, sublittoral and littoral sediments

The importance of the estuary feature, which covers most of the other habitat features of the harbour, is described in sections 1, 2, and 4. The coastal process and other factors effecting estuary dynamics are also described in section 4. Natural England's current view is that estuaries should be treated holistically rather than broken down to the sub-feature habitats and looked at in the marine condition assessment methodology so, though overlapping elements are described here the estuary feature is not further discussed in this section.

This section focusses on the littoral and sublittoral sediments and their relationship to the overarching estuaries feature. Littoral sediments SSSI monitoring guidance for Natural England covers all habitats between high and low waters but does not include saltmarsh, sand dunes or vegetated shingle, though littoral sediments often form very dynamic systems with these other estuarine features. These intertidal features, with the saltmarsh, cover the majority of area in Chichester Harbour. Shallow inshore sublittoral sediments guidance includes areas of habitat that are permanently covered by seawater on soft sediments (not rock) and are typically less than 20m below chart datum. This includes the main harbour channels and significant areas in the entrance to the harbour, in particular in SSSI unit 42 (see figure 3.1 for unit numbers).

The condition assessments of inshore littoral and sub-littoral sediments consider both physical sediment characteristics and biological communities. The precise shape, sediment type and ecological communities found in littoral and sublittoral sediments are a result of the coastal processes, the base geology and hydrology, and the influence of adjacent habitats such as saltmarsh, sand dunes, and vegetated shingle. The dynamic equilibrium described in section 3 is particularly important for littoral and sublittoral sediment features. A summary of the communities and the relevant SAC features that are covered by these broad habitat types are given in table 7.1 below. As well as features in their own right, sublittoral, and particularly littoral sediments are important features for birds as they form a main feeding source for many of the designated bird features. Table 7.1 attempts to make the link between the features and birds. It is based on a similar table in Natural England (2017) and amalgamations of feature tables from relevant CSMG. Littoral and sublittoral sediments are closely linked to seagrass communities which will be discussed separately in section 8.

7.2 What do Natural England measure?

Despite national and international importance of the estuaries, Natural England do not regularly monitor sediment invertebrate fauna, sediment types or biotopes (within littoral and sublittoral sediments) in Chichester Harbour though as this review will show information has been collected for a variety of studies. Information on the wider Solent features was also compiled as part of the 2018 marine SAC condition assessment. The CSMG for littoral sediments provides guidance on how to assess both the extent and quality of sub-feature biotopes including for sediment type and water quality for SSSIs.

The CSMG for sublittoral sediments provides guidance on how to assess extent and quality of biotopes including sediment type and water quality. The estuaries guidance is more generic as estuaries are so varied and many of their sub-features are covered in the sediment and other habitat guidance. Most of the attributes in these three sets of SSSI condition assessment guidance are also in the marine condition assessment guidance for relevant SAC features and some were assessed in the 2018 Solent Maritime Condition Assessment.

Table 7.1 Link between communities, SAC features, bird species and example species

Broad habitat type	SAC features	Communities (linked to CSMG)	Example of important or key taxa	Bird features feeding in feature habitat
Littoral sediments	1130 Estuaries	Intertidal mudflats and sandflat biotopes	*Periguae ulvae, Bathyporeia* spp.	Eg dark-bellied brent goose, black-tailed godwit, ringed plover, dunlin and redshank
		Intertidal mixed sediment biotopes	*Mytilus edulis, Crepidula fornicata*	Eg ringed plover, turnstone, shelduck, dark-bellied brent goose
		Intertidal eelgrass beds	*Zostera marina, Zostera noltii* and *Ruppia* spp.	Eg dark-bellied brent goose
	1140 Mudflats and sand flats not covered by seawater at low tide	Intertidal mud biotopes	*Arenicola marina Corophium volutator, Periguae ulve, Enteromorpha* spp.	Eg black-tailed godwit, redshank, greenshank, grey plover, dark-bellied brent goose
		Intertidal muddy sand biotopes	*Arenicola marina*, bivalve molluscs	Eg dunlin, redshank, curlew, black-tailed godwit
		Intertidal sand communities	*Arenicola marina Cerastoderma edule, Bathyporeia* spp.	Eg bar-tailed godwit, dunlin, grey plover, curlew
		Intertidal seagrass beds	*Zostera marina, Zostera noltii* and *Ruppia* spp	Eg dark-bellied brent geese
Sublittoral sediments	1110 Sandbanks which are slightly covered by seawater at all times	Subtidal sands and gravel biotopes	*Amphipods robust polychaetes* and mysid shrimps	Eg common, little, Sandwich and roseate terns, Mediterranean gulls, red-breasted merganser
		Subtidal muddy sand	*Tubificoides spp, Nephyts hombergii, Capitella capitata*	
		Subtidal eelgrass beds	*Zostera marina, Zostera noltii* and *Ruppia* spp.	Eg terns and red-breasted merganser (will feed on small fish that live in the seagrass)
	1130 Estuaries	Inshore subtidal mudflat and sandflat and mixed sediment communities	Amphipods, robust polychaetes and mysid shrimps	Eg common, little, Sandwich and roseate terns, Mediterranean gulls
		Subtidal seagrass beds	*Zostera marina, Zostera noltii* and *Ruppia* spp.	Eg terns and red-breasted merganser (will feed on small fish that live in the seagrass)
		Mytilus edulis beds	*Mytilus edulis*	Eg knot, oystercatcher

A summary of the key attribute targets from the three sets of guidance, (excluding those related to eelgrass beds which are provided in section 8), is provided below. It is important to note that not all these attributes are within the Chichester Harbour FCTs as neither the estuary nor the sublittoral CSMG guidance was used in drawing up the existing FCTs and estuary is not a SSSI feature but is a SAC feature within Chichester Harbour.

The critical targets of estuaries, littoral and sublittoral sediment in relation to Chichester Harbour are:

- No loss of extent of estuary, littoral or sublittoral sediment or estuary habitats outside of natural dynamic change
- Maintain morphological equilibrium of the estuary habitat
- No change in extent or topography of inshore sublittoral sediments
- No change in extent, composition or distribution of littoral sediment or sublittoral sediment biotopes subject to natural succession or dynamics
- Maintain abundance and population structure of notable species in sublittoral or littoral sediments
- No signs of eutrophication (measured as phytoplankton blooms (Chlorophyll-a)) using WFD metrics for sublittoral sediment and opportunistic macroalgae for littoral sediment and both for estuaries.

Where the targets are ‘no change’ or ‘maintain’ this includes restoration if historic losses or damage have occurred. The important and notable biotope eelgrass is covered in section 8 so is not covered further here. These SSSI targets have been to some extent superseded or rather supplemented by the Supplementary Advice to the Conservation Objectives where many have restored objectives specific to the Solent Maritime SAC designation and these attributes were assessed at the whole SAC level in the 2018 condition assessment.

7.3 What the Environment Agency measure - WFD benthic invertebrates (Infaunal Quality Index)

The WFD guidance has two metrics which are of particular interest to littoral and sublittoral sediments and estuary features: benthic invertebrate metrics and water quality metrics (the latter is covered in section 3 and section 7.6). The WFD requires that the assessment of the benthic invertebrate quality element considers abundance, diversity and the presence and/or absence of pollution-tolerant and disturbance-sensitive taxa.

The Infaunal Quality Index (IQI) is a multi-metric index composed of three individual components known as metrics, these are the:

- AZTI Marine Biotic Index (AMBI)
- Simpson’s Evenness (1-λ’)
- Number of taxa (S).

To calculate the IQI the following information is required:

- Abundance of benthic invertebrates (identified to lowest taxonomic level)
- Characterisation of the habitat sampled (salinity and substratum)
- Sampling methodology (eg sample method area and equipment used)
- Processing methodology (eg sieve mesh).

The Environment Agency do **not** frequently measure this metric at Chichester Harbour and therefore trend data on this metric is not available for this harbour though there is data on this metric from elsewhere in the Solent to underpin the Solent Maritime SAC condition assessment it is not available for the SSSI assessment for Chichester Harbour. In addition, some data on the infaunal data was provided by the Environment agency in 2014.

7.4 Intertidal mudflats and opportunistic macroalgae

Excessive nutrient levels, in particular nitrogen, have been shown to have direct effects on coastal habitats in particular on seagrass beds where excessive nutrient loading has been shown to cause a range of impacts. On saltmarsh there is some limited evidence of destabilisation due to excessive nutrients though mostly not in a UK context. These more direct impacts are covered in relevant saltmarsh and eelgrass sections (5 and 8 respectively) and will not be dealt with further in this section.

The main indirect impact identified by the current supplementary advice of excessive nutrient loading in Chichester Harbour is excessive opportunistic macroalgae growth. This can occur on the surface or most seriously within the sediment (entrainment) and can lead to a range of impacts including:

- Changes in sediment structure and deposition of subtidal habitats
- Changes in benthic fauna
- Smothering of saltmarsh and other vegetation (see saltmarsh section 5)
- Changes to saltmarsh structure and function (covered in section 5)
- Smothering or shading of eelgrass beds (covered in section 8)
- Changes in the prey availability distribution and type.

The supplementary advice to the conservation objectives' targets on water quality are given in table's 3.1 and 3.2, and above.

7.5 Analysis of opportunistic macroalgae – littoral sediment condition

Opportunistic macroalgae data is gathered by the Environment Agency as described in section 3 of this report, along with a suite of other data parameters. The data on opportunistic macroalgae was obtained for 2011, 2014 and 2018.

1) Defining the assessment areas

As explained in section 3 the Environment Agency assess opportunistic macroalgae coverage at the whole harbour level. In order to relate this to interest features, in particular birds and saltmarsh, Natural England needs to subdivide Chichester Harbour into a smaller spatial scale. There is good overlap between the spatial scale of the WeBS counts bird sectors (see section 6) and the SSSI unit boundaries but the SSSI boundaries are smaller. The data from WeBS counts cannot be subdivided (below WeBS count sector data) as the data is not georeferenced at a lower spatial scale. In order to undertake meaningful data analysis of the opportunistic macroalgae coverage in relation to other features, Natural England split the Environment Agency GIS files on opportunistic macroalgae (from 2011, 2014 and 2018) into 'assessment areas' described in table 7.2.

These areas are based on amalgams of the SSSI units but with two units spilt as shown below in table 7.3 to correlate with WeBS sectors the map of the assessment areas are show in figure 7.1:

a) SSSI unit 32 at west Itchenor spit in a direct line from the end of unit 24 with the upper (northern half) as unit 32 N and the southern half as unit 32 S
b) unit 2 at black point in a direct line from the point to the edge of the unit (western half as unit 2W and southern half as unit 2S).

Table 7.2 Macroalgae assessment areas

Assessment area name	SSSI units amalgamated to form assessment area
Fishbourne Channel	24, 27, 30, 31, 32N
Bosham Channel	22, 23
Thorney Channel	17, 20
Emsworth Channel	8, 10, 11, 12
Harbour East	36, 36, 32S
Harbour West	5, 2W
Harbour Central (sandy)	15
Harbour Outer	42, 2S

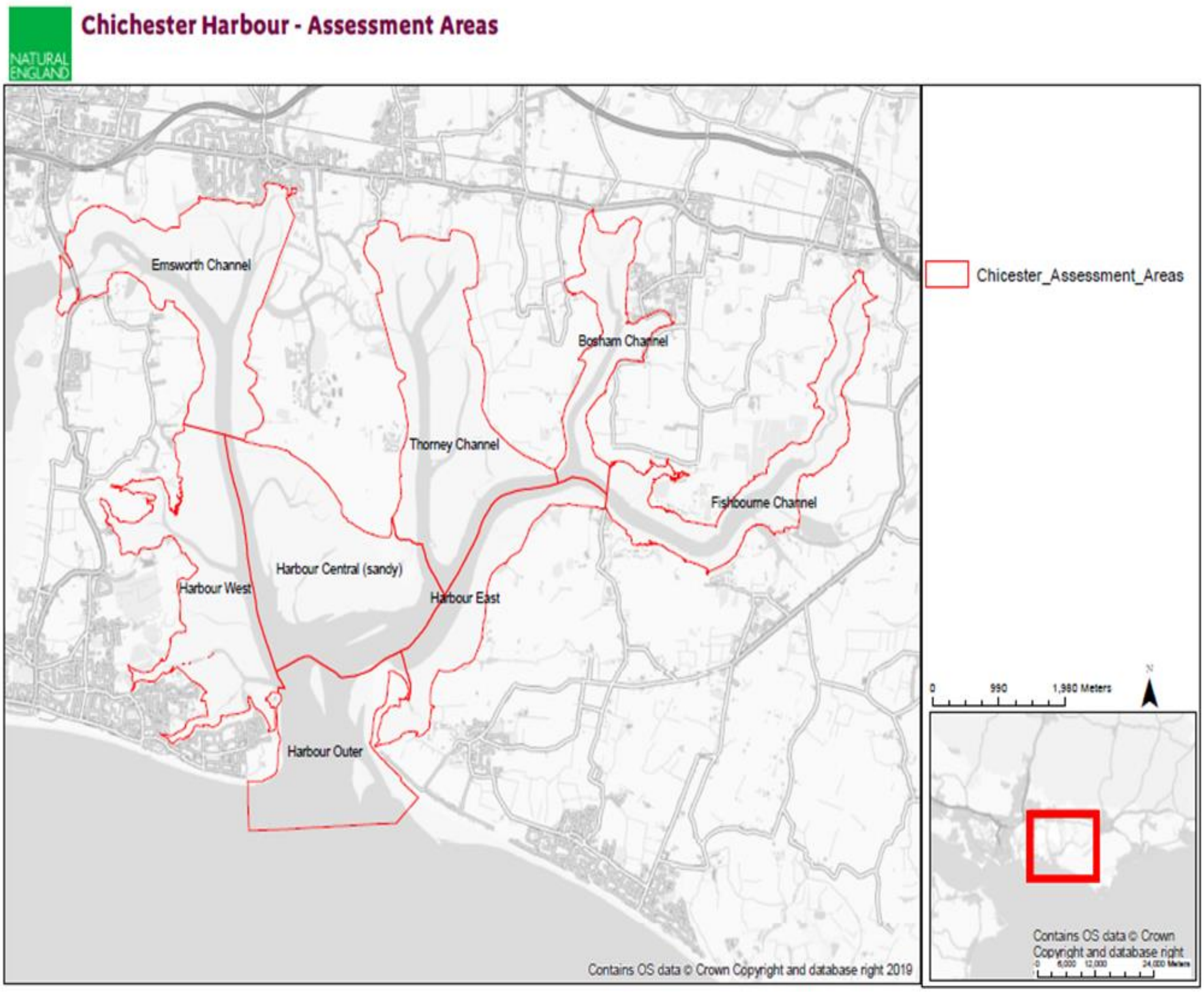


Figure 7.1 Assessment areas in Chichester Harbour

The data was obtained for each 'assessment area' for this study (2011, 2014, and 2018) where Natural England calculated the following:

1) Total area of assessment area in hectares
2) Total area of available intertidal habitat (AIH) in hectares in each assessment area
3) Percentage cover of opportunistic macroalgae in the available intertidal habitat (AIH).

Natural England had hoped also to undertake the following assessments, but the data provided to Natural England did not have the biomass metric in the attributes table and therefore this aspect was not undertaken in time for this report:

4) Mean biomass of opportunistic macroalgae in the AIH (g m^2) for each assessment area
5) Mean biomass of opportunistic macroalgae in the affected areas AfA (g m^2) for each assessment but only looking at those affected by the intertidal opportunistic macroalgae.

2) Opportunistic macroalgae assessment results

Table 7.3 shows the percentage opportunistic macroalgae coverage in assessment areas and whether the areas passed the attribute target for percentage coverage of <15% of opportunistic macroalgae covering the available intertidal area (AIH). The map of assessment areas is provided in figure 7.1 and the percentage coverage maps in Appendix 4. Opportunistic macroalgae percentage coverage varies markedly inter-annually and spatially within the harbour. All the harbour arms (or channels) fail the opportunistic macroalgae target for percentage cover in all years except Thorney Channel which passes the target in 2014. The outer harbour near the mouth of the harbour has low opportunistic macroalgal coverage in all three years but only a small area is intertidal in this assessment area. In 2014 there was a notable reduction in opportunistic macroalgae compared to both 2011 and 2018. Based on the failure of this attribute, the littoral sediment feature would be considered in unfavourable condition but there is insufficient data to assess the trend. The relationship between water quality, the opportunistic macroalgae and features is discussed in section 9.

Table 7.3 Percentage coverage of assessment areas of opportunistic macroalgae

Assessment area name	Assessment area (ha)	Area of intertidal habitat (AIH)(ha)	Percentage coverage of AIH of opportunistic macroalgae 2011	Percentage coverage of AIH of opportunistic macroalgae 2014	Percentage coverage of AIH of opportunistic macroalgae 2018
Fishbourne Channel*	325.11	223.98	42.84	22.52	35.58
Bosham Channel*	208.39	145.85	62.21	32.23	42.46
Thorney Channel*	597.55	450.40	48.30	12.76	21.41
Emsworth Channel	510.89	382.42	52.70	17.16	29.44
Harbour East	246.94	146.52	39.94	15.58 (borderline)	21.27
Harbour West	447.57	359.55	32.39	7.29	15.17 (borderline)
Harbour Central (sandy)	572.03	333.36	15.12 (borderline)	5.91	6.47
Harbour Outer	371.28	44.92	0.24	0.05	0.43

<15% coverage of the AIH is favourable condition attribute target.
RED = attribute failed
GREEN = attribute passed
* Assessment area has WwTW discharge directly into it or adjacent unit.

7.6 2015 review of littoral sediments - Marine Ecological Surveys Limited in 2016 and Natural England study in 2017

1) Methodology

In 2015 Natural England commissioned a review of SSSI intertidal mudflat data in Chichester Harbour by Marine Ecological Surveys Limited that was published in 2016 (MESL 2016). This report provided a preliminary assessment of the intertidal sediment feature. This MESL report combined with more recent assessment of opportunistic macroalgae coverage is the basis for this SSSI provisional condition assessment of littoral sediment.

The MESL report 2016 used aerial photography to delineate the extent of intertidal features and ground-truthed this with infaunal and particle size distribution (PSD) samples to classify habitat types using the European Nature Information System (EUNIS). The EUNIS habitats codes were converted to Marine Nature Conservation Review classification codes in order to match the biotope classification presented in the FCTs for the condition review attempted by MESL. The data used was based on a range of existing data sets up to 2014. Six data reports available between 2012 and 2014 were used as the 'current data set' and data from two reports from 2005 and 2007 were used as the 'baseline' data set. The substrate was categorised in line with Folk 1954. The data on which the MESL assessment was based were collected for different reasons and there was an absence of baseline data (05-07 data sets) in most units on the distribution of biotopes and the variety of biotopes. There was some limited information on the sediment composition in some SSSI units from the 05-07 baseline data sets.

Attempts were made to characterise the extent of different habitats and sediments, though the change in this over time was not possible due to the limitations of the 'baseline' data sets.

The change in sediment composition was also estimated though this was extremely limited. For some units the report was able to compare the biotopes found in the 2005-2007 data sets with those in the 2012 to 2014 data sets. However, this was not comprehensive and differences in the extents surveyed in the earlier time period (less than 10% of what was surveyed in 2012-2014) and differences in methodology, severely limits the confidence in the assessment. Nevertheless, some conclusions were made which are discussed below.

In 2017 the work of MESL and original studies were reviewed by Natural England along with other reports on subtidal features for a report across the whole Solent (Natural England, 2017).

2) Results

A total of 13 different Folk sediment groups were recorded across the intertidal sediments. Sandy mud was the most commonly sampled category and also represented the largest sediment group mapped in terms of total area (853.5 hectares). All interpolated Folk sediment types are shown on figure 7.2 (from MESL 2016). There are marked differences in the sediment characteristics across the harbour; the central unit 15 at Pilsey for example is considerably sandier than most other areas and the Fishbourne channel has notably more gravel and mixed sediments than other areas.

A total of nine habitats were assigned to the intertidal sediment of the sites, most common in terms of total area mapped was complex polychaete/oligochaete-dominated upper estuarine mud shores (A2.32), representing 34% of the total area mapped. These habitats and biotopes are plotted in figure 7.3 and in table 7.4 below. Data on habitats is heavily caveated as it was not collected specifically for the purposes of this report, so it was not possible to provide a comparative analysis of interpolated biotope distribution over time for the whole site. In addition, data was collected from a pre-determined set of taxa, rather than all taxa found, as some of the original surveys were linked to bird prey.

Figure 7.4 shows the simplified maps of the 2012 to 2014 sediment data with dots showing the sampling from the descriptive sediment analysis from 2005 to 2006 compiled data sets.

Unit 15 at Pilsey is showing change to both sandier sediments and communities that reflect this change between the two compiled data sets periods. This unit is also preferred by birds that use sandier sediments which have increased in density at this location so this change may reflect genuine trend in sediment at this location. Units 30 and 31 in the upper estuaries are also significantly sandier with mixed sediments dominating in the 2012-2014 data sets but with mud communities in the earlier samples. The 2012 to 2014 data was more heterogeneous than the earlier data however all these changes may simply reflect greater sampling intensity in the later data sets and different methodologies of sampling used.

A summary of biotopes per unit from the 2004 to 2005 compared with the 2012 to 2013 data sets at the end of the MESL study. For many units there is no 2004 to 2005 baseline however for a number of units, biotopes recorded in early data sets were not recorded in the later data sets despite the more detailed later mapping. This data and additional subtidal survey were included within the 2017 Natural England report. The Natural England study presented the biomass from the original sampling that showed invertebrate biomass (in milligrams dry weight) was greatest in the upper parts of the estuaries sampled and much lower in the outer and sandier parts of the harbour. Benthic invertebrate species richness and abundance was also higher in these upper estuarine muds. These areas coincide with the muddiest parts of the sites indicating these areas are of particular importance for bird prey availability. The original bird prey surveys noted 10 out of 12 sites sampled had dense opportunistic macroalgae covering. The Natural England report in 2017 showed that the faunal densities were higher in Chichester Harbour compared to Southampton Water and similar to Langstone Harbour. Again, this emphasizes the importance of Chichester Harbour littoral sediment in the Solent series in its own right and as foraging habitats for birds.

The MESL study notes the loss of the following biotopes across the whole harbour from the 2004 to 2005 ‘baseline’ and the 2012 to 2014 studies which could indicate the site is in unfavourable condition or that it is improving as the sediments and biotopes are changing.

- LR.LLR.FVS.FspiVS
- LR.LLR.FesVS
- LS.LSA.FiSA.Po
- LS.LCS.Sh.VarSh
- LR.LLR.FVS.Fcer
- Ls.LSA.MuSa.MAcAre.

The 2017 Natural England report notes that though there was a high degree of similarity between the sediments from 2004-2005 and 2012 to 2014, there are apparent decreases in abundance, and diversity and biomass have increased (though this may be due to the sampling effort being much greater in the later studies). This could indicate positive or negative impacts and the taxon identification level was none standard making drawing conclusions very challenging.

The 2017 Natural England study looked at the sensitivity of the sediments to disturbance by comparing to the MarLIN sensitivity assessments to activities for example scallop dredging. Several of the biotopes in Chichester Harbour are sensitive to physical disturbance. The 2017 Natural England report concludes that the sediments appear stable in the harbour despite the significant differences and loss of communities shown by the MESL report.

Table 7.4 Habitat distribution in Chichester Harbour assigned by MESL report

EUNIS CODE	Habitat name	Area Mapped (ha)
A2.1 **LS.LCS**	Littoral coarse/sediment	15.5
A2.12 **LS.LCS**	Estuarine coarse sediment shores No key taxa identified by MESL report	49.0
A2.2 **LS.LSa**	Littoral sand and muddy sand	40.5
A2.24 **LS.LSa.MuSa**	Polychaete/bivalve dominated muddy sand shores Key taxa polychaetes *Scoloplos armiger* and *spio martinensis* and bivalve *Cerastoderma edule*	94.3
A2.3 **LS.LMu.**	Littoral mud	364.7
A2.31 **LS.LMu.MEst**	Polychaete/bivalve dominated mid estuarine mud shores Key taxa *Peringia ulvae*, *Tubificoides benedii* and the polychaete *Tharys* Type A and phylum Nematoda	367.3
A2.32 **LS.LMu.UEst**	Polychaete/oligochaete dominated upper estuarine mud shores. Key taxa oligochaete *Tubificoides benedii* species from the phylum Nematoda and the polychaetes *Pygospio elegans* and *Capitella*	691.1
A2.4 **LS.LMx**	Littoral mixed sediments	274.1
A2.42 **LS.LMx.Mx**	Species rich mixed sediment shores Key taxa *Tubificoides benedii, Peringia ulvae* and *Capitella*	158.7

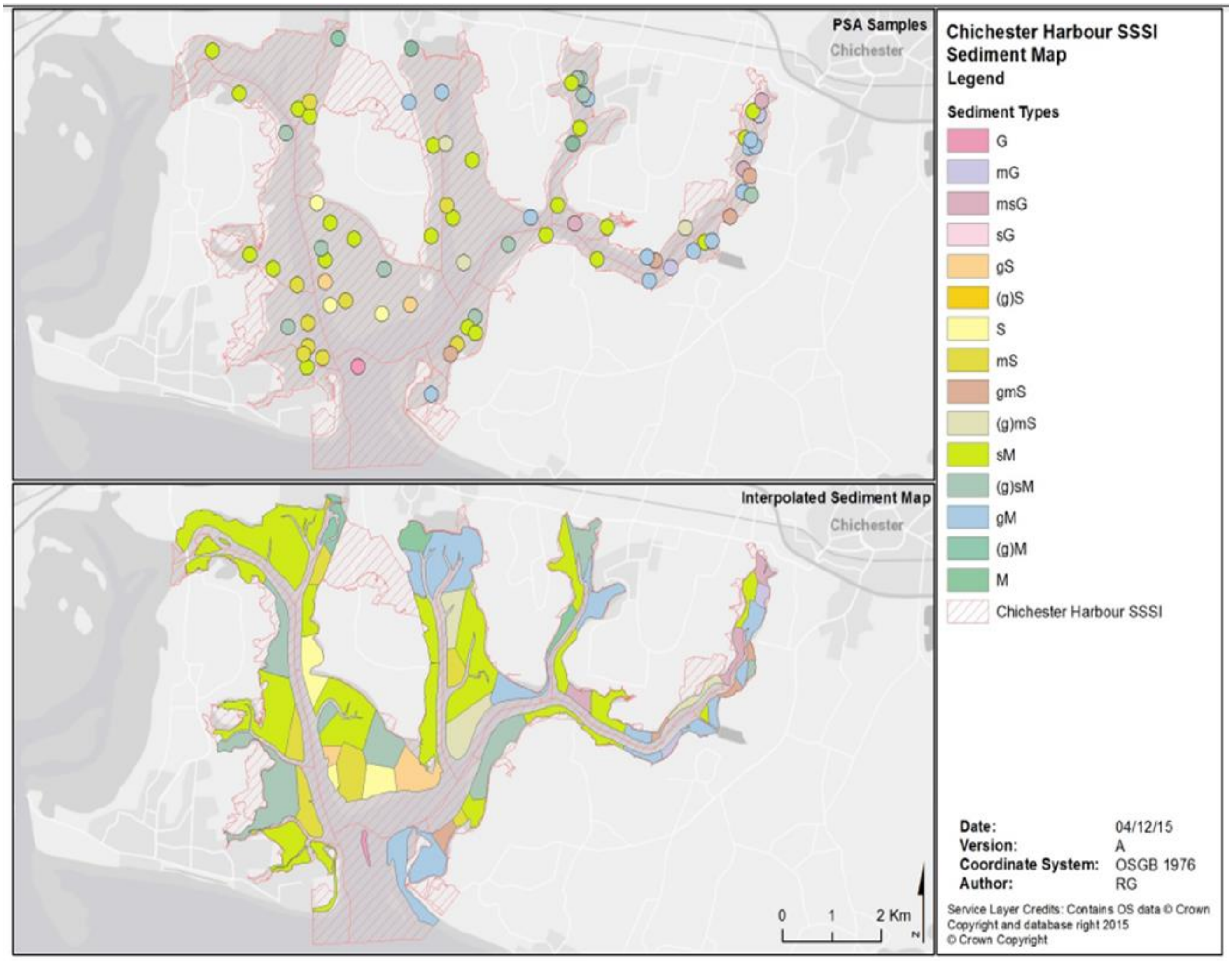


Figure 7.2 Interpolated Folk sediment types in Chichester Harbour and locations of sediment sampling (from MESL 2016)

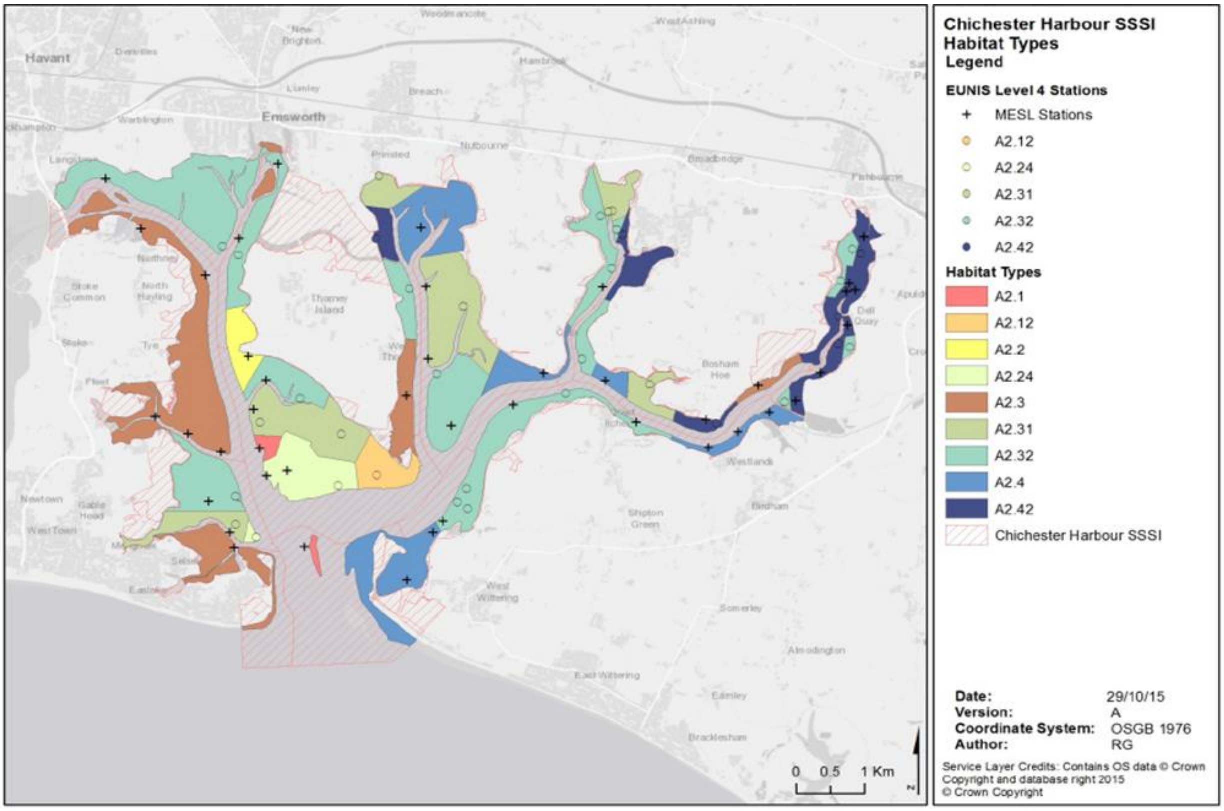


Figure 7.3 Interpolated EUNIS habitat types - Chichester Harbour (from MESL 2016)

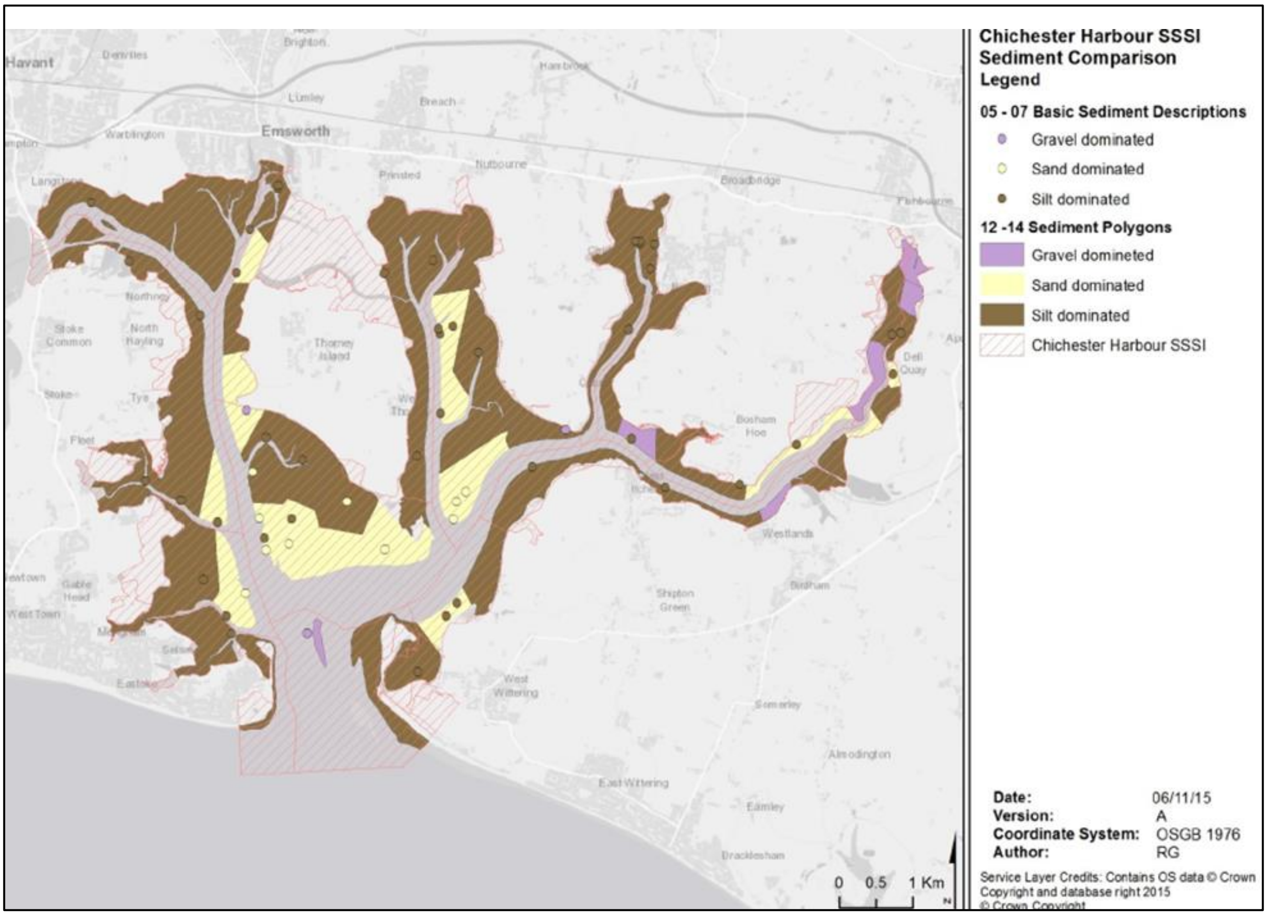


Figure 7.4 Sediment characteristic changes (from MESL 2016)

7.7 Condition of sublittoral sediments

The sublittoral sediments are not included in the Environment Agency opportunistic macroalgae data and do not feature in the 2016 published MESL study though some other limited data is available elsewhere. The water quality data for these features relates to phytoplankton (which can link to light availability) and dissolved oxygen which based on the WFD assessment are both at [high ecological status] at the whole Harbour scale. There is no indication for sublittoral sediments that water quality attributes are failing in Chichester Harbour.

Sublittoral features were reviewed in the Natural England 2017 desk top study of previous data including a different MESL report. This report found that the subtidal habitats in earlier studies (2006 and 2007) were dominated by mixed sediments with strong *Crepidula* communities with ascidians, anemones or *Mediomastus fragilis*. A later study quoted by Natural England (2017) assigned the dominant subtidal community to *Aphelochaeta* spp and *Polydora* species in variable salinity infralittoral mixed sediment. This suggests a slight change in the dominance of *Crepidula fornicata*. As with the littoral sediment this change may have resulted from methodological differences in data sampling and analysis. The early analysis of data from pre and post dredging on the sediments (presented in the 2017 Natural England study) indicated some impacts of dredge fishing on the subtidal fauna of Thorney Channel with a significant decrease in epifaunal subset of species pre and post dredge fishing sampling. The presence of a small number of native oysters in the harbour were noted as a potential for population recovery.

1) Discussion on sublittoral and littoral sediments

The intertidal and subtidal sediments of estuaries support biological communities that vary according to the type of sediment and salinity gradients within the estuary, though geographic location and the strength of tidal streams also influence community structure. In the upper parts of the harbour arms of Chichester the sediment-living animal communities are typically dominated by oligochaete worms, with few other invertebrates. The silt content of sediment usually decreases towards the mouth of the estuary, and the water gradually becomes more saline. In Chichester Harbour, it is dominated by marine mud and sandy areas occur within the middle of the harbour. Here the animal communities of the sediments are dominated by species such as ragworms, bivalves and sandhopper-like crustaceans. In the outer estuary, closer to the open sea, the substrate is often composed of fine sandy sediment, and supports more marine communities of bivalves, polychaete worms and amphipod crustaceans. In addition to the sedentary subtidal and intertidal communities, the water column of estuaries is an important conduit for free-living species, such as fish, and juvenile stages of benthic plants and animals which support foraging for terns and diving ducks. It is the means by which migratory fish species make the transition between the marine and freshwater environments.

The harbour sediments have medium sensitivity to physical disturbance and persistence of communities of this type is indicative that the fisheries byelaws in the harbour to limit physical disturbance to certain areas are maintaining these features. Though the changes to the biotopes could be concerning, this may simply be a result of the methodology and therefore the sediment habitats may be more stable than the data suggests. In addition, without good evidence of unimpacted baseline changes may be indicative of positive management interventions. Currently the main protected area byelaw (issued and enforced by Sussex Inshore Fisheries and Conservation Authority) is a prohibition against bottom towed fishing in historic eelgrass bed: [Chichester Harbour European Marine Site (Specified Areas) Prohibition of Fishing Method byelaw]. There are also the following byelaws in more localised areas within the harbour (west of the centre of Emsworth Channel); [Bottom towed fishing gear 2016 and Prohibition of gathering (sea fisheries resources) in seagrass beds] (issued and enforced by Southern Inshore Fisheries and Conservation Authority). Given the sensitivity of a number of the features of the littoral and sublittoral sediment and the potential for the native oysters to re-establish, it might be useful to consider additional areas for protection from physical disturbance.

The data on sublittoral sediments is so sparse and so little information is available specific to Chichester Harbour only it is not possible to determine a condition specific to the SSSI though indications are that some of the biotopes are sensitive to, and possibly impacted, by dredge fishing and this may hamper efforts to re-establish larger native oyster populations in the harbour. There is little if any evidence of water quality impacts on the sublittoral sediment features. The estuaries feature and sublittoral features of the Solent Maritime SAC marine features have been assessed using the whole data set for the wider Solent including some of the information described above but there is no data specific to Chichester Harbour that suggests a different SSSI condition assessment is required.

2) Summary of littoral sediments and sublittoral sediment condition

The littoral sediments appear to be in unfavourable condition based on an amalgam of data that suggests the sediment may be becoming sandier over time, some biotopes that are sensitive to disturbance were not recorded in later surveys, and opportunistic macroalgal percentage cover is above SACO target thresholds. However, with the exception of the opportunistic macroalgae data, the data is extremely limited and not collected consistently over time and therefore the condition is considered provisional and of low confidence. There is insufficient data to determine a trend in the littoral sediment elements assessed for the SSSI. The data on the sublittoral sediment is conflicting, the water quality data suggests no ecological response to the high nutrient as the phytoplankton is at high ecological status. The 2017 Natural England report suggests there is some sensitivity in the sediment features and that some sensitive sublittoral biotopes may have been lost. The estuaries feature and sublittoral features of the Solent Maritime SAC marine features have been assessed using the whole data set for the wider Solent including some of the information described above but there is no data specific to Chichester Harbour that suggests a different SSSI condition assessment is required.

Both littoral and sublittoral sediments are used for feeding by the bird interest features so bird features apply to these units. Saltmarsh features are not covered by Solent Maritime SAC marine condition assessments so information on these assessments needs to be incorporated into any relevant units which may also have littoral sediment alongside the SAC condition for estuaries etc. Only one littoral sediment unit (which is actually largely sublittoral sediment) is not considered to overlap with saltmarsh features (though it is used by foraging terns, and to some extent other birds, and has a fringing high tide roost including species that are declining (unit 42) for that unit), in this case the bird data has been used to set condition at the unit level (see section 10). The reason is the condition of unit cannot be better than the worse performing feature in that unit and since the terns and saltmarsh are both unfavourable declining in units where these occur, they are used to set the condition.

7.8 Recommendations

- More data is required to understand the littoral and sublittoral sediment distribution dynamics over time.
- In particular, assessment of infaunal invertebrates and physical sediment sampling is required.
- The mapping of the distribution of sediment types and biotopes by MESL for the 2012 to 2014 data should be used as the baseline to assess any change. The FCTs should be updated with this map. It should be noted that this baseline mapping is likely to represent an impacted baseline and should not be set as favourable condition target.
- Changes in biotopes from the baseline that is impacted may not represent a deterioration and consideration should be given to how to assess future changes in the littoral and sublittoral sediment features.
- The sensitivity of the harbour biotopes to physical disturbance may indicate the need for more nuanced approach to habitat and harbour management.

8 Review of littoral and sublittoral sediment - eelgrass trends

8.1 Ecological importance of eelgrass

The Solent Maritime SAC is the only European marine site within England to contain more than one physiographic estuary type, comprising four bar-built estuaries and four coastal plain estuaries of which Chichester Harbour is the largest. The importance of the eelgrass within the estuaries features is discussed in the Regulation 33 package (now Regulation 35) for the Solent Maritime SAC. Five of the estuaries, including Chichester Harbour are described as having significant areas of the nationally rare eelgrass habitat though the largest is within Langstone Harbour. Eelgrasses are also described within the typical species and important sub-features of the subtidal sandbanks, and intertidal mudflats and sandflats SAC features, as well as an estuarine sub-feature. Eelgrasses are part of the interest of the littoral sediment SSSI feature in Chichester Harbour and are explicitly referred to in the citation.

Seagrasses, including eelgrasses, are the only truly marine angiosperms and in addition to their existence value their importance for both ecosystem services and as a monitoring tool has been well established (eg ENRR 701; Jackson and others, 2013). The Jackson and others study shows that eelgrasses function as important nursery and foraging habitat for fish, shellfish and wildfowl and this confirms the earlier findings of an English Nature study into ecosystem services of intertidal habitats (English Nature 2003). They are also thought to oxygenate and stabilise sediments, provide shoreline stabilisation and protection from erosion, and actively sequester carbon and nutrients. Seagrasses are also a critical habitat for marine and coastal biodiversity. However, like saltmarsh, eelgrasses are only able to provide this significant range of ecosystem services when they are healthy, and they have been shown to be sensitive to a range of anthropogenic stressors including water quality.

8.2 Eelgrass and water quality

Much of the evidence of impacts of water quality on eelgrass is from the USA and caution should be used when drawing full conclusions based solely on non-UK habitats. The evidence is for a range of different features, habitats and species. There is overwhelming evidence of water quality impacts to eelgrass health and extent from both diffuse and point sources and in a range of different mechanisms. A recent (circa 2017) review of eelgrass and water quality impacts and conservation measures in the USA is provided by Department of Environmental conservation for New York State.

In the UK a comprehensive review of eelgrass is found in the EU LIFE Funded UK Marine SAC project. This gives a summary of the impacts on eelgrass beds including a review of impacts from nutrient enrichment stating that: nutrient enrichment is "*more often cited as a major cause of decline, or lack of recovery, of Zostera beds*". The project identifies five mechanisms for nutrient enrichment to impact eelgrass beds:

- Metabolic imbalance by high internal nitrate concentrations (including reduced internal carbon availability)
- Increased susceptibility to wasting disease (linked to the reduced phenolic compounds due to lowered internal carbon)
- Increased growth of epiphytic algae (smothering and reduced light)
- Smothering or shading by excessive growth of opportunistic macroalgae
- Shading by phytoplankton blooms or other turbidity.

An important note is that the wasting disease fungus (*Labyrinthula*) does not appear to cause the disease in conditions of low salinity. Impacts can vary spatially with large impacts often located close to sources of nutrients. For example, the eelgrass beds off the coast of Long Island showed local variation in nitrogen concentrations with significant elevations of nutrients around submarine groundwater discharge, high run-off or sewage outfalls (Simpson and Dahl 2017). In their literature review of marine angiosperms Jackson and others (2013) note that improvements to sewerage treatment and national regulations resulting from Urban Waste Water Treatment Directive and WFD have started to reduce these water quality pressures in the UK but this was not thought to be occurring everywhere. The Jackson and others review also noted continued direct physical pressures, such as anchoring, propeller scarring, dredging and destructive fishing methods, were increasingly resulting in further losses and fragmentation of many remaining beds.

8.3 What do the Environment Agency measure?

The Environment Agency have a number of WFD metrics that relate to interest features. Of most relevance in Chichester Harbour to estuaries and intertidal features are Infaunal Quality Index (both in the WFD Estuaries and coastal guidance) and coastal opportunistic macroalgae/angiosperms (WFD Coastal guidance) – including eelgrass.

The seagrass tool is a multimeric index composed of three individual metrics as below but is only applied to intertidal seagrass beds, where used and not to subtidal beds or saline lagoons:

(i) Taxonomic composition
(ii) Shoot density (as a percentage cover loss or gain in a single year) or shoot density (as a rolling mean of percentage cover loss or gain)*
(iii) Bed extent (percentage area loss or gain).

**Note:* shoot density is considered impractical in intertidal seagrass beds, and percentage cover of substratum is used instead.

Despite the fact this tool is designed to assess impact on intertidal seagrass communities to anthropogenic activity, the Environment Agency does not routinely monitor either eelgrass or the benthic invertebrates for the infaunal quality index within Chichester Harbour. The Environment Agency does note the presence of eelgrass when they come across the habitat during other surveys and have provided some information used in the current study. Eelgrass is monitored elsewhere in the Solent SAC and has been included in the Solent Maritime SAC marine features condition assessment.

8.4 What do Natural England measure?

Despite national and international importance of the eelgrass sub-feature of sublittoral sediments in Chichester Harbour, Natural England do not routinely measure subtidal eelgrass beds though some commissioned surveys occur. The CSMG for littoral sediments provides guidance on how to assess both the extent and quality of sub-feature biotopes including eelgrass.

In the absence of routine CSMG compliant monitoring data, Natural England undertook a desktop review to attempt to provide evidence of the trends of eelgrass extent and where possible condition over time, factors which may have contributed to any observed changes are discussed. In 2015 Natural England commissioned a desk-based review of the intertidal mudflat features in Chichester Harbour including the eelgrass features.

Table 8.1 The two baseline extents for Chichester Harbour's favourable condition tables against which the 'no decrease of eelgrass beds' attribute should be measured

Baselines	Area hectares	Source cited on FCTs
SSSI baseline (1980)	47.20	Portsmouth University/English Nature survey data (1980)
SAC baseline (1996)	70.10	Portsmouth University/English Nature survey data (1996)

8.5 Extent of eelgrass

1) Historical extent

A desktop review of Natural England data was undertaken. Some review of historic literature was also undertaken though this was far from comprehensive. The focus of the literature review was the data sets used to establish extent at designation. Only data sets readily available online or held by Natural England were included though some literature was ordered from library services. Natural England has not attempted to establish the extent of historic eelgrass beds using aerial photographs as this is fraught with difficulties of distinguishing the eelgrass from opportunistic macroalgae as established by the previous studies which used this technique (eg Budd and Coulson 1981). The information available is summarised in table A5.1 in Appendix 5 with a synopsis below.

According to Tubbs (1999) eelgrass beds were once commonplace in the Solent "*forming luxuriant green meadows across the intertidal flats, streaming in the tide in the low water channels and creeks of the estuaries and harbours*". This important component of the Solent marine ecosystem was devastated by wasting disease in the 1920's and 1930's with only small relicts surviving. In Chichester Harbour two littoral beds were found at West Wittering and south of Thorney Island (Butcher, 1934 in Tubbs, 1999) but by the 1950's the only *Zostera* beds known to remain on the mudflats in the Solent were two small mixed *Z. noltii* and *Z. angustifolia* beds in Langstone Harbour with smaller patches of *Z. marina* occurring in scattered localities elsewhere (Tubbs, 1999)[20]. From about 1960 the beds in Langstone Harbour started to recover as the *Spartina anglica*, which had grown to occupy the niche vacated by the eelgrass following disease die back. Tubbs estimated *Zostera* in Langstone Harbour to occupy approximately 280 hectares by 1979 and 340 hectares by 1987.

Recovery in Chichester Harbour seems to have followed a similar timeline with two small beds discovered in 1974. By 1979 Tubbs estimated the extent of *Zostera* in Chichester Harbour to be 130 hectares, increasing to 220 hectares by 1988 (as quoted in Tubbs, 1999 see appendix A5.1). Further declines due to wasting disease during the 1980's and 1990's impacted eelgrass habitat in Chichester Harbour so that by August 1993 the former extensive meadows in the Nutbourne Inlet (Thorney Channel) and on the east side of the Emsworth Channel were reduced to small but numerous residual patches. (Tubbs, 1999).

There is a significant gap in reliable data between Tubb's surveys in the 1990's and 2008 when the Hampshire and Isle of Wight Wildlife Trust (HIWWT) began surveying as part of the Solent seagrass project, set up in 2006. The 2011 data inventory, produced by HIWWT as part of the project, provides details of earlier surveys carried out by them in 2008, 2009 and 2010 and also includes data from other sources and historical evidence (Dale, Chesworth & Leggett, 2011). This inventory was

[20] In the UK literature *Zostera marina* is distinguished from *Zostera angustifolia* on the basis of morphology. However, outside the UK most authors consider *Zostera angustifolia* to be a phenotypic variant of *Zostera marina*.

updated with reports in 2015, 2016 and 2018, and reports shared with Natural England under a collaborative agreement[21].

Between 2006 and 2014, 693.07 hectares of intertidal and subtidal seagrass has been mapped in the Hampshire and Isle of Wight area (Marsden and Chesworth, 2015), this figure assumed to be an underestimation of total coverage. It is important to understand that the survey plan is designed to fill in data gaps and is not an annual repeat survey therefore data from this inventory is cumulative.

2) Current extent

In 2015 Natural England commissioned a desktop data review of the SSSI intertidal mudflat habitats in Chichester Harbour (MESL 2016) including the extent of seagrass beds. The data source for current extent is the summary of the MESL desk top summary, which is based on the HIWWT survey data from 2008, 2009, 2010 and 2013. The current extent survey is shown in table 8.2 and figure 8.1 which is taken from table 5 in the MESL survey plus a summary taken from each of the HIWWT reports. These extents vary slightly from those in the HIWWT reports (eg Dale & Chesworth, 2011, 2013, Marsden & Chesworth 2014, 2015, Marsden 2016). There are no updates for Chichester Harbour in the 2015 reports.

These estimates do not include earlier anecdotal references or pre 2006 survey data. For the whole Solent extent figures are based on surveys conducted by the HIWWT, Ken Collins (National Oceanographic Centre), and the Environment Agency since 2006 however only HIWWT data is available for Chichester Harbour.

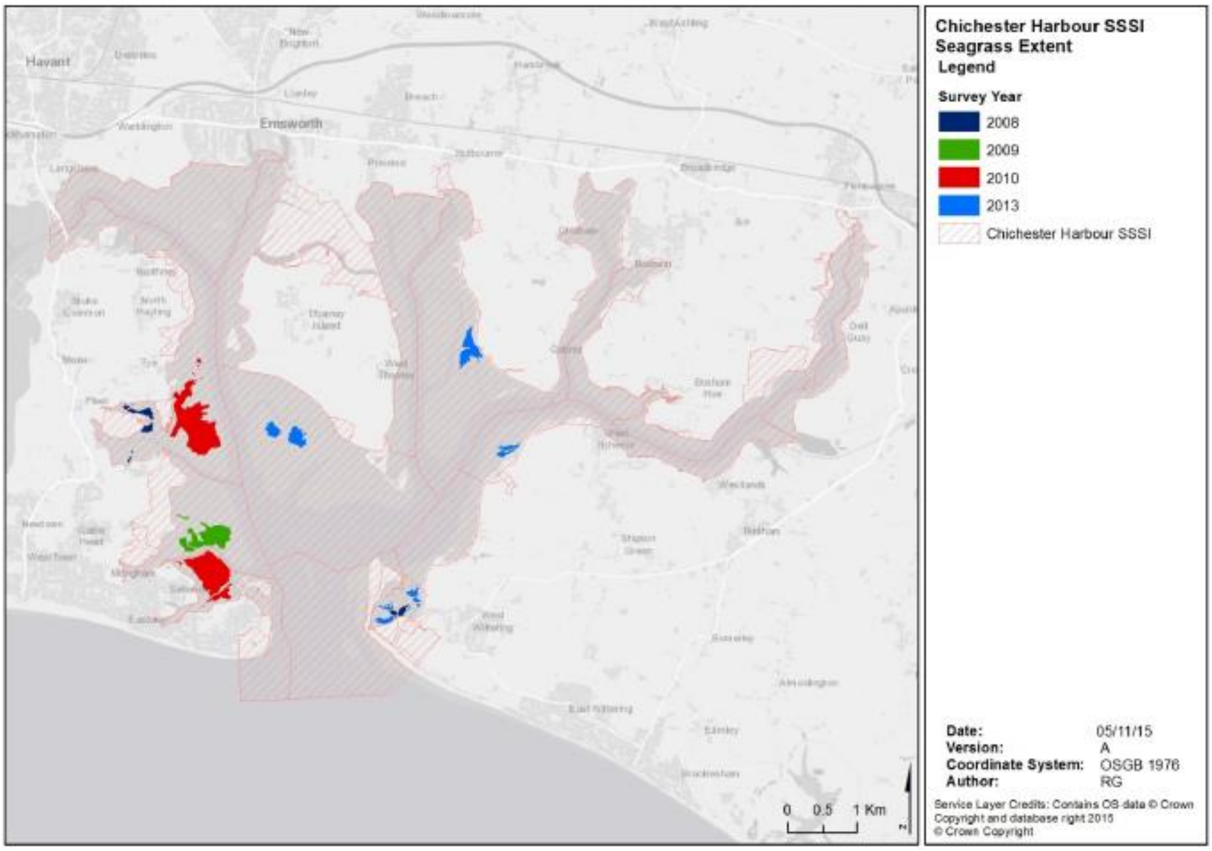


Figure 8.1 Map to show eelgrass beds up to 2013 from Hampshire and Isle of Wight Wildlife Trust surveys (taken from MESL 2016)

[21] Natural England single-tender-authorisation, Solent seagrass survey 2015.

The limitations of the surveys in estimating full current extent are noted in Dale and Chesworth 2013 report: "*many of the known beds need further survey to estimate area and bed boundary extent. Furthermore, some locations that are thought to host Zostera have had little or no survey work conducted there to confirm presence and extent. Therefore, current knowledge of the distribution of Zostera in the Solent is incomplete and this should be born in mind when consulting the data in the inventory (as the absence of seagrass records in an area does not necessarily mean it is not present".*

Table 8.2 Eelgrass extent after MESL (2016)

Survey year	Number of beds surveyed in Chichester	Total area (ha)	Average area of beds (ha)	HIWWT report value Chichester Harbour	HIWWT value for whole Solent
2008	4	6.9	1.7		
2009	1	18	18.0	100.64	590.6
2010	2	66.1	33.1	100.24	658.54
2013	11	25.3	2.3	116.08	673.97
2014				116.09	693.01
2015					703.01
Total		116.3		116.09	

The most recent surveys carried out at Chichester Harbour for the seagrass project were in 2015 (Marsden, 2016). Areas surveyed were Mill Rithe, Oar Rithe, Yacht Haven, Crake Rithe, East Head, Horse Pond and Chalkdock Point. Sand banks south of Crake Rithe and Horsedock Point were two new survey areas, but both were found not to support seagrass. Although the 2016 report of the 2015 survey provides details about the Chichester surveys it does not include a breakdown of extent for Chichester Harbour, only for the Solent as a whole (703.01 hectares). In the absence of the updated inventory reports investigation of the GIS data would be needed to determine the updated extent for Chichester Harbour which Natural England has not yet received.

However, the HIWWT report suggests a slight increase of seagrass bed extent in Chichester Harbour between 2008 and 2015 re-surveys. Several large areas were re-surveyed in 2015 and although most were similar in size to previous surveys, beds at Yacht Haven and Mill Rithe had increased compared to the last surveys which were in 2008 and 2010 respectively. There was also a slight increase in coverage at East Head, but this is due to a slight change in survey methods.

There is no WFD classification for seagrass in Chichester Harbour and the Environment Agency does not undertake routine seagrass surveys at this site. However, the Environment Agency reported seeing eelgrass in Chichester Harbour in previously unrecorded locations during their 2018 opportunistic macroalgae survey (pers. comm. C. Broomfield October 2019).

Little detail on the species distribution is reported in any of the reports but the interesting composition of the seagrass stands at East Head are noted in the HIWWT reports which states: "*substantial stands of Ruppia maritima were found at East Head, often with Zostera noltii and Zostera marina var. angustifolia close by, making this area one of the few locations we have observed where all three 'species' can be seen together*".

8.6 Evaluation of seagrass change over time

A systematic numeric assessment of change of distribution of seagrass within the SSSI over time is not possible due to the limitations of the overall data set, the absence of a reliable baseline and the changing survey methodology used. There appears to be a slight increase in some areas of seagrass in Chichester Harbour where sites originally surveyed in 2008 were re-surveyed by HIWWT in 2015.

However, much of the difference appears to be due to survey effort, though some limited recovery appears to be occurring in the west of the harbour. Comparing the HIWWT data with other studies is fraught with difficulty due to the significant methodological differences in data collection. Seagrass habitat at Chichester Harbour is often interspersed with saltmarsh habitat or restricted to channels (for example in the north-eastern regions of East Head), making it challenging to accurately map using remote techniques.

Based on the FCT figures the current extent is greater than that at the baselines for the SAC and SSSI, and the site would be at favourable condition for eelgrass extent. However, the data on eelgrass extent at designation is confused at best. The data from the FCTs is cast into considerable doubt as it has been reviewed twice each coming up with a different figure. In addition, shore-based field surveys by Tubbs & Tubbs (1983) show 130 hectares of eelgrass in 1979 when the data used in the FCTs (using a remote survey technique from only one year later) shows 44.7 hectares. Though dramatic declines do occur, the Tubbs & Tubbs field surveys should take precedence for the SSSI baseline as they were from closer dates to the original designation (1970) than the figure currently quoted on the FCTs. The difficulties of accurately drawing conclusion on eelgrass trends are noted by all other recording attempts to estimate its change over time (eg MESL 2016), and Marsden and Chesworth (2015) note that gaps in data from the early 1980s to the current day make meaningful comparisons of *Zostera* populations over the last 20-30 years difficult.

At present, eelgrass in Chichester Harbour appears relatively stable and confined mostly to the west of the harbour. The current extent of 116 hectares appears to be significantly below historic values but represents a recovery from historic lows following wasting disease losses. A figure of between 130 and 220 hectares, based on the Tubbs shoreline-based surveys of 1979 and 1988, would be a reasonable provisional figure range for favourable condition extent but should be used with low confidence. Based on these revised SSSI baseline figures the current extent would be at unfavourable condition. There is insufficient consistently collected data to assess a trend over time.

8.7 Factors affecting eelgrass recovery – literature review

Eelgrass extent in Chichester Harbour, like many other UK sites has varied over time and has been impacted by a number of factors which appear to function synergistically. It is not possible to undertake numeric analysis with the data set due to the variabilities in the collection of data, however there are some likely contributing factors to the eelgrass declines which have been taken from the available literature elsewhere and related to the abiotic factors observed in the harbour.

As described in section 8.2 a primary determinant in all previous reviews of eelgrass trends is water quality though physical disturbance from boat-based activity is also a key factor in the health of the UK eelgrass (eg Unsworth and Jones, 2016; Jackson and others, 2013). Unsworth and Jones (2016) found that tissue nitrogen levels are 75% higher in surveys of UK eelgrass beds than the global average indicating widespread eutrophication of waters. They found some sites were of high environmental health but that all UK sites were considered at risk from anthropogenic impacts, particularly poor water quality and boating-based disturbances. In some temperate estuaries, areas of seagrass habitat decrease logarithmically, and percentage loss of habitat increases logarithmically as nitrogen loading rates increase (Hauxwell and others, 2003).

The mechanisms with which high levels of nutrients impact eelgrass are relatively well understood. In a Natural England commissioned review Jackson and others (2013) summarised the effects of excessive nutrients into three attributes: high environmental nitrogen (+/- orthophosphate), low oxygen and low light availability. The relationship between these abiotic attributes and seagrass trends, survival and health is so strong it has led to a number of authors attempting to set thresholds for seagrass bed survival. Table's 8.3, 8.4, 8.5, and 8.6 summarise some of the key thresholds for these attributes taken from a range of literature but following the format and data in Simpson and Dahl 2017. Connell and others (2017) experimented with addition of nitrogen to healthy seagrass beds in Australia and showed that leaf turnover switched from positive to negative at 0.13-0.15 mg/l of DIN due to significantly increased leaf drop, though new leaves continued to grow. Other authors have taken a different approach to nitrogen for example Lattimer and Rego 2010 who looked at catchment loading and eelgrass (*Zostera marina*) bed coverage in New England. They found that catchment loadings at, or below 50Kg ha^{-1} yr^{-1} eelgrass extent was not controlled by nitrogen but above this there is a decline in relative extent. Eelgrass was largely absent at loading levels greater than or equal to 100Kgha^{-1} yr^{-1}. The difficulty of applying these thresholds in the UK context and to Chichester Harbour are discussed in section 9.

The recovery of eelgrass when nitrogen levels reduced has been noted by several authors but Wang and others 2020 notes recovery when high nutrients were the primary cause of loss, is limited unless significant nutrient reduction has occurred. Recovery of eelgrass is not straight forward and does not always follow nutrient reduction. Understanding the complex synergies between food webs, anthropogenic stressors, environmental conditions and seagrass bed dynamics is a major challenge to conservation efforts. Taking an ecosystem approach is essential to understand and predict seagrass losses and recovery (eg Crowder and Norse 2008). It has been suggested that the loss of eelgrass meadows in Danish fjords caused a regime shift from clear waters with high eelgrass cover to turbid waters with plankton dominance (eg Duarte 1995). The complex relationship between eelgrass mesograzers and food webs has been shown by Hughes and others (2017) who found return of sea otters helped enable the recovery of seagrass.

1) High nitrogen

High nitrogen in tissues is a result of a high nitrogen in the environment as eelgrass readily takes up nitrogen from both roots and shoots (Jackson and others, 2013). Eelgrass (*Z. marina*) readily removes inorganic nitrogen but also urea, and dissolved free amino acids from the water column (Hansen and others, 2000) though dissolved inorganic nitrogen made up the majority of the nutrients taken up. When looking at nitrogen uptake by plants, other authors have found that ammonia was the preferred source of nitrogen overall for uptake in *Z. marina,* but plants preferred dissolved organic nitrogen (DON) to nitrate. The uptake of DON was greatest in the roots but did occur through the shoots (eg Alexandre and others, 2015). *Z. noltii* plants were also shown to preferentially take up ammonium ions through leaves at a rate of 100 times greater than nitrate (Alexandre and others, 2011). The strong and multiple mechanisms for intake of nitrogen in eelgrass suggests evolutionary adaptation to low nitrogen environments.

In high nitrogen environments, eelgrass suffers from a metabolic imbalance which results in too much nitrogen and too little carbon. Due to this imbalance the presence of phenolic compounds drops in the eelgrass tissues (due to inadequate carbon to nitrogen ratios). Phenolic compounds are known to have protective properties in many plants and help with disease resistance. *Labyrinthula* is a fungus that is widely found in the environment but when eelgrass is suffering from other environmental stressors, in particular the metabolic imbalance caused by high nitrogen, it becomes susceptible to the fungal infection and the wasting disease caused by *Labryrinthula*. The metabolic imbalance from elevated nitrogen has also been shown to have direct structural effects on seagrass plants through a process called ‘carbon drain’ that weakens the eelgrass tissues and causes the roots and rhizomes to deteriorate (eg Burkholder and others, 1992, 1994). Some authors have postulated that increasing carbon dioxide may reduce the imbalance in eelgrass beds suffering from eutrophication. However, Martinez-Crego and others (2014) found that in *Z. noltii* the phenolic reduction in the eelgrass tissues continued with nutrient increases despite elevated carbon dioxide treatments.

Water quality determinants other than dissolved inorganic nitrogen can also cause impacts on eelgrass. Increased organic matter loading, and the subsequent decomposition in the sediment creating sulphur compounds, can increase the sulphur concentration in seagrass roots and rhizomes (Roca and others, 2016). Evidence from around the world shows that sediment acts synergistically with nutrients and other potential determinants to impact seagrass beds (eg Siciliano and others, 2019 for New Zealand). Other forms of nitrogen have also been shown to impact seagrass beds. For example, ammonium/ammonia increases in sheltered eutrophic estuaries due to the decomposition of organic matter from phytoplankton and seaweed, but also from anthropogenic wastewater sources

(Van der Heide and others, 2008) has been shown to impact eelgrass. Impacts of ammonium are shown to be seasonal and ammonium toxicity effects were more pronounced in plants grown on sand and at the higher temperature. Ammonium toxicity effects on *Z. marina* are expected to be strongest in autumn when irradiance decreases, temperature is still high, and ambient ammonium concentrations rise (Katwijk and others, 1997). The relationship between nitrogen and eelgrass is discussed further in section 9.

2) Low oxygen availability

Seagrasses require oxygen in both roots, rhizomes and shoots. Deoxygenation is more common in below ground environments and rhizomes of eelgrasses can exhibit physiological adaptations to allow anaerobic metabolism to occur for limited periods. This metabolism accumulates toxic metabolites and is less efficient than aerobic metabolism (Jackson and others 2013). Anoxic sediments are often associated with sulphides which can be toxic to eelgrasses and lead to bed reduction (Jackson and others, 2013). Oxygen uptake in eelgrass leaves is related to the width of the diffusion layer which is related to factors such as water velocity and epiphyte layer.

The dissolved oxygen in Chichester Harbour is measured as part of the WFD assessment and this attribute is at high ecological status so there is no concern with oxygen in Chichester Harbour at the water body assessment level. The data for the WFD assessment uses relatively infrequent sampling and diurnal and prolonged seasonal changes may not be reflected. The Rogers MSc (2019) into saltmarsh found a correlation with years with lower dissolved oxygen and saltmarsh erosion, this hints that dissolved oxygen may be more of a concern than the WFD high attribute classification initially suggests. Assessment of sediment anoxic conditions is not measured regularly in WFD assessment but the opportunistic macroalgae assessment does note the presence of blackened anoxic sediment in the opportunistic macroalgae sampling points and anoxic sediments have been observed in some locations of the Chichester Harbour 2019 saltmarsh surveys, though only anecdotally from the surveyors.

There is clearly a need for higher temporal and spatial resolution data on dissolved oxygen near the seagrass beds in Chichester Harbour and assessment of sediment analysis. In addition, any further study of eelgrass in Chichester Harbour should look at the epiphyte growth (which increases the thickness of diffusion layers on eelgrass blades and therefore effects uptake of oxygen eg Agustí and others, 1994).

3) Low light availability

Jackson and others (2013) found that low light availability reduces eelgrass productivity, reducing the amount of oxygen for respiration by the roots and rhizomes and lowering nutrient uptake. Resulting hypoxic conditions leads to a build-up of sulphides and ammonium which can be toxic to seagrass at high concentrations (Mateo and others, 2007; van Katwijk and others, 1997). Lower productivity and toxic stress will lower the resilience of the plant to other impacts including wasting disease. Similar to saltmarsh the reduced root biomass can reduce the stability of sediments leading to full scale bed erosion (Jackson and others, 2013). Low light availability is frequently synergistic with high nitrogen and the subsequent metabolic imbalance (described above). There is no evidence of extensive phytoplankton blooms in Chichester Harbour from the WFD assessments as the phytoplankton attribute is at high ecological status. However, there are extensive areas of opportunistic macroalgae which will block out light and is seen smothering intertidal habitats in many areas of the harbour including during the 2019 surveys undertaken for this report. Further work on eelgrass in Chichester Harbour should assess the sediment and roots of eelgrass beds to assess if this root/shoot imbalance is occurring in the harbour.

4) Physical stressors, synergistic impacts and climate change

Storms and wave action are known to cause erosion of eelgrass beds under unimpacted conditions (eg Short & Wyllie-Echeverria 1996). However other anthropogenic stressors such as dredging will exacerbate the physical stress on eelgrass beds and can cause temporary low light and anoxic conditions. Some types of moorings have been shown to scour seagrass bed roots and rhizomes significantly affecting areas of beds (Jackson and others, 2013).

There is some limited evidence of physical stress on some eelgrass beds from the HIWWT survey of Chichester Harbour, which reports observations where moored boats were found to be resting on seagrass in the Yacht Haven and East Head areas, with access to the boats resulting in further damage from trampling. Keel scars and 'holes' in the habitat resulting from boats swinging on their moorings have also been noted in Tubbs (1999) and the HIWWT reports. Fixed moorings and advanced mooring systems and marinas are the key to preventing eelgrass damage from moorings. The Harbour Conservancy has the power to review the mooring risk and behaviour of the harbours boat users.

Fisheries dredging and bottom trawling can cause physical disturbance to eelgrass beds and prevent their regeneration. Currently the main byelaw on physical disturbance is a prohibition against bottom towed fishing in historic eelgrass bed: Chichester Harbour European Marine Site (Specified Areas) Prohibition of Fishing Method byelaw. The areas of this byelaw cover much of the current seagrass beds (in Sussex) but could be extended to cover areas of historic beds to promote recovery.

Boström, and others (2014) looked at the northern European eelgrass beds and factors that affected their recovery. They stated: "*There is an extensive literature on links between nutrients, water quality and eelgrass health. However, with the exception of some areas (eg western Sweden and parts of the Baltic Sea), managers are still largely unaware of the importance of top-down control (role of predation and grazing and their interaction) in relation to bottom-up processes (nutrient pollution). As identified in this review, eelgrass food webs differ in structure and function with important implications for eelgrass loss mechanisms. This and previous work (Moksnes* et al.*, 2008; Baden* et al.*, 2010; Hughes* et al.*, 2013) clearly highlights the need for a more holistic and flexible (offshore and coastal) management strategy including stronger links between fisheries management and eelgrass conservation.*"

The mesograzer community dynamic is also important in helping eelgrass to adapt to climate change. Alstreberg and others (2013) found that grazers on epiphytic microfauna and on opportunistic macroalgae reduced the effects of experimentally elevated acidification and temperature (climate change) in eelgrass mesocosms. This removed the impacts of the climate induced reduction in eelgrass biomass from increased epiphytic fauna and light reduction from phytoplankton and smothering by opportunistic macroalgae.

The relationship to boat facilities and moorings, fisheries bylaws, fish stocks, mesograzers and eelgrass beds in Chichester Harbour and the wider Solent was not explored in the current study but further work on the health of associated food webs will be needed alongside nutrient reduction to ensure full recovery of healthy eelgrass ecosystems.

Table 8.3 Thresholds for seagrass beds taken from literature (after Simpson and Dahl 2017): a) nutrients

Citation/Source	Total nitrogen mg/l	Dissolved inorganic nitrogen mg/l	Total phosphorus mg/l	Dissolved Inorganic Phosphorus mg/l
Batiuk et al 2000		<0.15		<0.02
Benson et al 2013	<0.34			
PEP 1998	<0.4	0.009+/-0.001		
Vaudrey 2008		<0.03		<0.02
Vaudrey et al 2013	<0.029*		<0.071*	
Yarish et al 2006		<0.03		<0.02
Connell et al 2017		0.12-0.15mg/l**		

* These were defined as optimal thresholds rather than thresholds for seagrass survival. Most of these studies were on *Zostera marina* and most averages were values in summer.

** The Connell study was the value of added nitrogen to the system where bed failure was triggered for the seagrass beds dominated by *Amphibolis antarctica.*

Table 8.4 Thresholds for seagrass beds taken from literature (after Simpson and Dahl 2017): b) light and water clarity

Citation/Source	Chll a µg /l	Water column light %	Kd m^{-1}	Secchi Depth m	TSS mg/l	Light at leaf surface %
Batiuk et al 2000	<15	22	1.5		<15	>15%
Benson et al 2013	5.1	>25				
Ferguson et al 1993				0.3-2		
Greening et al 2014	4.6-13.2	20.5				
USEPA 2003	8	22		0.2-1.9		
Vaudrey 2008	<5.5	22	<0.7			
Vaudrey et al 2013		>25%	<0.46*			>15%
Yarish et al 2006	<5.5		<0.7		<30	

*These were defined as optimal thresholds rather than thresholds for seagrass survival.

Table 8.5 Thresholds for seagrass beds taken from literature (after Simpson and Dahl 2017): c) sediment characteristics

Citation/Source	Clay/silt %	Organic content%	H2S
Kemp et al 2004	<20-30	<5	<2mM
Koch 2001	2-56	0.4-16	<1mM
Vaudrey 2008		0.4-10	
Vaudrey et al 2013	<2*	<0.5*	
Yarish et al 2006	<20	3-5	<400µM

*These were defined as optimal thresholds rather than thresholds for seagrass survival.

Table 8.6 Thresholds for seagrass beds taken from literature (after Simpson and Dahl 2017): d) physical characteristics

Citation/Source	Temperature ºC	Water movement min cm/s	Water movement max cm/s	Wave tolerance
Hoffle et al 2011	<27			
Koch 2001		3-16	50-180	<2m
Vaudrey et al 2013	<21*			
Yarish et al 2006		5	100	

*These were defined as optimal thresholds rather than thresholds for seagrass survival.

8.8 Condition summary for eelgrass

It is not possible to reliably set a figure for the unimpacted historic extent and therefore what the extent is to meet favourable condition. However, based on the review of historic data, Natural England's judgement is that the Tubbs & Tubbs 1979 figure of 130 hectares in the harbour can be used as a provisional figure to update the FCTs as the extent at SSSI designation. It is likely to represent a middle figure in the recovery cycle of eelgrass and a figure of 220 hectares as a minimum for favourable condition may be more appropriate. The figures should be caveated with a note that figures will be revised should any better data on the historic extent be forthcoming. Better data on the current extent and health of eelgrass is urgently needed to ensure that conservation measures for the harbour can be directed to the correct locations.

Since the estimated current extent from best available data (cumulative summary of HIWWT most recent surveys) is below both 130 and 220 hectares figures the eelgrass feature is considered to be in unfavourable condition by the authors of this report. It is not possible to reliably assign a quantified trend to this condition assessment due to the variable data collection methodologies used. This condition assessment is low confidence and should be considered provisional as it only partially complies with the CSMG standards for this sub-feature.

8.9 Recommendations

- The figure for SSSI baseline extent should be updated on the FCTs with a new baseline figure of 130 hectares and consideration given to the implications for the SAC baseline and SACOs.

- An eelgrass extent survey of the whole harbour in a single year is required and this should be used to update conservation measures in the harbour to protect eelgrass.
- Surveys looking at shoot density, epiphyte cover, and signs of *Labryrinthula* should also be undertaken.
- An assessment of sediment and rhizomes should be made to look for signs of anaerobic conditions, and tissues should be analysed to provide Nitrogen:Carbon:Phosphorus (N:C:P) ratio assessment to inform if the high levels of nutrients in the harbour are an issue for the eelgrass health.
- Conservation measures should focus on removing physical and nutrient pressures to remaining eelgrass beds.
- If possible, exploration of the health of associated ecosystem fauna focussing on fish and top predators that may have been lost should be undertaken.
- All measures to reduce nutrients should be undertaken (see section 9).
- Replanting should only be done in areas of low nitrogen and limited physical pressures and a preference is for natural recolonisation.

9 Review of water quality trends – focussing on nitrogen

9.1 Limiting factors

Ecological systems are limited by various factors in the amount of plant life (biomass) they can produce, these are called limiting factors. Traditionally, in flowing freshwater systems the limiting nutrient is largely regarded to be phosphorus. In purely marine environments the limiting nutrient is regarded as nitrogen and in estuarine environments both nutrients can be limiting (referred to as co-limitation), with the gradation depending on a range of factors. In reality, it is often much more complex than this and the actual response a system shows to nutrient enrichment is dependent on a number of physical, chemical and biotic factors. One of the most comprehensive reviews of the impacts of nutrients on estuaries was undertaken by English Nature and Environment Agency (Scott and others, 1999) which demonstrated there are many factors effecting biological response to nutrients which are varied, including; light (turbidity and season), temperature, estuarine depth, daily sunlight, salinity, prevailing wind conditions and estuarine flushing time.

The sources of nutrient enrichment from 'allochthonous' or new sources are usually classified into point and diffuse sources. There are three main processes in the nitrogen cycle relevant to the marine environment: nitrogen fixation, nitrification, and denitrification.

- Nitrogen fixation is conversion of gaseous nitrogen N_2 into Ammonia (NH3) or ammonium (NH_4^+) which can then be assimilated into organic nitrogen (biomass) or subject to microbial respiration.
- Nitrification is the oxidation of ammonia to nitrite (NO_2^-) or nitrate (NO_3^-) or the oxidation of nitrite to nitrate.
- Denitrification is an anaerobic process that results in emission of gaseous nitrogen N_2.

These processes are all part of a natural marine nitrogen cycle, but nutrient enrichment can shift the relative balance of processes across a whole marine ecosystem.

Nutrient over-enrichment can influence the integrity of the coastal ecosystems in a range of mechanisms including but not limited to:

- increased primary production
- changes to competitive balance and species composition
- changes to community metabolism
- changes in consumer activity
- changes to carbon sequestration.

(Morris and Bradley, 1999; Pennings and others, 2002; Crain, 2007, Bertness and others, 2008, Slocum and Mendelssohn, 2008; Frost and others, 2009; Graham and Mendelssohn, 2010; Ramirez and others, 2012).

9.2 Nutrient trend analysis

In order to assess the trends in nutrient enrichment, data on nitrogen and phosphorus were obtained and analysis of various abiotic data sets were used to assess and compare the trends in nutrients over time and spatially within Chichester Harbour. This information was used to help inform the decision from biological assessments in other sections on whether ongoing conservation efforts are sufficient to help restore favourable condition and conservation status to the harbour's features.

1) Data sources and limitations

Though data on the freshwater inputs into the harbour are available, the freshwater data sets have comparatively limited data on the dissolved inorganic nitrogen (DIN) metric. The main use of the freshwater data set for the intertidal habitat would be alongside modelling data in ascribing the relevant source apportionment. Natural England had no modelling resource available for this investigation and was not able to undertake the source apportionment modelling at the ‘assessment area’ scale (identified in section 7). It is recommended that the freshwater data is analysed alongside source apportionment modelling at the ‘assessment area’ scale as soon as modelling resource becomes available.

The WFD assessment shows that both dissolved oxygen and phytoplankton attributes are at high ecological status, therefore no analysis of the dissolved oxygen or phytoplankton data have been undertaken in the current report, as it was assumed at the beginning of the study they are not a major contributor to unfavourable condition. The literature reviews including Rogers MSc study of harbour saltmarsh indicate dissolved oxygen levels correlate to saltmarsh loss and this warrants a more detailed study than can be achieved with data sets available.

The nitrogen has been shown to be the main limiting factor for Chichester Harbour by the Environment Agency’s nitrate vulnerable zone assessment (2017), the main metric used is dissolved inorganic nitrogen (DIN). The DIN metric as measured in Chichester Harbour has a detectable limit of $0.12mgl^{-1}$ so where this is the value given for plotting or analysis the value is set to half this value (ie $0.06mgl^{-1}$). The ammoniacal nitrogen is measured to a limit of 0.03 mgl^{-1} with nitrate and nitrite to much lower limits of detection. A list of the nutrient parameters used and what data sets were provided is shown in Appendix 6.

Rainfall

Rainfall data was sourced from the met office, daily rainfall data (1 December 1991 to 21 September 2019) from the Thorney Island weather station (which is within Chichester Harbour). Data was not sourced from before 1991. To numerically represent whether the season has been wet or dry, the metric; 90-day total rainfall, was calculated which summed the total daily rainfall for the previous 90 days. This then provided a daily data set that summarised the seasonal rainfall (for the previous 90 days). Meteorological seasons are considered to be 3 months so for consistency the 3 months x approximately 30 day per month was used to represent the rainfall season total to the date of the nitrogen sampling. This allowed for the data to represent all the rainfall prior to the date on which the nitrogen sample was taken even though the samples were taken on different days across the harbour and different times of year in different years.

In other words, this data represents a numeric figure of how wet the weather has been in the time before the sample was taken. A whole season was seen as the best metric because the Western Streams catchment in which Chichester Harbour sits is a largely groundwater dominated catchment. In such catchments there can be a lag as groundwater rises into the unsaturated zones as well as surface runoff and interflow. There is therefore a significant change in flow, both into the rivers and harbour directly from groundwater as well as groundwater infiltration into sewerage catchments at times of higher groundwater. This can increase the nitrogen from all sources. Rainfall can also increase the phosphorus from effluent from increased ‘storming’ of the Wastewater Treatment Works (WwTW) and from surface run-off of urban surfaces. The cumulative rainfall for the whole data series is shown in figure 9.1.

Nitrogen

Water quality determinants were sourced from the Environment Agency WFD monitoring data. The initial available data was from 2007 to 2017 as this data set has a consistently collected nitrogen determinant but subsequently the nitrogen determinants from 9 February 1977 to 9 May 2018 were obtained from the Environment Agency. The determinant dissolved accessible inorganic nitrogen in mgl^{-1} (DAIN[22]) was chosen as the basis for water quality assessment in this report, as the data set for total nitrogen was extremely limited and the DAIN metric is used in the WFD assessment. The determinants of nitrogen that were available changed over the period with a change in 2005 related to use of filtered versus unfiltered samples. The data set notes this change is not significant, so analysis has been of the whole time period. The DAIN/DIN metric was calculated from the various available determinants based on the advice of the Environment Agency (Udal Pers Comm), the data to consistently calculate this metric was only available back to 1995. The following is an explanation of the various forms of nitrogen measured or calculated in the Environment Agency data set.

- DAIN = TON (Total Oxidised Nitrogen ie nitrate + nitrite) + Ammoniacal N (NH3-N)
- Ammoniacal N = NH_4 (ionised) + NH_3 (unionised)
- keldalh nitrogen = organic N + ammoniacal N (NH_3)
- So organic N = keldalh - ammonia
- Total N = Organic N + ammoniacal N + TON
- Total N = Organic N + NH_4 + NH_3 + nitrate + nitrite.

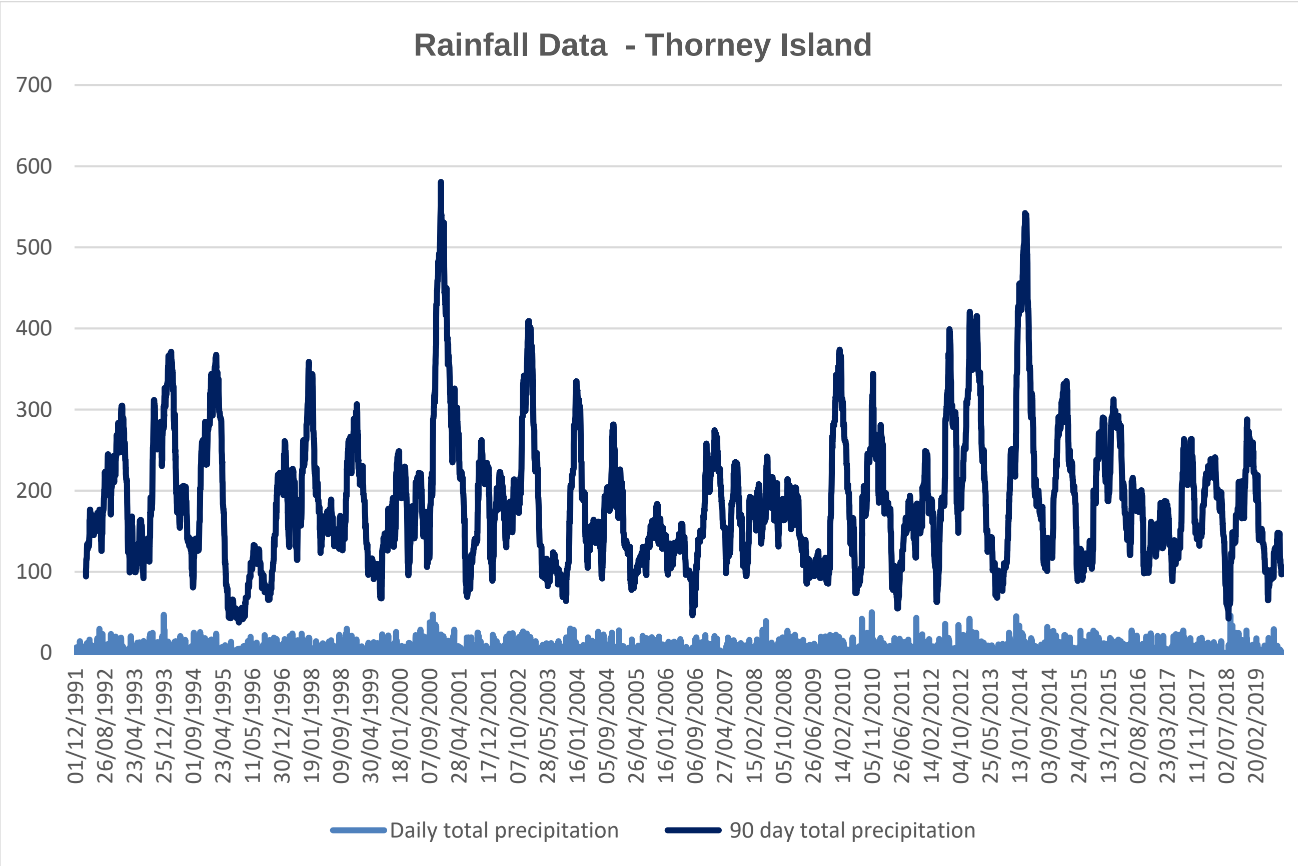


Figure 9.1 90-day rainfall total and daily rainfall total Thorney Island

Where gaps in any one of the three determinants were found, the sample was not used in the analysis. A summary of the timeline for each data set and whether derived or measured and a list of the site names by habitat type (freshwater vs estuarine) is provided in Appendix 6. Only the data from the intertidal/estuarine sites was used for this analysis to relate to the areas of study for the current condition. The locations of each intertidal (or subtidal) monitoring point are provided in table A6.2 in Appendix 6.

[22] DAIN is considered equivalent to Dissolved inorganic nitrogen DIN and these are used interchangeably in this document.

Phosphorus and N:P ratio
Only orthophosphate data was available for the time series and for the same locations as the nitrogen. The nitrogen and phosphorus ratio was calculated by dividing the value of N in mgl^{-1} by the value of orthophosphate in mgl^{-1}. These were then plotted and are shown in Appendix A6.5 for each of the saline monitoring points.

9.3 Results

1) Temporal trend (variation with time)

Both nutrients show significant variation seasonally, inter-annually and spatially within the harbour. Illustrative examples showing the temporal variation are shown in figure 9.2 for nitrogen and figure 9.3 for phosphorus with complete data shown in figures A6.3 and A6.4. Note these figures are shown at different scales to enable the temporal variation to be obvious.

At all monitoring points the summer growing season removes nutrients (both nitrogen and phosphorus) at most sites in most years to below limits of detection for the methodology used or to very low values. To correct for this the seasonally adjusted 'winter' data was created by removing April through September values from the data set. This provided winter data that corresponded to the wintering bird season. The trend lines for these winter data sets were plotted. The trend lines and linear regression values (if lines showed linear trends) are given in Appendix A6.6. In one site (Langstone Bridge) the phosphorus values are a better fit to a logarithmic trend line regression, so this is plotted for that site. Figure 9.4a and b show examples of trend lines for winter DIN for high and low nitrogen monitoring points. Figures 9.5a and b show examples of trend lines for winter orthophosphate for high and low nutrient monitoring points.

There is no statistically significant change in phosphorus or nitrogen trend generally except at Langstone Bridge where both DIN and orthophosphate show a strong step downwards after 2001 and remain lower after this point as shown on figures 9.4c and 9.5c respectively.

Dell Quay also shows slight downward slopes for DIN and a stronger downward trend for orthophosphate, but they are not significant. Chichester Channel shellfish (DIN) shows a slight upwards trend though it is marginal.

2) Spatial variation in nutrients

As can be seen by figures 9.2, 9.3, 9.4 and 9.5 and appendix figures A6.1 and A6.2 the nutrient values vary considerably within the harbour. Since the data is not showing a statistically significant temporal trend at most locations, the mean and standard deviation of the winter nitrogen and phosphorus data sets were calculated for each sampling location across the whole data period. These mean figures are shown in table 9.1 and plotted in figure 9.6. The sites mean winter DIN values are highest on the eastern side of the harbour and at the tops of the harbour arms however the east-west variation is greater than the north-south spatial variation in DIN.

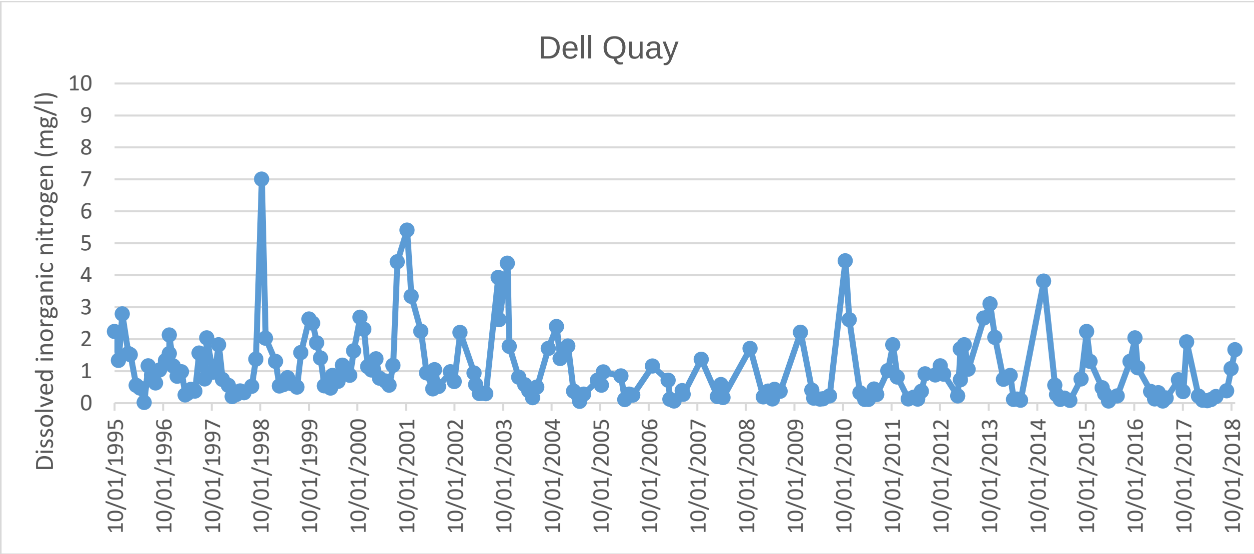
The mean DIN values from Point G at Fishbourne Channel and Fishbourne Channel downstream of Footbridge are higher than other parts of the designated sites. This is partly due to the smaller data set with only data from 2011-13/2012-15 available at these locations, which correspond with very wet years. However, the high values are reflective of a higher overall mean shown in the other Fishbourne channel data set at Dell Quay, which is more complete and comparable to the other locations. Dell Quay has a mean winter DIN (1.789 mgl^{-1}) that is nearly double the next highest value (0.959 mgl^{-1}) which is at the bottom of Fishbourne channel. The lowest value for mean winter dissolved inorganic nitrogen is at Fisheries Buoy (16) which is located at the edge of the intertidal towards the centre of the main harbour. To compare the DIN values spatially, the percentage winter DIN mean value above the lowest value was calculated and is show in table 9.1. The mean winter DIN at Dell Quay is six times greater (598%) than that at the lowest value at Fisheries Buoy. The percentage values for the other Fishbourne channel data sets (downstream of Footbridge and Point

G) are nearly 18 and 30 times (1787% and 2936%) greater than the lowest DIN mean at Fisheries Buoy 16. However, this reflects not only the higher nitrogen at those sites but the large rainfall, hence nitrogen peaks in the years over which these limited data sets were calculated and therefore this latter is not a sound comparison.

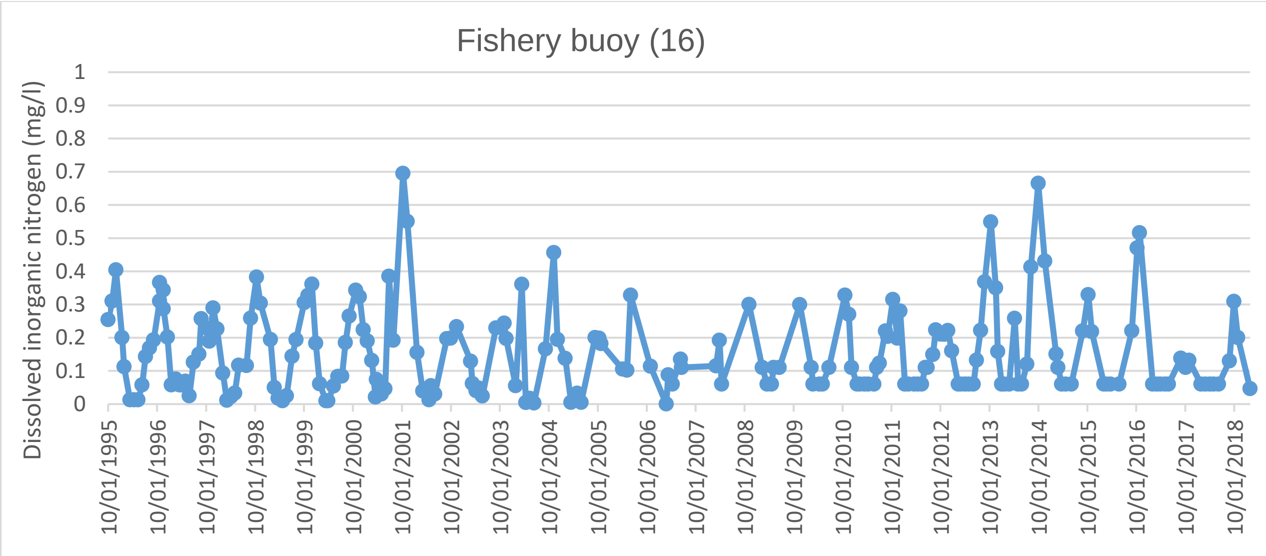
The mean orthophosphate values also vary spatially with the highest value at Dell Quay in the Fishbourne Channel and the lowest value at Fisheries Buoy in the western outer harbour. The trend of increasing nutrients west to east and south to north is still present in orthophosphate but with a marked difference in the incomplete data sets in the upper part of Fishbourne channel. Dell Quay has a winter orthophosphate that is nearly five times as high (490%) than the lowest values at Fisheries Buoy and Thornham Channel shellfish water.

3) Nutrients and rainfall data

The winter dissolved inorganic nitrogen (DIN) values correlate with the winter 90-day rainfall, the best fit for logarithmic of rainfall total and with high levels of rainfall, resulting in much higher DIN values. Though the relationship is visible it is not statistically significant at all sites. Figure 9.6 shows the logarithmic trend and fit for the monitoring points with highest and lowest DIN with the large data sets at Dell Quay and at Fisheries Buoy with all the remaining graphs in Appendix A6.3. Figure 9.7 also shows the winter orthophosphate and rainfall at the same monitoring points with trend lines for reference only. There is no obvious or statistically significant relationship between orthophosphate and rainfall. The rainfall and orthophosphate at the remaining monitoring points are in Appendix A6.4. The graphs illustrate significant correlation of DIN and rainfall and absence of relationship between rainfall and orthophosphate.

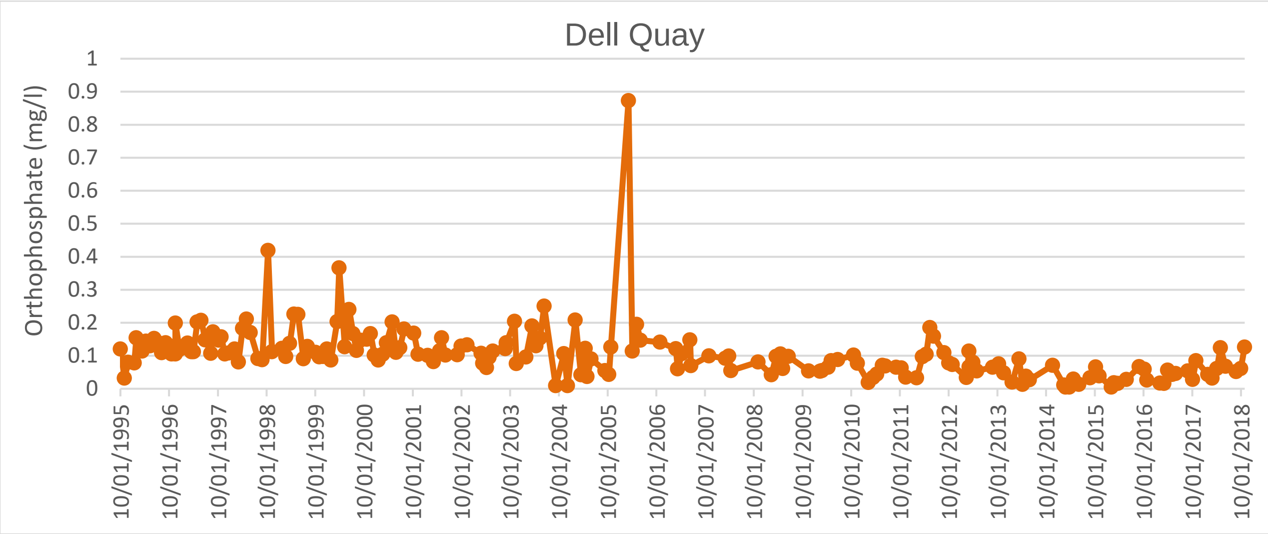


9.2 a Seasonal and long-term variation at Chichester Harbour site with high nitrogen –Dell Quay

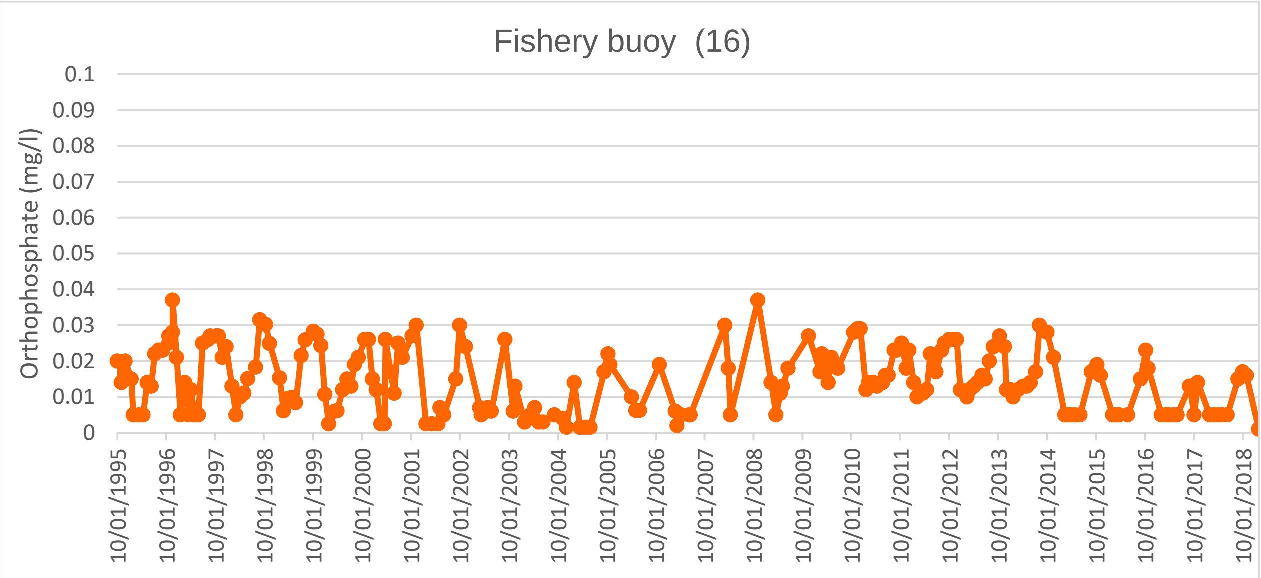


9.2 b Seasonal and long-term variation at Chichester Harbour site with low nitrogen – Fishery Buoy 16

Figure 9.2 **(a and b)** Seasonal and long-term variation for sites in Chichester Harbour for nitrogen (note different scales)

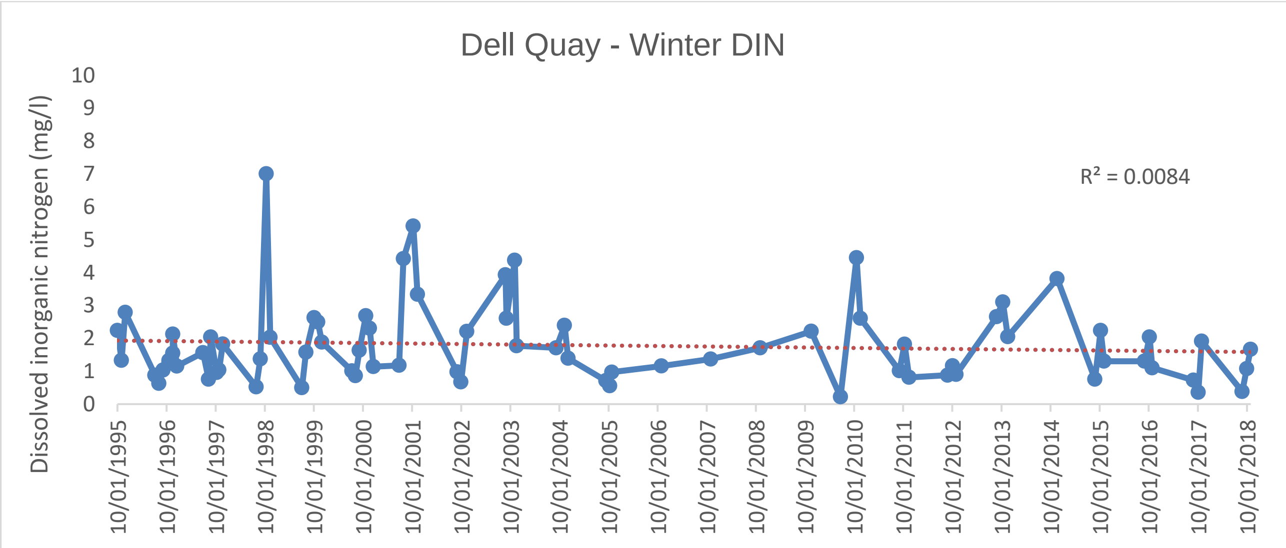


9.3 a Seasonal and long-term variation in at Chichester Harbour site with high-orthophosphate - Dell Quay (note different scales)

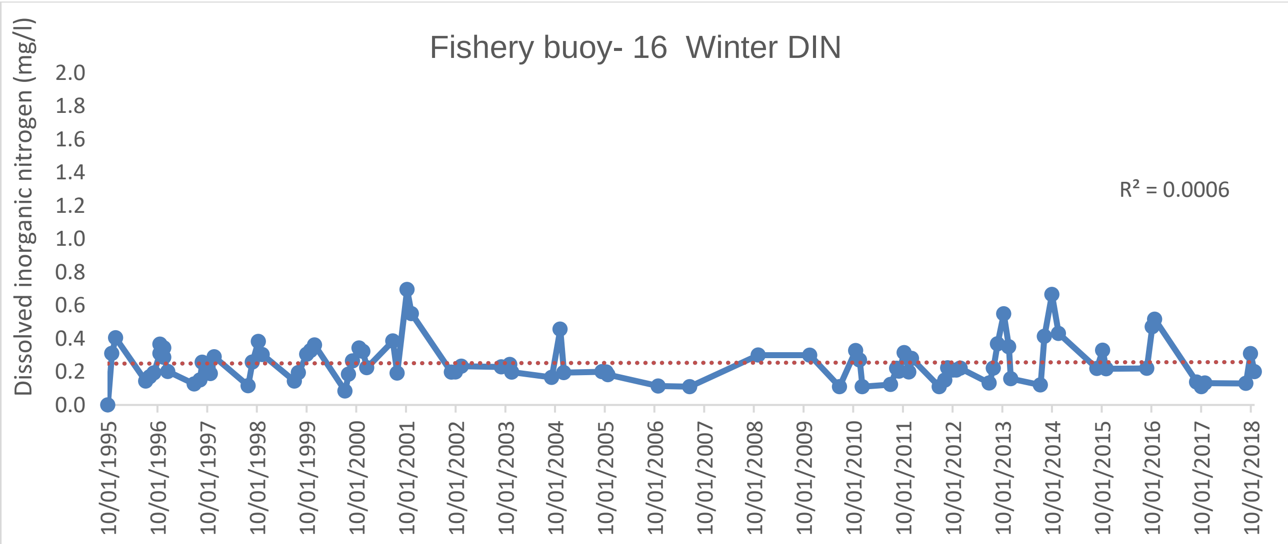


9.3 b Seasonal and long-term variation in at Chichester Harbour site with low-orthophosphate - Fishery Buoy 16

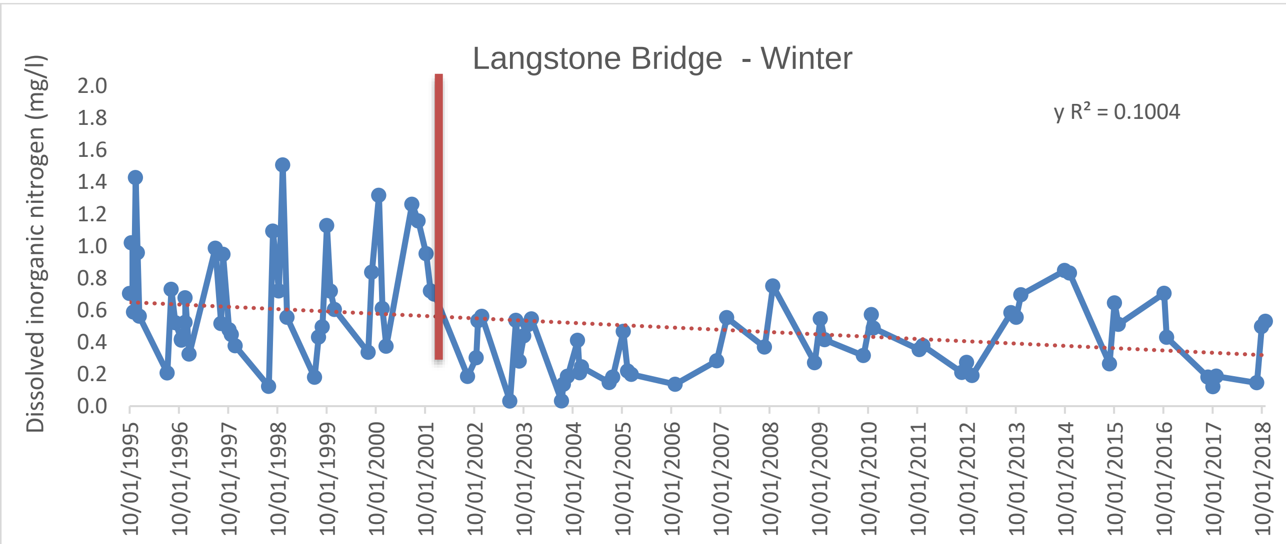
Figure 9.3 **(a and b)** Seasonal and long-term variation for sites in Chichester Harbour for orthophosphate (note different scales)



9.4 a Winter DIN trend lines for Dell Quay - high nitrogen monitoring point

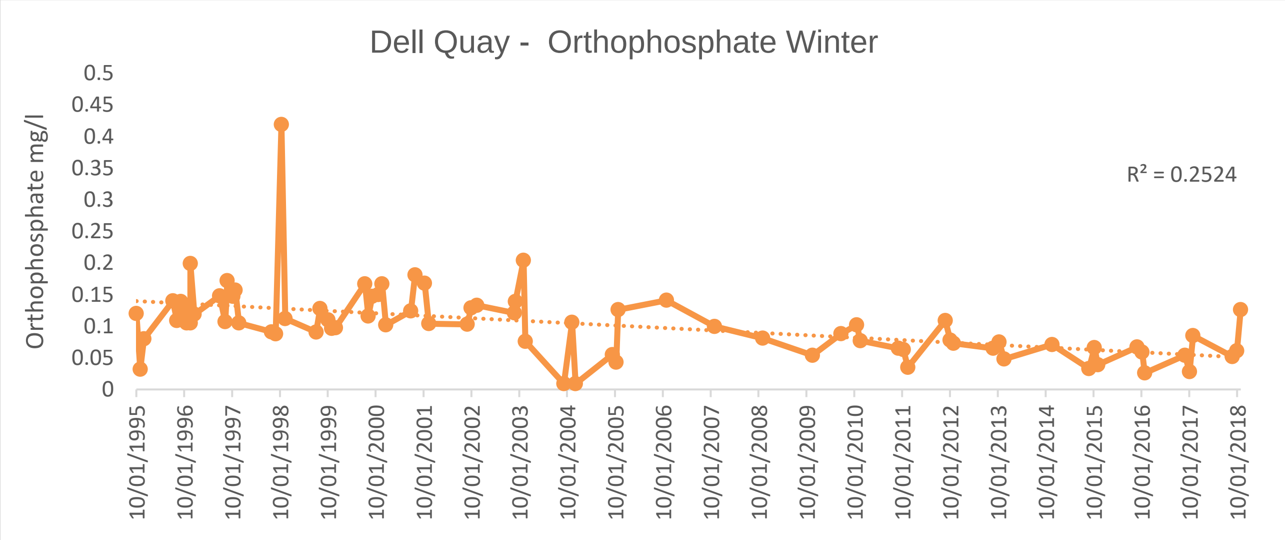


9.4 b Winter DIN trend lines for Fishery Buoy - low nitrogen monitoring point

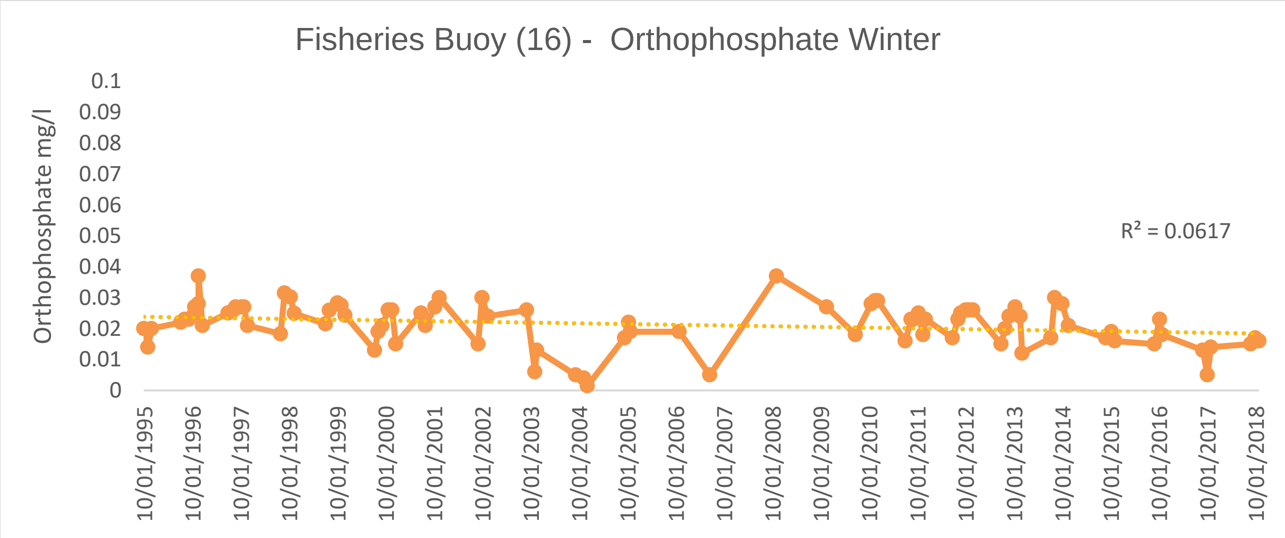


9.4 c Winter DIN trend lines for Langstone Bridge where declining trend

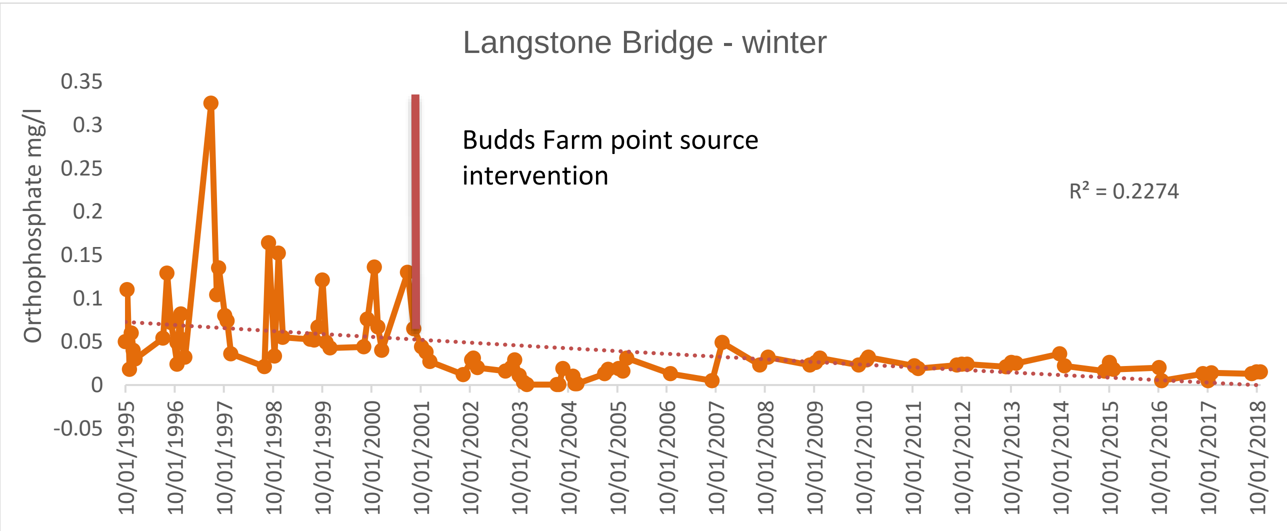
Figure 9.4 **(a, b and c)** Winter DIN trend lines for sites in Chichester Harbour (note different scales)



9.5 a Winter orthophosphate trend lines for Dell Quay - high orthophosphate monitoring point



9.5 b Winter orthophosphate trend lines for Fishery Buoy - low orthophosphate monitoring point



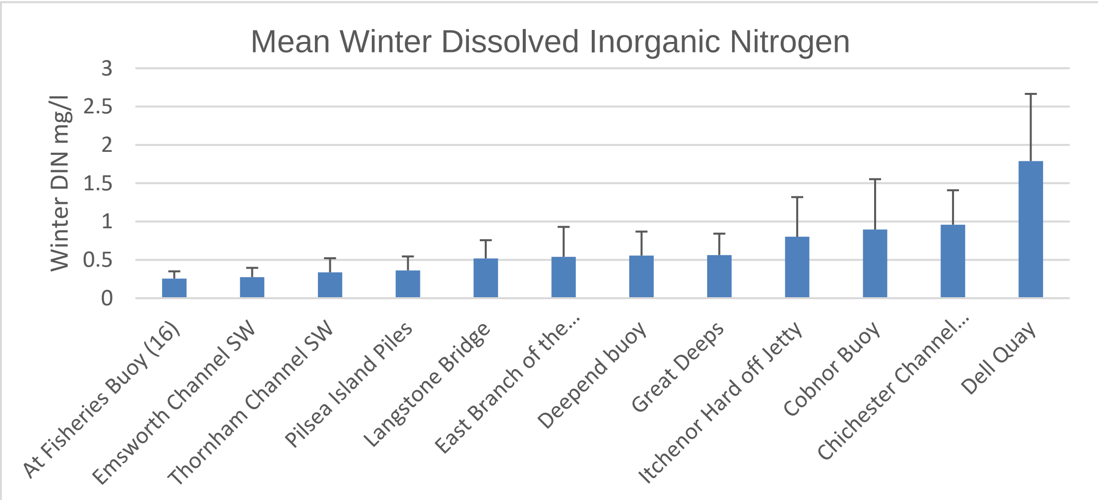
9.5 c Winter orthophosphate trend lines for Langstone Bridge showing declines

Figure 9.5 **(a, b and c)** Winter orthophosphate trend lines for sites in Chichester Harbour (note different scales)

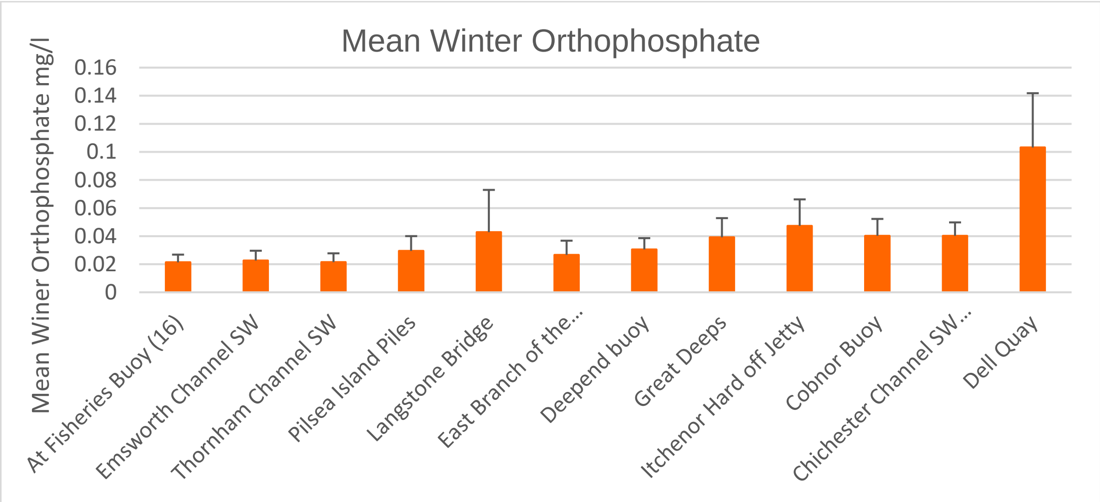
Table 9.1 Mean and standard deviation of winter DIN and orthophosphate values for each site including percentage above lowest mean in brackets

Sampling Location	Mean DIN mgl^{-1}	St Dev DIN mgl^{-1}	Mean Orthophosphate μgl^{-1}	St dev orthophosphate μgl^{-1}
At Fisheries Buoy (16)	0.256	0.094	21	6
Emsworth Channel SW	0.275 (7%)	0.121	23 (6%)	7
Thornham Channel SW	0.337 (32%)	0.184	21	6
Pilsea Island Piles	0.363 (42%)	0.182	29 (35%)	11
Langstone Bridge	0.519 (103%)	0.238	43 (104%)	30
East Branch of the Channel (20)	0.540 (111%)	0.390	27 (28%)	10
Deepend buoy	0.556 (119%)	0.313	30 (33.3%)	8
Great Deeps	0.562 (122%)	0.280	39 (38%)	13
Itchenor Hard off Jetty	0.802 (213%)	0.517	47 (124%)	19
Cobnor Buoy	0.895 (249%)	0.658	40 (90%)	12
Chichester Channel SW Birdham Beacon	0.959 (274%)	0.449	40 (90%)	9.6
Dell Quay	1.789 (598%)	0.876	103 (490%)	39
Fishbourne D/S of footbridge	4.835* (1787%)	1.084	66 (214%)	19
Point G at Fishbourne	7.777* (2936%)	0.600	35(67%)	9

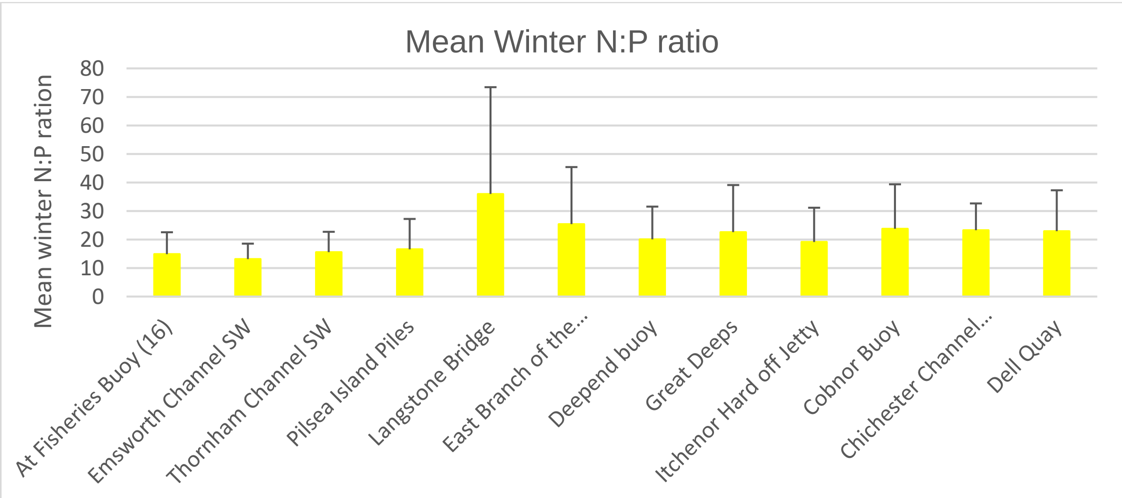
*both Fishbourne data sets only have limited data points so comparisons should be treated with caution. Value in Brackets is the percentage the value is higher than the lowest value (PL) where the mean DIN /orthophosphate value = N the mean DIN/orthophosphate value at lowest site = L and is calculated as PL= $\frac{(n-L)}{L}$ x 100. Red =above threshold for hypereutrophic conditions; values based on Smith and others (1999)



9.6 a Mean DIN across time series



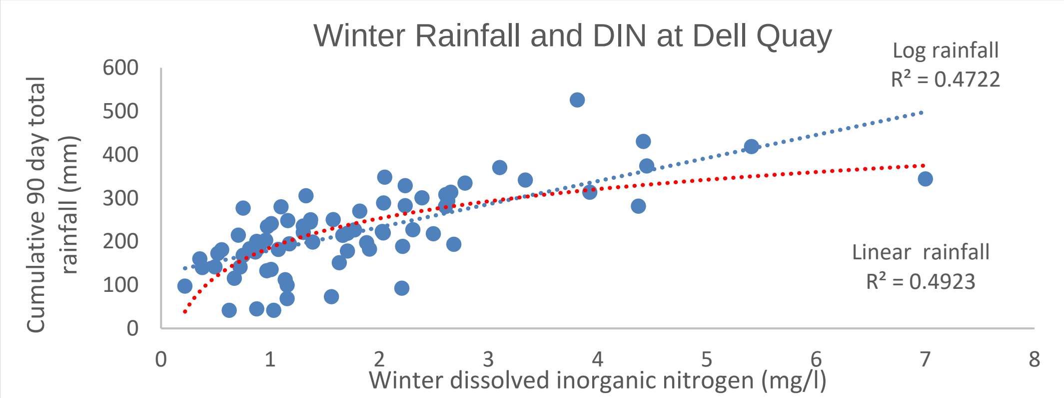
9.6 b Mean Orthophosphate across time series



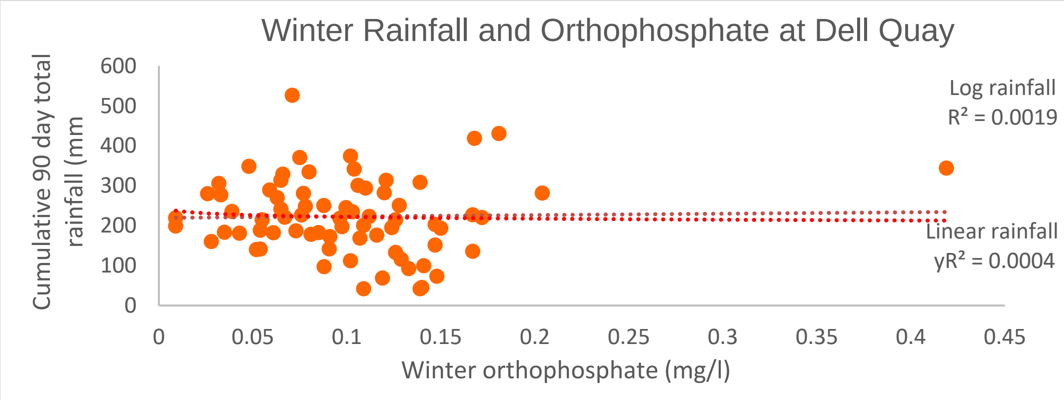
9.6 c Mean N:P ratio across time series

Figure 9.6 **(a, b and c)** Mean DIN, orthophosphate and N:P ratio across time series for sites in Chichester Harbour

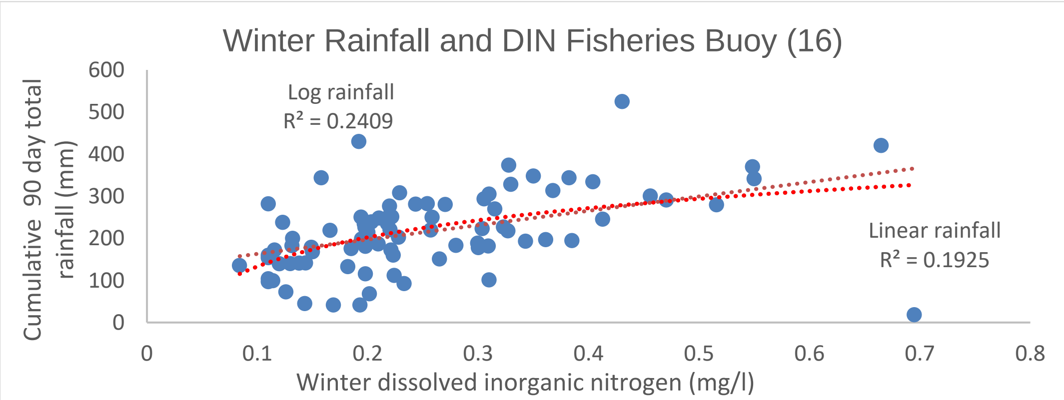
NB all saline monitoring points with full time series are shown. Point G at Fishbourne channel and downstream of Fishbourne footbridge are not due to limited data sets



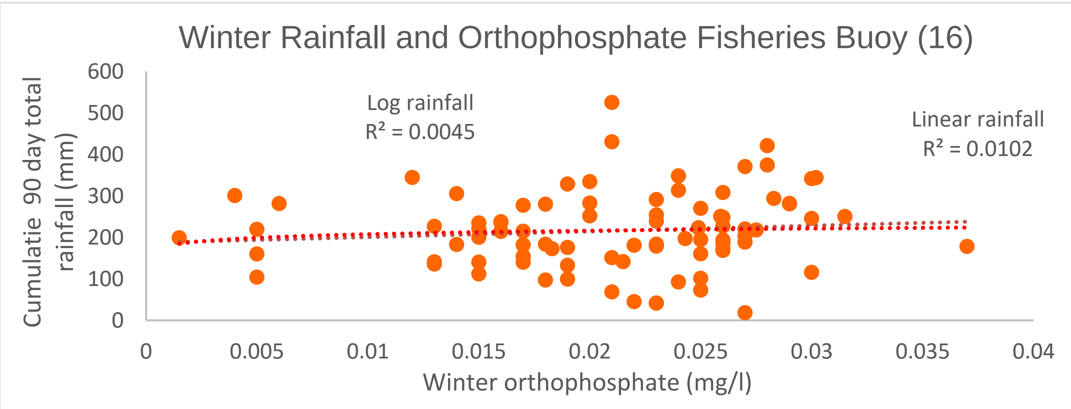
9.7 a Winter rainfall and DIN at Dell Quay



9.7 b Winter rainfall and orthophosphate at Dell Quay



9.7 c Winter rainfall and DIN at Fisheries Buoy (16)



9.7 d Winter rainfall and orthophosphate at Fisheries Buoy (16)

Figure 9.7 **(a, b, c and d)** Winter DIN and orthophosphate with rainfall for high and low nutrient monitoring points in Chichester Harbour

9.4 Discussion

1) Sources of nutrients and spatial scale

In Chichester Harbour the key anthropogenic nutrients entering the harbour are phosphorus and nitrogen. The concerns around excessive nutrient in the harbour have long been established with designation as a Sensitive Area in 1998 under the Urban Waste Water Treatment Directive (UWWTD). The harbour was designated as a polluted water (eutrophic) under the Nitrates Directive in 2008 and a Nitrate Vulnerable Zone was established in the catchment. Udal and others (2014) confirmed earlier Environment Agency work showing that the main limiting nutrient in the harbour is nitrogen. No attempt has been made to model the sources of pollution as the current assessment was focussing on the trends over time (and spatially) and any observable relationship with interest feature, distribution or trends rather than focussing on source apportionment.

The relative contribution of atmospheric deposition to nutrient cycling in an estuary, is in part related to its size. In smaller estuaries such as Chichester Harbour, the influence is therefore considered to be smaller (Scott and others, 1999). Atmospheric deposition could therefore be contributing the large offshore background, but the available evidence suggests air pollution is not a large overall contributory source to the high nitrogen. The Air Pollution Information System (APIS) gives the critical loads for saltmarsh and littoral sediments as 20-30 Kg N/ha/yr with the deposition values for the Solent Maritime SAC ranging from 9.4 to 19 with an average of 11.3 Kg N/ha/yr across the SAC mudflats and saltmarsh. APIS shows the trends of nitrogen deposition overall as stable with no rising or declining trends, though oxides of nitrogen appear to be rising.

Freshwater inputs are subject to a high degree of temporal variability due to changes in climatic conditions. Added to this is the fluctuation in groundwater inputs in the harbour catchment. The fluctuation in these inputs can affect both the nutrient balance (N:P ratio) and the total nutrients entering an estuary (summarised in Scott and others, 1999).

The relative contribution of diffuse and point source nutrients has been shown to affect the balance of the nutrient load that enters estuaries. In general systems with mainly diffuse inputs have high Total Nitrogen to Total Phosphorus ratios (TN:TP) while those with point sources have correspondingly lower ratios (Boynton and others, 1995). Though the values in this study are DIN and orthophosphate which adds layers of complexity and adds to the difficulty of interpreting the data the ratio should still provide some indications of source.

Udal and others (2014) assessed the source apportionment for Chichester Harbour for WFD. This assessment included two water bodies: Chichester Harbour East which equates to Fishbourne Channel and Chichester Harbour Outer, which included all the remaining harbour. The source apportionment for the two parts of the harbour varied but is summarised in table 9.2. This assessment suggests that source apportionment varies significantly with spatial scale. As described above the current study did not assess source apportionment, but in any future assessment of sources of nutrient into the harbour the spatial scale of the assessment is likely to be important.

Scott and others 1999 noted that diffuse nitrogen sources can double in some estuaries in a wet compared with a dry year and noted that point sources varied little between wet and dry years. In general, the strong response of the harbour nitrogen to rainfall would suggest that diffuse is the dominant source of nitrogen. However, the influence of high groundwater on the sewerage catchments of the harbour in wet years is a local circumstance that was not covered in the studies looked at by Scott and others but cannot be ruled out in the Chichester Harbour catchment. The deep groundwater that enters the harbour directly through deep groundwater connectivity is likely to be unchanged by rainfall suggesting this source is not a major contributor to the overall loading. The absence of correlation between rainfall and orthophosphate indicates this is largely a point source origin. It does not however indicate lack of storming because the three works which discharge directly into the harbour are not phosphate stripped and therefore the difference between storming and normal output is less.

Table 9.2 Source apportionment into Chichester Harbour after (Udal and others, 2014)

Sources	Chichester Harbour Outer	Chichester Harbour East
Coastal background Outer harbour	56% (N/A)	19% 3%
Direct River Lavant Direct River Lavant (rural diffuse) Direct River Lavant (urban diffuse) Lavant WwTW	2% N/A N/A N/A	N/A 21% 5% 12%
Direct Thornham WwTW	3%	N/A
Direct Chichester WwTW	1%	20%
Direct River Ems	5%	N/A
Direct Ham Brook	1%	N/A
Chichester Canal	N/A	2%
Direct Fishbourne Stream	N/A	8%
Offshore Wallington	9%	3%
Offshore Langstone Rivers	7%	2%
Offshore River Itchen	2%	5% (all<1% each)
Offshore River Test	2%	
Offshore Christchurch	2%	
Offshore/other rivers/STW (<1%)	7% (all <1% each)	

Modelled source apportionment by EA WFD assessment – showing spatial scale effects.

Modelled coastal background in this context will include sources from within the harbour not just offshore sources. The lowest mean winter DIN values are in the outer harbour, it could be argued this adds weight to the suggestion that a portion of the coastal background in the outer harbour includes sources from within the harbour itself.

2) Temporal and seasonal variation

There is a clear seasonal cycle of nitrogen and to a lesser extent phosphorus with it being used by the catchment, and in particular the algal and angiosperm growth in the harbour during summer months is observable in the nutrient data, with low summer values. This seasonal variation shown on figures 9.2 and 9.3 of the current study is the exact inverse of the seasonal variation of opportunistic macroalgae (which peaks in the summer months and troughs in January) observed in Langstone Harbour by Tubbs 1999 (page 106 figure 8.1). Opportunistic macroalgae data is only available for a single point during the year in Chichester Harbour and the nitrogen data is not collected monthly so it is not possible to assess the variation of opportunistic macroalgae seasonally with nutrients in this way. In addition, there is some anecdotal evidence that the warming winters are resulting in the opportunistic macroalgae persisting well into November in some years as evidenced by the cover photo of this report.

In some estuaries, the spring peaks in rainfall entering estuaries lead to spring peaks in biological response (usually phytoplankton). In other estuaries this response is delayed, thought to be due to recycled (or autochthonous) nitrogen rather than river inputs. These studies were all based on estuaries with much larger relative freshwater inputs compared to the estuary volume than is the case at Chichester Harbour. The tidal regime in an estuary also influences biological response. The strength of tidal driven water can influence the stability of the sediments and therefore turbidity as well as the ability of algal mats to form.

In Chichester Harbour nutrient enrichment results in an abundant growth of opportunistic macroalgae but no corresponding increase in phytoplankton (chlorophyll–a levels). A similar situation was reported on the Ythan estuary due to the rapid flushing time and/or strong tidal regime which was thought to leave insufficient time for the development of phytoplankton blooms to utilise the available nutrients (eg Balls and others, 1995). However, benthic algae have a competitive advantage in intertidal regions which are turbid, where they can photosynthesize and take up the nutrients during the low tide.

The temporal and spatial variation in both the abiotic nitrogen values and the biological response shown in Chichester Harbour has been reported in almost all estuarine studies. Periods of calm weather and/or bright conditions are often needed to prompt seasonal blooms (Scott and others, 1999). This appears to be the case for Chichester Harbour.

The fact that orthophosphate drops in the summer months and yet there is no phosphate stripping at the works and discharges are year-round, indicates two possible mechanisms which are likely acting together. The first is the storming in winter and some small diffuse input from the wider catchment are much reduced in summer months. The second is that the phosphorus is likely being used in the opportunistic macroalgal growth within the harbour in summer months.

3) Interest features, opportunistic macroalgae and nutrients

The best areas of remaining saltmarsh and the seagrass beds are all found in areas of lower nitrogen. Figure 9.8 shows the saltmarsh, eelgrass and mean winter DIN values and figure 9.9 the same features but with the mean winter orthophosphate values.

None of the winter DIN means in Chichester Harbour are below the DIN thresholds from literature shown in table 8.3 for eelgrass. However, the thresholds for eelgrass nitrogen in table 8.3 are given largely for the growing season in the northern hemisphere except for the Connell study. The Connell study equates to values of nitrogen added to the water column and includes late winter/early spring; however, this study is from Australia (for species not found in Chichester Harbour) and cannot therefore be used as a corollary for Chichester Harbour. It is not possible to know what the mean summer DIN is within the harbour as it drops to below the limits of detection for the methodology used to monitor DIN in most summers. In addition, sampling frequency is too low to identify what DIN values would be before uptake by the opportunistic macroalgal growth. All but one of the DIN thresholds in table 8.3 are below the limits of detection used to measure DIN in Chichester Harbour ($0.12mgl^{-1}$). Further work using more sensitive nitrogen methods would be extremely useful, enabling assessment of the values in the harbour during the growing season and comparison of these to the international figures for *Zostera marina* (in table 8.3). Figure 9.8 shows the largest eelgrass beds and those with multiple species are found in areas with the lowest winter DIN mean values (0.256 and $0.275mgl^{-1}$). Small beds near the following water quality monitoring points were confirmed in recent history (since 1970) and have subsequently been resurveyed by Hampshire and Isle of Wight Wildlife Trust (HIWWT) and appear to have been lost or much reduced including:

- East branch of the channel (mean winter DIN $0.54mgl^{-1}$)
- Pilsea Island Piles (mean winter DIN 0.36 mgl^{-1})
- Thornham Channel shellfish waters (mean winter DIN 0.34 mgl^{-1}).

From this data, it could be postulated that a mean winter DIN of less than $0.3mgl^{-1}$ may be suitable for long term eelgrass survival and stability in Chichester Harbour. However, setting objective standards based on two data points, even over such long data sets, is not recommended. High inter-annual variation of DIN due to its link to rainfall and the likelihood that DIN peaks will increase with higher intensity rainfall events caused by climate change (this would need to be considered in any standard setting). Very high DIN peaks especially in spring may put stress on the growing eelgrass due to the reduced phenolic compounds and metabolic imbalance (see section 8 for references) and this could still result in susceptibility to *Labyrinthula* and resultant bed loss even when mean DIN is low. The variability of the DIN at the two monitoring points near the largest eelgrass beds is comparatively low and is not characterised by significant spikes which may be another contributing factor to the survival of eelgrass beds in this location. However, the survival may be related to other factors such as substrate or protection of these areas for physical disturbance or most likely a combination of these factors. Further work on the condition of the eelgrass beds in Chichester Harbour is required to understand if the tissues and growth form are indicating healthy or stressed nutrient conditions. Extrapolating further from the data currently available is not possible but the current study can be used as the evidence base for pursuing further work to improve our understanding of the factors affecting eelgrass survival such as:

- Repeating the current analysis of long-term nutrient trends and eelgrass recovery in the wider Solent, where better historic extent data exists.
- Assessing the importance of other stressors and their management measures (such as restrictions on physical stressors such as moorings and bottom trawling).
- Assessing spring and summer nutrient values using more sensitive methods comparable to the studies in table 8.3 are also required.

Rogers (2019) in her MSc Thesis looked at three of the data points included in this study against very detailed analysis of four areas of saltmarsh accretion and erosion (East Head spit, East Hayling Island, Fowley Island and East Thorney Island) for 2002, 2005, 2008, 2013 and 2016. She states the highest values of nitrate are found in the west of the harbour - but this is because Rogers does not look at the areas of saltmarsh with higher nitrogen in the east of the harbour in either Bosham or Fishbourne Channels. Rogers also found a statistically significant increase in nitrate in the years she looked at (2002 to 2016) the three sites for which she had data. However, this is likely due to the limited data set and no statistical trend was found in the longer time series at the same locations in the current study looking at winter values. As discussed in section 5 of this report, Rogers (2019) confirmed the observation of the current study that nutrients are not acting alone but are likely to be acting synergistically with other anthropogenic stressors to contribute to the overall erosion of the saltmarsh habitat in Chichester Harbour.

As shown in table 7.3, opportunistic macroalgae growth is found in all parts of the harbour. Some opportunistic macroalgal growth is compatible with a healthy ecosystem however in 2011 opportunistic macroalgal growth exceeds standards for percentage cover in most parts of the harbour except the outer harbour mouth. The harbour arms have the highest opportunistic macroalgal growth and exceed percentage cover targets in at least two out of three of the survey years. The opportunistic macroalgal growth is found in areas of high nutrients but there is not a straightforward relationship between percentage cover and nitrogen. For example, the highest nitrogen is in Fishbourne Channel but the highest opportunistic macroalgal percentage coverage is in Bosham Channel. The literature reviewed in sections 5 and 8 for saltmarsh and eelgrass sets out the mechanisms by which high nitrogen can directly and indirectly affect these features (through smothering and reduced light availability). Smothering of pioneer marsh and intertidal habitat was observed on all saltmarsh survey transects in 2019 and table 7.3 shows failure of opportunistic macroalgae percentage coverage in all assessment areas with saltmarsh apart from the central sandy areas which has very little saltmarsh. Though eelgrass was not surveyed in 2019, the 2018 opportunistic macroalgal data shows failure of opportunistic macroalgal coverage targets in Harbour West where the majority of large eelgrass beds remain.

Smith and others (1999) quotes values of total nitrogen of greater than 0.40mgl^{-1}and total phosphorus of greater than 40 micrograms per litre as the hypereutrophic condition for marine and coastal waters in northern Europe. The mean winter DIN values only represent a proportion of the total nitrogen in the harbour, despite this many of the sampling locations have mean DIN values in excess of this example of hypereutrophic threshold for total nitrogen. Orthophosphate is only a proportion of total phosphorus but in just under half of the monitoring points in Chichester Harbour the orthophosphate winter mean value exceeds the value for hypereutrophic conditions. This potential indicator of hyper-eutrophication is supported by the Environment Agency (2016) summary of Nitrate Vulnerable Zone (NVZ) waters which also shows all sampling locations mean winter nutrient values in Chichester Harbour exceeding the standards used in the UWWTD for ‘hypernutrification’.

The harbour appears to be exhibiting hypereutrophic conditions in terms of nutrient values and this is resulting in excessive growth of opportunistic macroalgae though observations of the Environment Agency WFD monitoring at the whole water body scale suggest this may be lessening. The opportunistic macroalgae were causing direct visible smothering of saltmarsh in all transects surveyed in 2019. Impacts are apparent in two ways; growing algae appears to smother and outcompete the pioneer marsh and the rotting dead opportunistic macroalgae smothers the already narrow and squeezed upper/middle marsh. The root shoot imbalance and the other mechanisms described for nutrients impacting saltmarsh (described in section 5) may also be occurring in Chichester Harbour, however this mechanism has not yet been proven in a UK context and further study could be undertaken to confirm these mechanisms. The observed impact of nutrients on the saltmarsh in terms of smothering is particularly prevalent in the harbour arms where the marsh is narrow and in the east where nitrogen is highest. The rotting opportunistic macroalgae is seen in all parts of the harbour where saltmarsh was surveyed, even in areas of lower nitrogen where opportunistic macroalgae growth is visibly less. It is possible there is a disproportionate impact of the smothering by opportunistic macroalgae in the narrower fringing saltmarsh around the harbour arms than the larger more ‘stable’ marsh areas simply due to the relative area of the remaining marsh that is covered by the opportunistic macroalgae in this vulnerable fringing marsh which is often less than 50m in width.

The association of the largest areas of saltmarsh and eelgrass with lower nitrogen concentration does not prove a causal relationship. The compiled evidence and literature reviews in this report indicates the ongoing hypereutrophic conditions in the harbour, acting synergistically with other anthropogenic stressors, in particular coastal process disruption, cannot be ruled out as a contributory factor to the ongoing adverse condition in the harbour. The previous chapters have identified eelgrass, saltmarsh, littoral sediment and those wintering birds that are unable to switch to alternative food sources as particularly vulnerable to the synergistic impacts of water quality with other stressors.

4) Efficacy of conservation measures

Measures to improve the harbour’s hypereutrophic status have been underway for considerable time, a sample of which are described below:

- Diffuse agricultural pollution reduction measures
    - Diffuse water pollution plan (DWPP) implementation of some elements
    - Catchment Sensitive Farming measures eg Downs and Harbours Clean Water Partnership
    - Agri-environment schemes – higher level stewardship around the harbour
    - Environmentally Sensitive Areas measures (including agri-environment schemes)
    - Nitrate Vulnerable Zone measures (including agri-environment schemes).
- Point source pollution reduction measures
    - Action plan including infiltration reduction linked to completed enforcement action on Apuldram wastewater treatment works
    - Upgrades to Chichester WwTW see table 9.3.
- Urban diffuse/boating diffuse
    - Policies limiting non mains drainage into harbour
    - Approach of Harbour Conservancy to non mains drainage
    - Works by Harbour Conservancy to provide pumping facilities for recreational boaters.
- Atmospheric
    - National measures to reduce NOx deposition.
    - Chichester Air Quality Action plan

- Catchment Sensitive Farming advice on air quality.

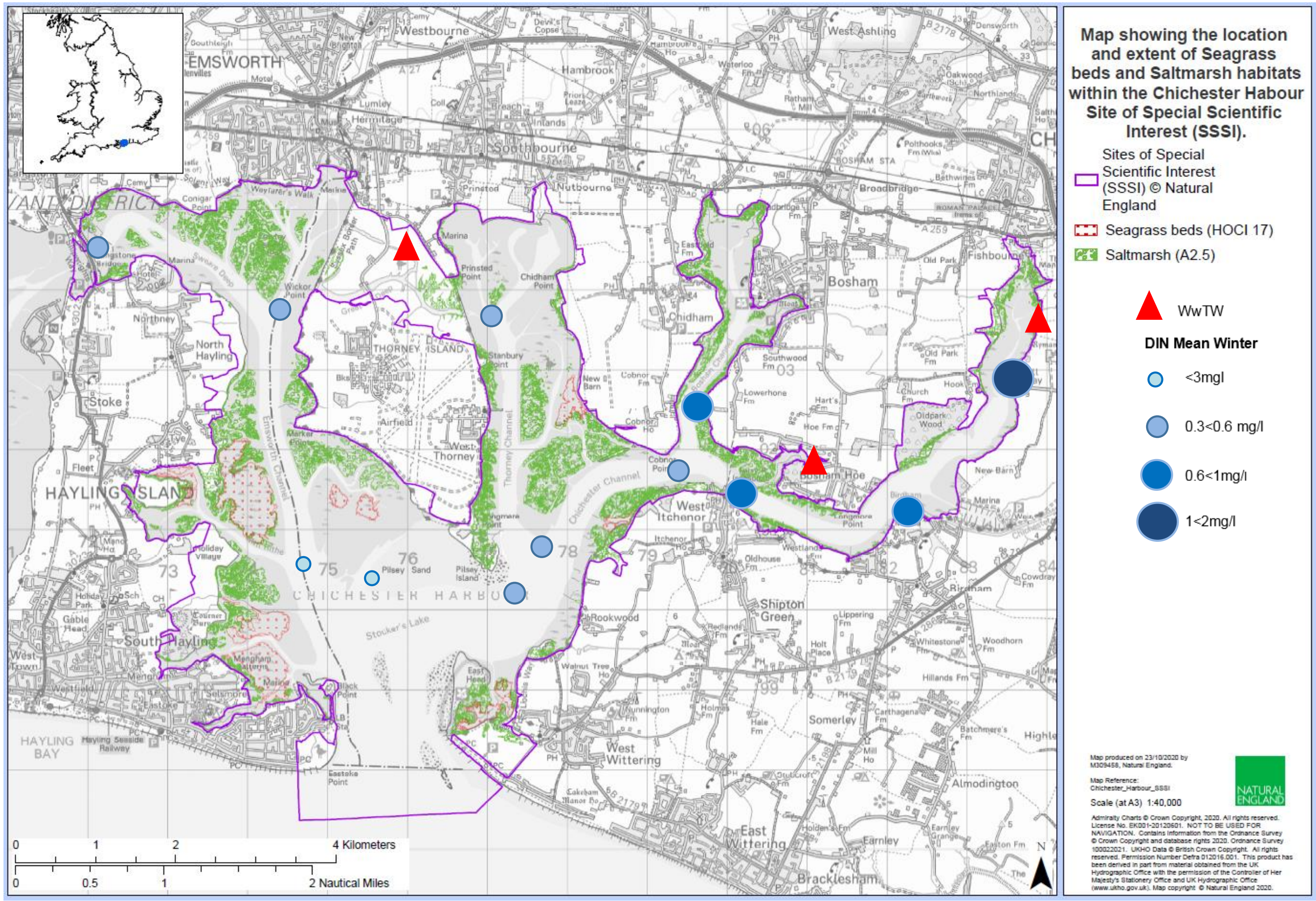


Figure 9.8 Intertidal features and mean winter DIN

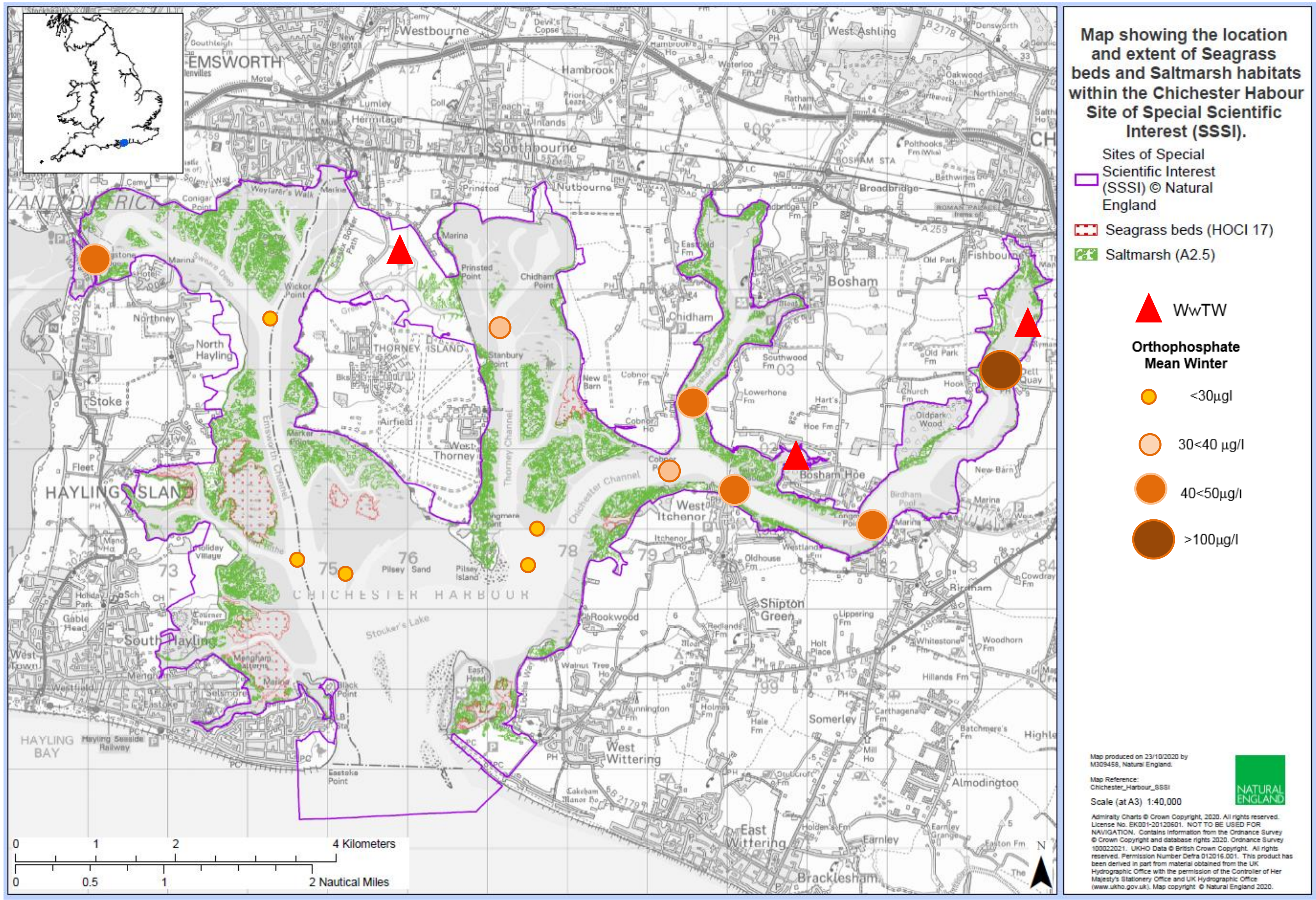


Figure 9.9 Intertidal features and mean winter orthophosphate

Table 9.3 Treatment works upgrades in Chichester Harbour

WwTW name	UWWTD requirement for Total N (mg/l)	By date (UWWTD)	Habitats ROC initial requirement for Total N (mg/l)	HD subsequent requirement (NEP AMP 5) growth related Total N (mg/l)	Implemented by date
Chichester	15	13/03/08 Delivered AMP4	10	9	31/03/12 (delivered 08)
Thornham	15		10	10	31/03/2015
Bosham	No qualified by SWS anticipated 15		10	10	31/03/2015
Budds Farm (into Langstone Harbour	Moved discharge location out of Langstone harbour to long sea outfall into main Solent				2001

There have been no upgrades for phosphorus. The tertiary treatment for nitrogen should remove approximately 38% of the phosphorus (Cole and Others, 1999), data from Environment Agency. RoC = Environment Agency Review of Consents. HD =Habitats Directive. NEP = National Environment Programme and AMP 5 = Asset Management Planning

There is also ongoing work to review the diffuse water pollution plan. This will review the key sources and evidence of the whole Solent diffuse water pollution plan. It will review the efficacy of measures, evidence gaps and suggest long term actions. The current report will feed into the baseline evidence.

The abiotic and biological data examined in this report suggests that the harbour remains hypereutrophic and this continues to impact some of the interest features some of which are continuing to decline. The nutrients in the harbour do not appear to be significantly changing though some localised improvements are occurring in particular at the Langstone Bridge location. The reduction in Langstone Bridge corresponds with the date at which the large discharge from Budds Farm was removed from the top of the adjacent Langstone Harbour. The data and literature suggest that synergistic impacts of coastal process interruption may result in the same level of nutrients producing greater biological impacts than if the nutrients were acting alone. Climate change also appears to be exacerbating these impacts as indicated by the correlations of high rainfall events, nutrient inputs and the increased incident of high rainfall events in the changing climate. Anecdotally the warm weather experienced in recent summers (2018-2019) and autumns is allowing opportunistic macroalgae to persist well into winter months[23].

The current and recent historic action on nutrients have not removed the hypereutrophic condition impacts on the designated sites features as indicated by the continued opportunistic macroalgae on the saltmarsh transects. Neither nitrogen nor phosphorus in the harbours are increasing, which could reasonably have been expected to occur due to increased economic growth and climate change. There is some localised evidence of improvements both in the percentage cover of opportunistic macroalgae and in the nitrogen and phosphorus data (eg Langstone Bridge). This indicates that the measures taken on point and diffuse sources are at least preventing nutrients from increasing and may be driving localised improvements. The measures have not removed the evidence of hyper-eutrification impacts on features and these features are continuing to decline so further measures are needed to reduce the nutrients to levels where they no longer act synergistically to adversely affect the condition of the interest features. The lack of significant downward trend in nitrogen at most monitoring points across the harbour, combined with ongoing declines in interest features suggests that measures to-date have been insufficient to promote recovery and therefore will be insufficient to

[23] Photographs and observation notes by various Natural England staff on personal and site visits outside of condition assessments taken at different locations in Chichester Harbour in autumn and winter).

achieve favourable condition. Further work on source apportionment is required at a spatial scale corresponding to assessment areas (identified in section 7) should be undertaken to better identify the sources and therefore solutions required to restore favourable condition.

9.5 Recommendations

- The data on water quality across the whole harbour does not show a consistent trend over time, it is not improving or declining but appears to vary with rainfall. However, there is some limited evidence of nitrogen and phosphorus improvements in the upper harbours in particular at Langstone Bridge monitoring point.
- The limited improvements to nutrients are not sufficient to support a recovering condition as there are still indicators of eutrophication evident on saltmarsh transects and in opportunistic macroalgae percentage coverage in harbour arms. Therefore, the condition trend (recovering/no change/declining) should be assessed based on the ecological features' assessment only. In any case other factors are contributing to adverse condition which also require additional measures.
- Monitoring of nutrients, nitrogen in particular in Chichester Harbour is inadequate to fully understand the impacts on features and requires additional study. In particular the metric for the current monitoring should be expanded to include total nitrogen metric and methods that are more sensitive for the eelgrass growing period.
- It would be helpful to identify a target against the total load reduction of nitrogen to Chichester Harbour required to support the achievement of favourable conservation status/favourable condition, further study is required for this.
- Nitrogen and phosphorus in the East of the harbour and harbour arms is generally too high and a reduction in nutrients is required.
- Further work on source apportionment is required at the assessment area spatial scale to confirm the measures that will best reduce nutrients in the harbour. This assessment should take account the impacts of sources in the context of synergistic impacts of nutrients with other stressors and climate change.
- Examples of measures that could be used to help reduce nutrients include:
    - Implementation of planning policies for new builds to prevent adding to the existing exceedances.
    - Mechanisms for encouraging retrofitting of SuDS to reduce urban diffuse nutrient inputs into the harbour.
    - Reviewing point source permits and addressing storming.
    - Implementation of any measures identified in the review of the diffuse water pollution plan such as the use of the new agri-environment measures in the wider catchment.
    - Identifying land which can be converted from high nutrient uses to low nutrient habitats.
    - Identify locations where land use change can incorporate more wetlands.
- Implement the recommendations of the other sections – in particular setting new standards for saltmarsh and eelgrass habitats, restoration of saltmarsh extent and climate change adaptation policies (see section 5).

10 Condition review – feature to unit and remedies

10.1 Feature to unit condition

In the previous chapters an assessment of the intertidal features and birds has been made at the feature level. However, as described in section 2, SSSI condition is currently reported at the unit level which may not correspond well to the features therefore in this section we amalgamate the features to provide a unit condition. A good example of this is saltmarsh and littoral sediment features. Though the distinction between littoral sediments and saltmarsh is made by the relevant common standards monitoring guidance at a unit level many of the units assigned to littoral sediment contain or contained at designation substantial areas of saltmarsh however the saltmarsh would rarely have made up the majority of any of the relevant littoral sediment units.

Many of the special transitions from saltmarsh to other habitat, for example to woodland, are noted on the SSSI citation as of particular interest and therefore key parts of the designation are included in terrestrial habitats. The terrestrial habitats themselves were not part of this condition review which only looked at intertidal habitats but did look at the transitions. This section describes how the unit reporting takes this into account. In addition, all units of the SSSI are used, at least to some extent, by the designated bird features. Natural England did not assess the breeding birds of the purely terrestrial habitats, but breeding terns were assessed. This section describes how we took account of the bird features of the relevant terrestrial and littoral sediment unit condition. Added to the different features in each unit is the confidence we have in the data used to make the feature condition assessment and the existing SAC condition reported for the Solent Maritime SAC marine features.

Table 10.1 Examples of the confidence levels of assessment methodologies and data sources

Data type	Confidence assigned	Examples
Survey by Natural England or other for condition assessment purposes using known and consistent methodology	Very High Confidence	Saltmarsh condition survey 2019
Remote sensing/georeferenced data using standard techniques known to work, consistent technique applied	High Confidence	Saltmarsh extent trend
Field data from standard national methodology and data sets routinely used in condition assessment	Very High Confidence	Wintering bird condition assessment/nesting bird data
Field data georeferenced but technique non-standard or survey effort dependant methodology, baseline at designation unclear or anecdotal	Low Confidence	Littoral sediment - eelgrass extent
Combined data (remote and field) varying types and methodology using data not designed for condition assessment with variable baseline	Low Confidence	Littoral sediment - type biotope extent data (at SSSI harbour only scale)
Combined data (remote and field) varying types and methodology using data not designed for condition assessment only anecdotal/ descriptive baseline	Low Confidence	Littoral sediment (at SSSI harbour only scale)
Remote sensing/ georeferenced data using standard techniques	High Confidence	Littoral sediment – opportunistic macroalgae assessment

1) Littoral sediment units

The focus of this condition assessment was the littoral or intertidal habitats and the features that use them. However, there are a number of units that are assigned as neutral grassland units that are described in previous condition assessments as saltmarsh. These units were treated as if they were littoral units for this condition assessment and are ascribed unfavourable declining condition for their saltmarsh attributes.

For these units, multiple features were assessed including birds, littoral sediment – eelgrass features, littoral sediment biotope extent and littoral sediment types as well as saltmarsh. If all the data was of high or very high confidence and multiple features were assessed with differing condition, then in line with guidance the unit was given the condition of the feature with the worst condition. In most littoral sediment units this meant the saltmarsh data dominated the unit condition as it has the most reliable data and was in the worst condition.

Most historic nesting tern sites are included in littoral sediment habitats so in SSSI units 15, 20 and 36 the unfavourable declining condition due to terns as well as saltmarsh was also reflected in these units.

Unit 42 is the only littoral sediment unit which has no saltmarsh at designation and in previous assessments. It does include a significant high tide roost and wintering bird area. It is subject to the coastal squeeze, process disruption and is habitat to many of the wintering birds that are in unfavourable condition. This unit is considered in unfavourable no change condition on average to represent the condition of the wintering birds assemblage and reflect the impacts on the high tide roost areas at the edge of the unit. This unit does support a high tide roost for sanderling which are in unfavourable declining condition, but officer judgement was that the sanderling declining condition was reflected in the intertidal habitats and the average wintering bird assemblage condition was more appropriate for this unit.

2) Terrestrial units

Terrestrial habitats such as woodland, neutral grassland (that is not saltmarsh) and supralittoral sediments such as sand dune and shingle were not assessed in this survey. However, some units that are labelled as the terrestrial habitats on Natural England's database do include areas that have features of relevance to this condition assessment.

- Terrestrial units – with important transitions to saltmarsh mentioned on citation
- Terrestrial/supralittoral units – where the transitions are being affected by coastal squeeze
- Terrestrial units – whose function is to support the wintering bird features assessed
- Terrestrial units – who support nesting tern habitat.

For terrestrial units thought to be affected by coastal squeeze and with important transitions, the units were left in their existing condition but at threat of coastal squeeze. Officer judgement was that the coastal squeeze and transition was dealt with by the adjacent littoral sediment unit condition.

Units 13 and 14 are considered terrestrial units but due to conservation efforts, including artificial tern islands, now have nesting terns. Though these features are using these units and it could be argued these units should be in unfavourable declining condition due to the tern features, these units are not the historic tern nesting sites, they are newly created artificial nesting sites. Officer judgement was these units would remain in their previous condition but with a threat of disturbance and predation for the terns. These units are also WeBS core count areas and high tide roosts but have good numbers of most species so have been left in favourable condition.

Many of the terrestrial units, especially the grassland, support wintering bird features and in some cases are primarily notified as supporting habitat for wintering birds, especially brent geese. These units were assessed against the relevant bird condition. Where these units are primarily used by species that are doing well (such as brent geese) they were left in their existing condition (eg units 13 and 14). However, for two units (19 and 29) the sites are significant for wintering bird species that are not in favourable condition and are high tide roosts for those species as well. These units were changed to unfavourable no change to reflect the overwintering bird features and local impacts such as coastal squeeze. Figure 10.1 shows the resultant condition of the Harbour.

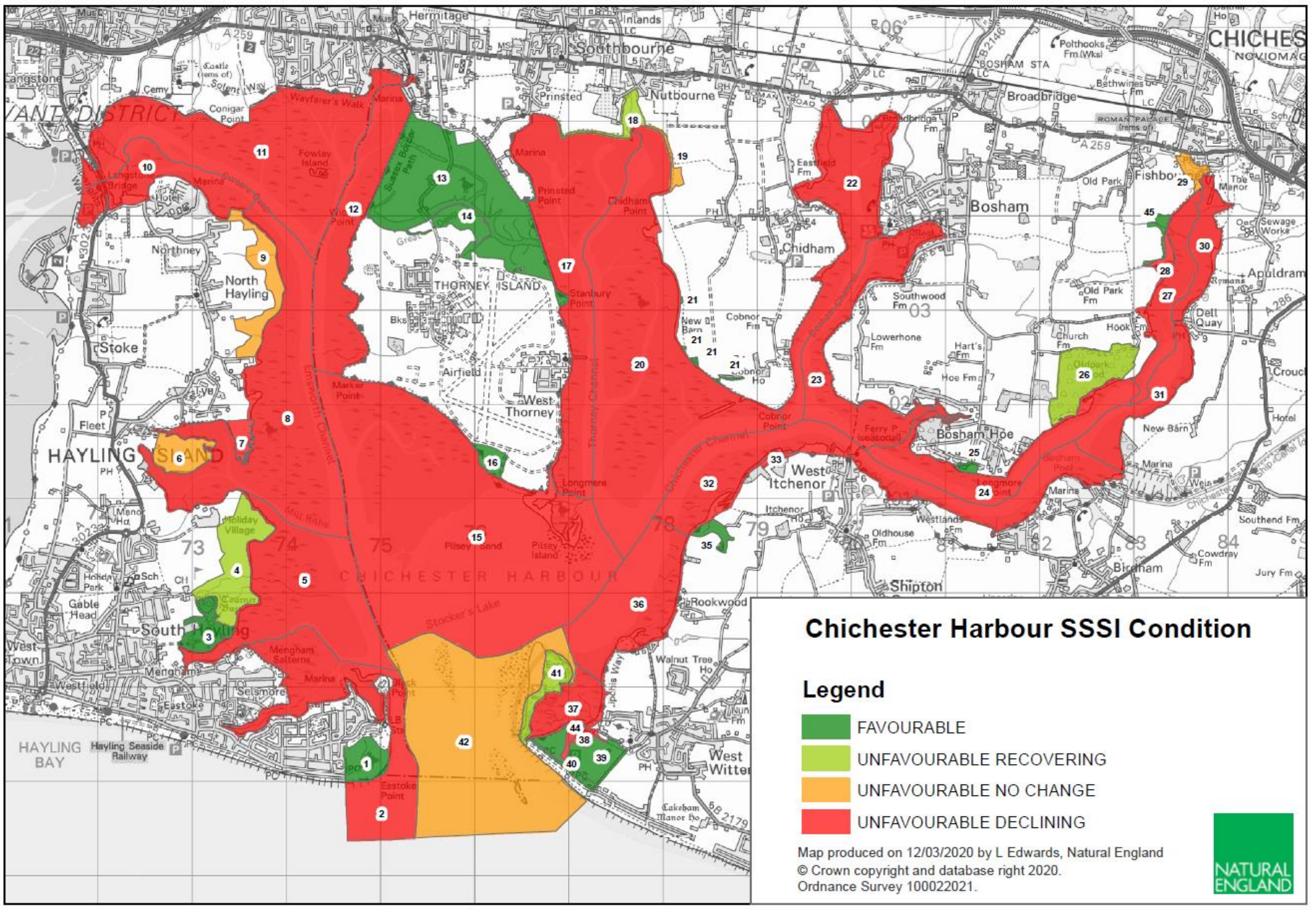


Figure 10.1 Current condition of Chichester Harbour reflecting the findings of this review

10.2 **Condition Summary**

Table 10.2 Summary of the condition of Chichester Harbour SSSI (of all the saltmarsh and bird designated features within the SSSI)

Designated sites condition following 2019/20 review	Area hectares (%)
Favourable	252.91 (6.77)
Unfavourable Recovering	115.83 (3.10)
Unfavourable No change	361.62 (9.69)
Unfavourable Declining	3003.17 (80.44)

10.3 **Summary and recommendation for actions and further work**

The assessment contained within the current report was sufficient to achieve the common standards monitoring guidance compliant assessment for saltmarsh, and nesting and wintering bird features. Therefore, it was sufficient to change the reported condition of the SSSI designated site. The other littoral and sublittoral features of the SSSI are covered by the Solent Maritime Condition Assessment and that should remain. The report has identified a number of significant gaps in feature monitoring, and failures of current targets and thresholds in the combined evidence base. The following are recommendations for the evidence base as well as conservation measures. The conservation measures are a compiled list of those identified by Natural England officers and should not be seen as definitive as Natural England expect to evolve these measures over time with partners and local stakeholders. The declines of features are so large the increased conservation measures listed below are urgently required. This report recommends that the increased conservation efforts should happen as soon as possible and not be delayed to await the updated evidence base.

1) Conservation recommendations

- Land should be identified and located for climate change adaptation, especially for saltmarsh restoration. This land should be clearly mapped and safeguarded in all relevant statutory plans.
- Work with partner organisations and existing project to investigate sources of sediment that are low in nutrients to stabilise marshes and ensure physical and management barriers do not hinder sediment placement.
- As a matter of urgency begin restoration of saltmarsh in Chichester Harbour to at least the figure at 1970 (SSSI designation) and ideally to the figure at 1949, in order to achieve favourable condition in extent terms for the SSSI and this will also restore conservation status for saltmarsh SAC feature (total value of 552.1 hectares and ideally 717 hectares of saltmarsh in Chichester Harbour). This requires at least an additional 257 hectares of realigned saltmarsh creation above 2016 area of saltmarsh in order to address historic losses of the SSSI saltmarsh feature. This would not address future losses due to climate change.
- If coastal processes and water quality issues can be addressed, the system may become more resilient and not need additional measures once historic losses of saltmarsh are addressed.
- Discuss and identify with partners potential options for funding for saltmarsh recreation for example through the Environment Agency Capital Improvement Programme and using any other appropriate sources of funding.
- Additional support should be provided to efforts such as those by Chichester Harbour Conservancy (CHC) and other appropriate managers to improve tern productivity, including supporting the provision of tern rafts and predator management if necessary.
- In partnership, investigate the feasibility of using shingle recharge to create suitable raised beaches at Stakes Island, with the aim of creating a network of sites that are less susceptible to tidal flooding.
- Where feasible, include creation of islands for breeding terns and high tide roosts when designing coastal habitat creation schemes.
- Implement measures to reduce nutrients, including potential measures set out in section 9.
- Explore the potential for additional eelgrass habitats identified by this report and any later studies to be protected from physical disturbance by, for example, inclusion within existing IFCA byelaws.
- Explore with stakeholders where the sensitivity of the harbour biotopes to physical disturbance indicates the need for a more nuanced approach to habitat and harbour management with regards to physical disturbance.

2) Evidence base recommendations

- Favourable condition tables for the SSSI are updated to incorporate the SACOs water quality targets including any revisions and change targets for eelgrass extent.
- Supplementary advice and site improvement plans should be updated to include recommendations from this report as relevant.
- Improved monitoring of total nitrogen, dissolved oxygen, littoral and sublittoral sediment features, saltmarsh and eelgrass extent and health are recommended subject to resources.

- Source apportionment and modelling at the assessment area spatial scale is required to identify the reduction of nitrogen. To undertake this modelling a target against which load reduction can be modelled should be agreed.
- Saltmarsh surveys should be undertaken every 3 to 5 years due to rate of decline.
- Further detailed analysis of WeBS low tide count data would be beneficial. Consider approaching universities as a Masters' project proposals for example.
- An assessment of the condition of Chichester Harbour for foraging terns has not been undertaken. Work with Chichester Harbour Conservancy and Sussex IFCA to understand the baseline condition of small fish populations in the harbour and whether this is influencing tern productivity.
- If possible, exploration of the health of associated ecosystem fauna focussing on fish and top predators that may have been lost should be undertaken.

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Only references where links to the paper or data are not included in the main text or footnotes above are provided below:

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Appendix 1 Policy and legislative context

A1.1 Status and function of Natural England

Natural England is a statutory body established under the Natural Environment and Rural Communities Act 2006 (NERC Act). Natural England is the statutory advisor to government on nature conservation in England and promotes the conservation of England's wildlife and natural features. It is financed by the Department for Environment, Food and Rural Affairs (Defra) but is a non-departmental public body, which forms its own views based on the best scientific evidence available.

Natural England works for people, places and nature, to enhance biodiversity, landscapes and wildlife in rural, urban, coastal and marine areas; promoting access, recreation and public well-being, and contributing to the way natural resources are managed so they can be enjoyed now and by future generations.

Section 2 of the NERC Act provides that Natural England's general statutory purpose is:

"… to ensure that the natural environment is conserved, enhanced and managed for the benefit of present and future generations, thereby contributing to sustainable development."

Section 2(2) states that Natural England's general purpose includes:

- promoting nature conservation and protecting biodiversity;
- conserving and enhancing the landscape;
- securing the provision and improvement of facilities for the study, understanding and enjoyment of the natural environment;
- promoting access to the countryside and open spaces and encouraging open-air recreation; and
- contributing, in other ways, to social and economic well-being through management of the natural environment.

Natural England is required to keep under review all matters relating to its general purpose,[24] and to provide public authorities with advice where they request this.[25] Natural England's remit extends to the territorial sea adjacent to England, up to the 12 nautical mile limit from the coastline.[26]

A1.2 Legislative framework

1) Duty to conserve biodiversity

Section 40 of the NERC Act imposes a "*duty to conserve biodiversity*" on public authorities, including the Secretary of State, local planning authorities, water companies and the Environment Agency. In pursuance of this, section 40(1) states:

[24] NERC Act, s.3(1).
[25] NERC Act, s.4(1).
[26] NERC Act, s.1(3).

"Every public authority must, in exercising its functions, have regard, so far as is consistent with the proper exercise of those functions, to the purpose of conserving biodiversity."

For the purposes of the NERC Act, conservation includes restoring or enhancing a habitat or population of organisms[27]. The public authorities must in particular have regard to the Convention on Biological Diversity when performing its duty.[28]

Section 41 of the NERC Act requires the Secretary of State to publish a list of the living organisms and types of habitat which in the Secretary of State's opinion are of principal importance for the purpose of conserving biodiversity in England. Section 41(3) states:

"*the Secretary of State must –*

(a) take such steps as appear to the Secretary of State to be reasonably practicable to further the conservation of the living organisms and types of habitat included in any list published under this section, or

(b) promote the taking by others of such steps."

2) International sites

The local planning authority, the Environment Agency and water companies are each a 'competent authority' for the purposes of the Conservation of Habitats and Species Regulations 2017 (as amended), with a duty to have regard to; the requirements of Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive), Directive 2009/147/EC of the European Parliament, and of the Council on the conservation of wild birds (Wild Birds Directive)[29]. So far as lies within their powers, a competent authority in exercising any function in or in relation to the United Kingdom must use all reasonable endeavours to avoid any pollution or deterioration of habitats of wild birds.

The local planning authority, the Environment Agency and water companies are also the 'appropriate authority' for the purposes of the Conservation of Habitats and Species Regulations 2017 (as amended). They must accordingly exercise their functions which are relevant to nature conservation so as to secure compliance with the requirements of the Conservation of Habitats and Species Regulations 2017 (as amended).

The Conservation of Habitats and Species Regulations 2017 (as amended) aims to contribute towards ensuring biodiversity is maintained and enhanced. Measures should be taken to maintain or restore, at favourable conservation status, natural habitats and species of wild fauna and flora covered by the Regulations and prevent deterioration or disturbance of any such habitats, species or wild birds.

3) Ramsar convention

The UK is party to the 1971 Convention on Wetlands of International Importance, done at Ramsar, Iran (the Ramsar Convention).

The government designates Ramsar sites in accordance with the criteria set out in the Convention, in recognition of the international importance of these sites as a wetland wildlife habitat.

[27] NERC Act, s.40(3).
[28] NERC Act, s.40(2).
[29] Habitats Regs, regs 7(1)(a), 3(1), and 9(3). Directive 2009/147/E replaced Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds. And this has subsequently been replaced by Conservation of Habitat and Species Regulations 2017 (as amended) and is adopted into UK law.

In accordance with *Government Circular: Biodiversity and Geological Conservation Statutory Obligations and their Impact within the Planning System* (ODPM 06/2005), and the *National Planning Policy Framework* (2012 and updated 2019), Ramsar sites are subject to the same procedure and protections as those covered in the preceding section as a matter of UK government policy, in order to assist the government in fully meeting its obligations under the Ramsar Convention.

4) Sites of Special Scientific Interest (SSSIs)

SSSIs are designated as such by Natural England under section 28 of the Wildlife and Countryside Act (WCA) 1981 (as amended), where we are of the opinion that land is of special interest by reason of any of its flora, fauna, geological or physiographical features.

Section 28G of the WCA 1981 (as amended) places legal obligations on public authorities in relation to SSSIs. These authorities are known as 'section 28G authorities'. An authority to whom section 28G applies has a duty in exercising its functions so far as their exercise is likely to affect the flora, fauna, geological or physiographical features by reason of which a SSSI is of special interest to:

"take reasonable steps, consistent with the proper exercise of the authority's functions, to further the conservation and enhancement of the flora, fauna or geological or physiographical features by reason of which the site is of special scientific interest."

Appendix 2 Water Framework Directive - water body sizes

Table A2.1 Solent transitional water body size

WFD transitional water body name	Size of WFD water body in hectares (data from Catchment Data Explorer (CDE))
Southampton Water	3091.32 (Environment Agency do break this down into some of the estuaries but not on CDE)
Chichester Harbour	3012.662
Langstone Harbour	1890.754
Portsmouth Harbour	1642.455
Newtown Harbour	191.77
Medina	162.704
Eastern Yar	81.061
Western Yar	51.031
Wooton Creek	22.934

Appendix 3 Saltmarsh survey criteria

A3.1 Saltmarsh survey methodology

The survey methodology is a combination of CSM and WFD (Environment Agency) style transects. Surveyors also noted any obvious changes within the wider saltmarsh area (like a walkover site check) and made target notes where necessary.

Transects are used for assessing saltmarsh zonation ie one 2m x 2m quadrat in each main zone along the transect, and an adjoining second quadrat 5m distant.

A GPS and note is made where one community zone ends, and another begins; the aim being to detect long-term trends in communities and zonation that may be occurring on site.

The start and end point for these transects were mapped as they will form a baseline for future monitoring.

A time structured walk-over survey (following the CSM guidance) was undertaken. A structured walk is a W-shaped walk to assess vegetation structure, species composition and negative indicators, with up to 10 stops within each assessment unit representing the different saltmarsh zones present. Quadrats (2m x 2m) are undertaken to assess species composition and sward height. The exact locations of each quadrat were recorded in the field using GPS. Note any quadrats recorded for the purposes of undertaking the transect also counted towards the 10 stops within the unit.

Before the walk-over survey is started, the entry and exit points were clearly identified with the help of the aerial photographs, maps and the survey team lead.

1) Further notes on transects methodology

Species and their percentage abundance were recorded in 2m x 2m quadrats, at sites along a transect line. **Transect start and end points were recorded (GPS coordinates provided on the survey form)**.

To carry out a precise transect, GPS coordinates (either by phone or iPad compass) were used to plot a straight line between the start and the end waypoints on the transect. Any landward side markers were identified to help, and the surveys were conducted from the seaward to landward side.

Units were mostly composed of *Phragmites* stands with a fringe of other vegetation at the landward side. Where possible, a representative transect was undertaken in this habitat to show zonation. However, if access was difficult this community was just marked on the map.

If the transect identified in advance was impossible another new transect that reflected the full range of communities at the selected location was created. Transects must:

- be placed primarily to address health and safety issues such as avoiding large creeks and gullies
- cover the saltmarsh from the landward to seaward extent. During the field survey though, you can work in either direction: seaward-landward or landward-seaward, and
- be placed to cross over the areas of the marsh which encompass the most communities. In most cases this will be perpendicular to the coastline.

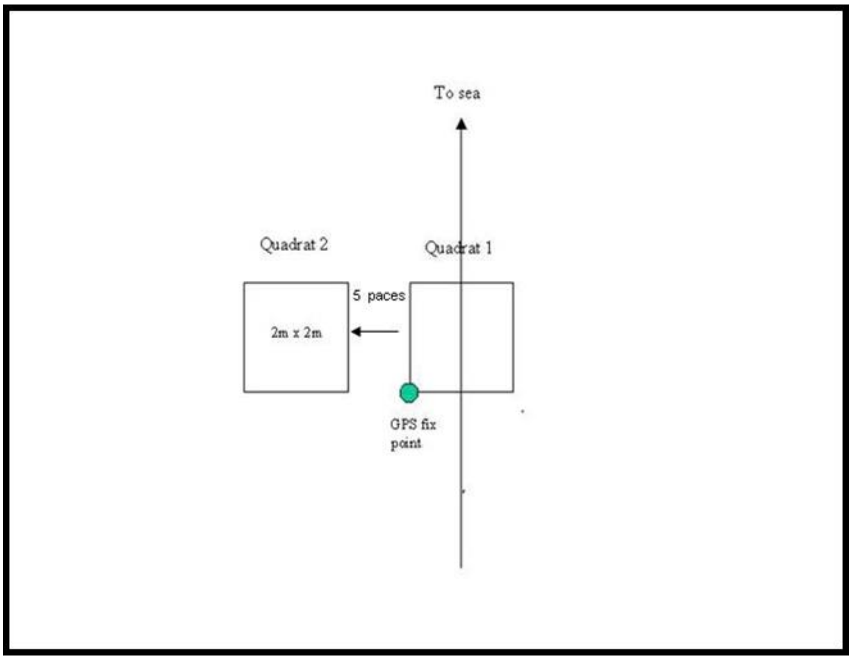


Figure A3.1 Saltmarsh transect example

For field data requirements, there are four categories of information that need to be recorded along the transect as detailed in table A3.1 below.

Table A3.1 The methodology for each of the categories for recording information during a transect

	Category of information	What is required
1	The most landward and seaward saltmarsh points	GPS position and target notes. Photograph and notes if erosion occurring
2	Major saltmarsh zone/community transition points	GPS position and any target notes, photo showing the transition
3	Quadrat sample sites in major saltmarsh zones	GPS position, quadrat data, target notes, photo facing the shoreline

- A quadrat is required within each major community type/transition zone on the transect and another quadrat 5m to the left (seaward side). Quadrats were placed well within the actual community zone, not at the edge of the transition.
- A 2m x 2m quadrat was marked with a bamboo cane, tape measure, or pegs/string and an average sward height (in cm) was recorded.
- Photos were taken of the quadrat, the quadrat reference and/or the transition reference. All associated quadrats were labelled.
- If the second quadrat was not seen to be representative (eg creek channels) to the first quadrat, then a target note was made and a quadrat moved a further 5m, eg a total of 10m to the left of quadrat #a and GPS left hand corner of quadrat #b.
- Quadrat photographs were taken looking towards the shoreline from the bottom left hand corner (where it is also possible to take the GPS grid reference from) for quadrat #a.

- The percentage cover of all species within the quadrat was estimated using DOMIN scale. A total of all the DAFOR values for the species can exceed 100% cover because of structural overlap of the plants.
- Bare ground and algae were included in this percentage cover.
- The vegetation community in which the quadrat is placed was recorded; pioneer, low saltmarsh, etc. To note, the terrestrial community should be GPS marked and quadrated where saltmarsh plants become less than 5% of a predominantly terrestrial plant community.
- A record was made of features within the wider area in target notes (details and GPS location where possible or their location indicated on the map with a sketch, if not visible on aerial photos supplied), including:
    - Structural features, eg small creeks or saltpans that are not visible on aerial photos supplied.
    - Presence/absence of opportunistic algal mats, giving an idea of the extent and location (marked on the base map).
    - Presence/absence of litter lines (high tide lines), GPS used to mark points on the litter line and marked on the base map.
    - Presence/absence of coastal defences, if not present the upper saltmarsh transitions were used, giving an idea of the extent and location (marked on the base map).
    - Evidence of management measures (eg grazing intensity/period, farming/agriculture).
    - Evidence of adverse activities (eg vehicle damage, trampling).
    - Accreting or erosion – attempted to give an indication of whether this was slight, moderate or rapid.
    - Details of negative indicators (eg artificial drainage channels adversely affecting hydrology, obvious signs of pollution, evidence of turf cutting, increases in bare substrate).
    - Invasive and non-native species.
    - Rare species seen.

2) Additional optional CSM walk-over survey

The transect and transect quadrats were always done first. If there was time, surveyors undertook up to 10 sample points spread through the saltmarsh zones on each unit. However, if most of the unit was very similar (eg species poor *Spartina* stands) fewer stops were made and a note was added that the vegetation community was homogeneous. Alternatively, if the unit was very large and diverse, more than 10 sample stops were undertaken to get a representative cover of the unit.

The 10 sample points included some or all of those on the WFD style transect(s) (described in section 2.1). The quadrat methodology was the same as above, but a second quadrat 5m away was not needed.

Photos were taken of anything of interest that needed reporting, and these were labelled eg U6TN1 (Unit 6, target note 1) or if it was a non-transect quadrat U6Q1 (Unit 6, quadrat 1).

Target notes were made at each quadrat sample point and a summary of the location was written.

3) Note regarding the edge of saltmarsh/mudflats

The edge of the pioneer zone/mudflats was only marked in situ where it was safe to do so. A note was made if the pioneer zone could not be reached. Mudflats were avoided largely for safety reasons.

Any erosion/cliffing at the saltmarsh/mudflat edge was noted by taking a photo and noting the location on a map (this was to aid work on geomorphological change in the estuary).

Notes were made of algal mats on the mudflat, and the grid reference recorded. This was to aid distinguishing between saltmarsh and algal mats when using aerial photography.

The grid reference of priority or County rare species was recorded. The survey spreadsheet contained the less common plants listed on the Sussex Rare Plant register as a prompt to record the location and the size of any plant population found.

4) Unit/Location site summary

A survey location summary and any other factors affecting condition eg management and note advice for improvement, if appropriate. Examples of things to note:

- Disturbance noted, or alignment of creeks
- Heavy poaching
- Distribution of creeks/pans
- Presence of algae
- Management - whether the saltmarsh is grazed or not
- Terracing/cliffing present
- Negative indicators
- Extent of *Spartina* across the unit
- Negative indicators (manmade features (eg sea walls), artificial drainage channels, pollution, turf cutting, vehicle tracks)
- Evidence of erosion (eg widening of creeks, vegetation dieback, stepping and overhanging/collapsing pan and creek edges, whether the pioneer zone edge is falling in blocks or a gradual erosion).

A3.2 Saltmarsh survey target notes

Areas highlighted in yellow are signs of coastal squeeze, compressed transitions or concerns with regards to coastal structures. Water quality impacts are noted in green. The targets notes are largely as written so include reference to all photographs taken on the transects day– only a selection of photographs is included in section A3.3 of this report. Photographs chosen were selected as they best illustrate the general habitat, features and issues observed and noted during the 2019 survey.

1) Unit 32 – West Itchenor, survey date: 10th September 2019

Transect 1
A number of quadrats were done in each defined zone of vegetation as it changed however, they did not relate to the standard upper/mid/lower zones - there was a short upper area on a naturally raising bank but this still had low depression with *Spartina* present with depression and standing water. There was some drift material at the very lower end where a creek started, and this was eroding into the bank. The creek in front of the terrestrial zone we walked around, and this was where quadrat 2 was started. The zones below this creek, where there was a mid-low marsh zone (photograph figure 29) with a change in composition of species, we identified four different zonations until a zone which was more obviously very low marsh (75% plus glasswort). Two quadrats were surveyed there. From that point (seaward) there was still 30 metres of *Spartina* dominated marsh, but it was too dangerous to walk further.

Photographs were taken in quadrat 2a (Q2a) and in other quadrats with sea purslane - *Catanella repans*, an epiphytic alga, and a bleached red seaweed called scorpion-tailed saltmarsh weed *Bostrychia scorpioides*.

Q2 clumps sea lavender within 30m of transects.

Target notes:

- Drainage ditch and culvert - to access the site we needed to work over a culvert (there are photos of this) and a manhole and ditch. This seemed to have some pollution in it but also contained a lot of golden samphire. Photographs of the ditch and culvert pollution are provided in figure 30 a and b in section A3.3.
- On the walk to the site we went passed a 'management realignment' tidal exchange site, where the tidal flap had been left open and created some nice saltmarsh the other side of the main path. We included some photos - the site was called Chalk Dock marsh.
- Rare plants [seen on main transect and walkover] included perennial glasswort, golden samphire and Laxflower sea lavender (photographs taken and labelled). Photographs of perennial glasswort and golden samphire are provided in figure 31 a and b in section A3.3.

2) Unit 8 - Hayling Island, survey date: 9th September 2019

Transect 1
The upper marsh was mainly sea couch at the earth embankment with some common couch higher up towards the top of the earth bund. There was just a 3.5m clump of sea club rush at the start of this transect (T1 Quadrat 1), just in front of the earth embankment which was at the top of a creek system with White Lodge in the background. The narrow sea club rush patch then dropped into tidal strandline and a 'plateau area' mosaic of mid-saltmarsh species - best represented by T1Q2. This 'plateau' was slightly higher, approximately 0.5m above the mainly *Spartina* and salt pan vegetation typified by T1Q3. The transect stopped near to a large creek that curled around this plateau. There was almost an island of *Spartina* in front of the transect end point, before the *Spartina* island reached the main Emsworth Channel. Photographs of the upper marsh dropping to the Spartina and 'salt pan' are provided in figure 32 a and b.

T1 Q1b The duplicate quadrat T1 Q1b landed within a small creek system and could not be moved further over as this would still have been in the creek system that was on lower ground. The location of the 2x2m quadrat was clear to see without directly accessing the creek floor, and the vegetation of the edges was identifiable so the vegetation cover for this quadrat was estimated from one corner of the quadrat.

Target Note 1 Perennial glassworts seen in unit 8 within the transect and elsewhere on the unit walkover. Golden samphire and lax flowered sea lavender were also seen.

Q2 transect notes Transect 1 Q2 within the 'plateau area'. There were occasional clumps of perennial glasswort on this 50cm raised plateau that had a mosaic of lower and mid saltmarsh species as represented by Q2 quadrat. Lax flowered sea lavender was seen nearby. Below and surrounding the plateau was a *Spartina* and salt pan system interwoven with occasional smaller creeks.

Q3 notes Cord grass, salt pans and smaller creeks coming off the main tidal channels. Opportunistic macroalgae was entangled amongst the cord grass. No adjoining quadrat Q3b was done on this WFD transect as Q3a was next to a large salt pan complex and it was too soft to safely access. Q3b would have been amongst brown fucoid seaweeds, bare mud and clumps of *Spartina*. There were several shore crabs within the salt pans.

Boat survey noted *Spartina* with some sea lavender and aster. Brown algae within *Spartina,* very little green algae present.

3) Unit 27 – Fishbourne, survey date: 10th September 2019

Unit summary
Survey was split between two survey teams. This formed the main transect with some walkover points. The unit showed zonation from terrestrial to upper with red fescue, spear-leaved orache and sea couch dominating. It then very quickly transitioned into a mix of low marsh with mid zone vegetation - sea purslane with sea aster, lax, normal sea lavender and *Suaeda maritima*. Small channels which appear naturally sinuous across the marsh perpendicular to the shore, the marsh had varying topography and communities formed mosaics with patches of the same species. Sea plantain and sea arrow grass were generally only seen in small patches in the middle part of the area surveyed. Some species including sea spurrey and *Glaux maritima* were uncommon. Close to the sea, *Spartina anglica* dominated with very few glassworts and covering of fibrous green algae. Small pools (2m across or so) were occasional across the marsh and all showed algal blooms. Dried alga was strewn across the *Spartina* community, indicating algae washed over the saltmarsh by the tide. Disturbance by people, although footpath was mainly screened by scrub and trees and did not appear heavily used, not used by vehicles. Boats were moored in the main channel. Large numbers of birds seen on the channel - including mute swan, lapwing, curlew, grey heron and little egret. It was noted from the main outfall pipe on the sea wall, the community became much less diverse on visual inspection. This section was not accessed on this survey but was visually seen using binoculars as *Spartina* dominated with sea aster and sea lavender. The majority indicating the upper, and mid communities were not present, with pioneer dominating.

U27Q1 Walkover quadrat. Sea couch dominant here - hairs and no hairs, mix with hybrid? More yellow than glaucous. Footpath adjacent to quadrat 1 but partially screened by trees.

U27Q2 Sea couch more glaucous than Q1 and had hairs. Adjacent to quadrat, communities were diverse with different topography and runnels. On the edge of quadrat there were patches of sea purslane however, the quadrat was dominated by sea couch and *Suaeda*. Footpath close by partially screened by trees.

U27TN1 Channel 1 was apparently a natural drainage channel. Sinuous and narrow, maximum 2 feet. Pond landward of the marsh and channel may connect this with the sea. Kingfisher heard near footpath in the pond (SU8338703604).

U27Q3 Within 30m of footpath. Annual sea blite - one plant facetiated (an anomalous growth defect).

U27T1Q1a and b Footpath bisected the transect and both overshadowed by oak trees. *Agrostis stolonifera* and red fescue.

U27TN2 Transition 2 of transect 1 - hard to distinguish as went from sea couch dominating with *Agrostis*, to just sea couch with spear-leaved atriplex and no *Agrostis stolonifera*. Sea purslane started from this point.

U27T1Q2a Sea purslane dominated with frequent to dominant sea couch. Sea aster frequent and close by sea rush which had formed in depressions. Clear but slightly sloping shelves where communities graded into each other. Overall, it was a mosaic of larger patches with small meandering channels seaward from path.

U27T12b Same as above. The 30m surrounding had more sea aster frequenting seaward of here and the occasional sea lavender, the majority of which seen being lax-flowered sea lavender. A photograph of this transect is provided in figure 34.

U27TN3 Small areas of lower marsh interspersed with mid. Sea plantain common with frequent sea aster and occasionally sea lavender. Here the ground was covered in red fescue with occasional sea couch.

U27TN4 (SU8340603666) End of mid marsh to low/pioneer where it was dominated by *Spartina anglica*. Area no longer dominated by sea purslane. In the transition area, sea arrow grass and sea plantain frequent, occasionally with sea aster the same. *Puccinelia maritima* now common over red fescue.

U27Q4 Additional quadrat in transition. Here sea arrow grass was more common and *Spatina* was encroaching.

U27TN5 (SU8342203667) Lax-flowered sea lavender seen. On the edge of marsh with dominant cord grass.

U27T1Q3a *Spartina* dominated with occasional sea aster and clumps of sea purslane. Small pools and creeks across this area. Much wetter underfoot. Areas of algae seen forming mats. See pics x2.

U27T1Q3b As above with rare sea spurrey. Bare ground had opportunistic macroalgae but only patchy and small areas. Formed more extensive mats in surrounding small pools. Dried algal mats seen strewn on *Spartina* from tide but not drift line per se. This was from general inundation across pioneer zone.

U27TN6 (SU8345703670) Edge of saltmarsh. Mud covered by green filamentous algae. Dried algae covered *Spartina* and glassworts. Indicated pollution. Glassworts very rare and *Spartina* only present right at the edge of saltmarsh where *Spartina* and bare mud intersected.

U27TN7 (SU8333303809) From path landward of saltmarsh the diversity of saltmarsh north of this point declined and became *Spartina* dominated, with much lower species diversity. Along path up to this point from the south were small sea spurrey plants, grass leaved orache and common mallow. The main channel which divides unit in half was covered in green algae, sea beet and red fescue.

U27TN8 (SU8336303908) Main outfall pipe.

4) Unit 22 - Colner Creek, survey date: 9th September 2019

Transect
Mid marsh and upper marsh were very compressed and mid marsh was only 1.8m wide. Upper marsh was 3.8m wide. Zone of disturbance between mid upper and upper was 2.6m.

Target Note Survey summary: we approached the unit as requested from the west, walking east towards the main creek. We looked for the most representative stretch of the saltmarsh and started the transect along the line from SU8026305029 to SU8025805034. It was apparent that the low marsh habitat was by far the most extensive. We walked out into it as far as was tested to be safe and measured the length, then approximated the full length of the low marsh to be 37m seawards. The subsequent intertidal mudflat to be another 12m. Mid marsh habitat was unfortunately squashed into a mere 1.8m, where saltmarsh grass and aster were dominant. Behind that was another squashed section of upper mid marsh which was only 2m in width and was dominated by sea purslane but with some sea spurrey and sea blite amongst the new species found. Between the mid and upper marsh there was an area of high disturbance 1.8m wide, with bare mud showing lots of footprints, indicating a desire line for walkers. A lot of the bare mud was covered with dead algal mats and the rest of the zone was trampled saltmarsh grass. The upper marsh was short and quickly graded into a scrubby layer of hawthorn. Sea couch grass was growing on the bund but was then abruptly stopped by the arable field. A photograph of the whole transect is provided in figure 35.

In general, across the marsh there were patches of thick algal growth with dead mats or green algae clinging to the vegetation. The amount varied from 5% to 25%, having a negative effect on the marsh, preventing succession and smothering vegetation. This taken together with the truncated nature of the saltmarsh zones led to the conclusion that it is in declining condition.

5) Unit 15 - Thorney Island, survey date: 9th September 2019

Transect
Overall, the site appeared to be in relatively good condition. Marsh appeared to be accreting, with accretion mounds forming at the seaward end of the marsh. However, there were some (minimal) signs of erosion around a few hummocks of *Spartina anglica* on the side of a creek near the shingle jetty (see Target Note 1). No evidence of grazing. Minimal anthropogenic impact (two tracks and some pieces of litter). Little evidence of water quality issues, some dark green weed (see Target Note 2). There were pools and a pan dotted through the low marsh area, good creek system. Vehicle tyre track stretching along the top of the upper marsh in front of the scrub and running under a linear stand of sea couch. Vegetation covered the tracks, but deep parallel ruts were evident when walking over this area. Photographs of the pools and creek system and a low mid-marsh quadrat are provided in figure 36.

The site was relatively species rich, but some key plants were not seen to be present, or only a few specimens found on the survey, eg Lesser sea-spurrey/Greater sea-spurrey *Spergularia spp*. Could not differentiate Common Sea-Lavender.

Target Notes:
Spartina was on the edge of low shingle ridge, which had influenced vegetation. Shingle ridge probably manmade - to reach old structure. Associated with this was a single track created by human footfall, forming in the lower part of the low marsh going into pioneer marsh, and creating a linear stretch of bare ground. This classes as low impact and of least concern, but something to keep an eye on. Only noticeable as there was little bare ground in this area.

Spartina on mud in pioneer marsh area, green algal mats and brown seaweed. Mats not likely to be an issue for birds.

Pioneer marsh to the left of T1Q1b showing *Salicornia* and tyre - some anthropogenic litter.

Pool in low-mid marsh at SU7689301096, creeks in background.

Brown moss, later identified as *Bostrychia scorpoides*, in quadrat throughout, under other plants.

Golden samphire, *Inula crithmoides* in T1Q3a at SU7684801115, with *Juncus gerardii* that had gone over.

6) Unit 23 – Bosham, survey site: 9th September 2019

General comment on unit
Survey covered south and south east part of the unit where there was a wider area of saltmarsh. From Bosham Hoe the saltmarsh was seen at close quarters from sea road but not surveyed. At this area the zone was dominated by pioneer *Spartina*, glasswort, sea aster and sea lavender. For the area surveyed the zones were very thin, in most places they formed a mosaic, with small patches of different communities. The saltmarsh appeared to be suffering from coastal squeeze but previous extents not available to us at this survey. *Spartina* was encroaching into upper communities, and at some points meeting reedbed areas due to very narrow width. Drift line high up the saltmarsh and nearly at the top of the terrestrial habitat, some pollution but mainly organic matter here. The main issue appeared to be water quality with green algae covering much in the unit, although not the pioneer areas of *Spartina* to the south, this does increase to the north west of the unit towards Bosham town. Golden samphire, marshmallow nice finds, sea plantain and sea arrow grass rare in this unit, with small patches of *Glaux maritima* and sea spurreys. To the south west the terrestrial habitat was gorse and thrift and stags horn plantain.

U23T1Q1a and b Squeezed area of terrestrial and upper saltmarsh so forming very indeterminate zones - more as a mosaic due to varying topography. The landward boundary was an eroded bank with oak trees and scrub which bordered mown grassland lawns, grounds of houses.

There is opportunity here for wildlife enhancing management landward in this private land, although outside of the SSSI boundary. Saltmarsh here basically all transitioning and influenced by shading from trees. Discrete area of saltmarsh pockets depending on topography with lower pockets *Suaeda maritima* dominated, others dominated by *Atriplex prostrata*, sea couch. Areas of *Phragmites* reedbed along this boundary edge where freshwater influenced. Quadrat taken 10-15m from a thin wire fence in disrepair, thick runs from land across part of the saltmarsh. Litter line formed along the zone between terrestrial/upper and mid/low marsh here. Small amounts of plastic, mainly organic matter.

U23T1Q2a Saltmarsh had formed small hummocks where eroding around more stable areas, bare soil evident from erosion on the edge and between these. Area squeezed, appeared to all be transition with terrestrial, and low marsh all mixed into a mosaic. Sea purslane dominant with saltmarsh grass, sea lavender and glasswort next most frequent. *Spartina anglica* was encroaching - appears the area of upper/mid/and low saltmarsh was being lost to *Spartina* dominated marsh.

U23T1Q2b Same as 2a. In areas between hummocks some patches of *Suaeda maritima*, and glasswort sp. dominated areas present.

U23T1Q3a and transition photos Transition area between *Spartina* and low/mid marsh saltmarsh grass. *Spartina* dominated by glassworts and *Suaeda* with occasional sea lavender and sea aster rare.

U23T1Q3b Dominant *Spartina* transition from saltmarsh grass. Sea lavender frequent. Again, this was a transition between pioneer and lower marsh, patchy mosaic.

U23TN1 Golden samphire (SU8054401888) and sea couch on edge of saltmarsh, seen scattered along landward edge of saltmarsh from this point north east of unit.

U23T1Q4a *Spartina* dominated mudflat with brown spiral seaweed covering bare ground. Extensive small channels blocking access on foot, very soft mud making access further seaward unsafe.

U23T1Q4b As above. Tiny amount of green filamentous algae seen but majority was brown seaweed, within *Spartina* the occasional sea aster closer to shore, with occasional glassworts but otherwise a monoculture.

U23Q1 Walkover survey, sea purslane dominated lower marsh with *Spartina*. Also, nearby grass-leaved orache, spear-leaved orache and *Phragmites*.

U23Q2 *Spartina* dominated community bordering sea purslane. Very little glasswort.

U23TN2 Pond (SU8056801918), freshwater influenced. Scirpus sea club rush present around edge, this was only seen very rarely elsewhere in unit, other location by outfall pipe. Sea aster around pond.

U23TN3 Reedbed transition (SU8058701898), end of reedbed from drainage pond to start of transition to sea purslane dominated marsh.

U23TN4 Transition from sea purslane to *Spartina* with frequent glassworts (SU8059001894). Area previously dominated by sea purslane with occasional *Suaeda maritima*, glassworts.

U23TN5 Sea rush (SU8064701943). Band of mud rush *Juncus gerardi*. Close to terrestrial, near houses. In other areas it formed small patches dominating with *Puccinellia maritima*.

U23TN6 Mud covered in algae in channel from point above. Main - large channel to east of unit 23 was covered in a bloom of green filamentous algae. This continued around the coast and worsened at Bosham Hoe. Bare areas of mud were present but suspected this indicating pollution/a water quality issue.

U23TN7 Golden samphire (SU8065201963). Golden samphire one plant in sea blight *Suaeda*.

U23TN8 Artificial drainage. Pipe and valve set to open. Erosion close by - dry areas (SU8065901961), erosion of saltmarsh here. Close to house.

TN9 metal pollution (SU8067201978) Dump of ferrous metal and copper nails and other pieces which was corroding. Bare patch surrounding them - appeared to be a work area for boat mending? Boats 50m or so nearby.

U23TN10 Water channel (SU8067901994), edge of drainage natural channel where it dropped off to *Spartina*. Sea purslane dominating with *Suaeda* and glasswort. The otherside of channel dwellings where coastal squeeze very apparent, boats moored on land there also.

U23Q3 Low marsh community dominated by sea purslane and sea lavender. Frequent saltmarsh grass and occasional glassworts and rare sea aster. No defined edge before becomes *Spartina*. Painted lady and red admiral seen.

TN11 Golden samphire and sea plantain (SU8062101937), rare in unit at top of marsh, very little sea plantain seen over this southern and eastern area of the unit.

U23Q4 *Juncus gerardi* was dying, uncertain if seasonal or sea aster inundation.

U23TN12 Landward extent of *Spartina* at this section (SU8032302016). *Spartina* landward extent. Eroded beach area with *Puccinelia* and glassworts. Sea purslane formed small clumps. Coastal squeeze. *Scirpus maritimus* by outfall pipe, as before this has been rare in unit, only seen near freshwater source - pond and outfall pipes.

U23Q5 (SU8024802047) Upper saltmarsh. Marshmallow sea couch. Micro cliff with erosion. Drift line with debris. Coastal squeeze.

U23TN13 Outfall pipe (SU8017302048). The saltmarsh was bare in this area with pebbles, small areas of *Suaeda* and sea spurrey (photographs in figure 38)

Terrestrial marsh with thrift, *Glaucoma maritima,* red fescue but occasional *Suaeda* and glassworts.

SU76985502120 - Terrestrial marsh with thrift, *Glaux maritima*, stag's horn plantain, red fescue but occasional *Suaeda* and glassworts. Too narrow to do 2x2 quadrat. Pictures taken of erosion of landward marsh - clear areas of erosion. Footpath went through this area of beach however erosion was throughout this area. Appears rabbit grazed.

A3.3 Saltmarsh condition - 2019 survey sample photographs

The following are a selection of photographs taken to illustrate some areas of quality, of concern, typical features or/and locally distinctive features.

Figure A3.2 West Itchen transect Quadrat showing mixed mid-low marsh

Figure A3.3 (a and b) Creek and signs of pollution caused by culvert and sea defences at landward side of West Itchenor transects

Figure A3.4 (a and b) Indicators of local distinctiveness - Golden samphire and flowering perennial glasswort - West Itchenor transects

Figure A3.5 (a and b) Hayling Island transects –Upper marsh– showing rapid drop to ‘salt pan’ amongst cordgrass shown in photo b

Figure A3.6 Fishbourne transects - showing pools with algal bloom and dried macroalgae across cordgrass dominated low transitioning to pioneer marsh

Figure A3.7 Fishbourne transects – Quadrat U27T1Q2b showing sea purslane dominated communities

Figure A3.8 Colner Creek - whole transect showing narrow upper marsh

Figure A3.9 Thorney Island transects - with good quality saltmarsh pools and creek system in background and quadrat showing creeks in more detail

Figure A3.10 Bosham transect - shown dead alga on the cordgrass and marsh and growing opportunistic macroalgae on mudflats

Figure A3.11 Bosham transect - drainage pipe and impacts

A3.4 Saltmarsh condition – saltmarsh quality criteria from CSMG and FCT

Table A3.2 gives a summary of the attributes assessed in saltmarsh transects and walkover for each transect and whether the relevant common standards monitoring targets for those attributes are passed or failed (refer to section 5.4, table 5.5).

Table A3.2 Littoral sediment – saltmarsh quality criteria from CSMG and FCT. Summary of transect data from 2019 surveys

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 West Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
Vegetation structure – zonation of vegetation	Maintain characteristic range of zones for Chichester Harbour: **Pioneer saltmarsh** SM4, SM5, SM6, SM7 SM8, SM9, SM11, SM12 **Low-mid marsh** SM13, SM14 **Mid-upper marsh** SM16, SM22, SM23 **Drift line** SM24	Mid and upper marsh very compressed. Mid marsh - saltmarsh grass and aster dominant. Upper mid marsh was dominated by sea purslane but with some sea spurrey and sea blite. Upper marsh quickly graded into a scrubby layer of hawthorn. Sea couch grass was growing on the bund but was then abruptly stopped by the arable field. The low marsh habitat was by far the most extensive at 37 m wide.	The zones are very thin, in most places they form a mosaic, with small patches of different communities. The saltmarsh appears to be suffering from coastal squeeze. *Spartina* was encroaching into upper communities, and at some points meeting reedbed areas due to very narrow width. Drift line high up the saltmarsh and nearly at the top of the terrestrial habitat.	Zonation from terrestrial to upper with red fescue, spear-leaved orache and sea couch dominating, then very quickly transitioned into a mix of low marsh with mid zone vegetation - sea purslane with sea aster and lax, normal sea lavender and *Suaeda maritima*. Marsh has varying topography and communities form mosaics with patches of the same species. Sea plantain and sea arrow grass were generally only seen in small patches in the middle part of the area surveyed, some species including sea spurrey and *Glaux maritima* were uncommon. Close to the sea *Spartina anglica* dominated with very few glassworts and covering of fibrous green algae.	A number of quadrants were done in each defined zone of vegetation as it changed however, they did not relate to the standard upper/mid/lower zones.	The upper marsh is mainly sea couch at the earth embankment with some common couch higher up towards the top of the earth bund. There is just a 3.5 m clump of sea club rush at the start of this transect. This then dropped into tidal strandline and a 'plateau area' mosaic of mid-saltmarsh species best represented by T1Q2. This 'plateau' was slightly higher, approx. 0.5m, above the mainly *Spartina* and salt pan vegetation typified by T1Q3. The transect stopped near to at a large creek that curled around this plateau. There was almost an island of *Spartina* in front of the transect end point, before the *Spartina* reached		No mid upper marsh recorded on this transect but was on the boat survey but upper marsh was recorded so good range of transitions though in an unusual distribution	Overall, the site appeared to be in relatively good condition compared to other sites though upper marsh compressed. Marsh appears to be accreting. All marsh transitions were observed.

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 West Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
						the main Emsworth Channel.			
Vegetation structure – sward height	<10cm in some areas in bird areas No indicators of excessive grazing	Average sward height > 10 cm in 7/10. Two areas of 5 cm sward where high level of disturbance from walkers/ vehicles.	Average sward height > 10 cm in 6/8 and two at 10 cm.	Average sward height > 10 cm in 7/7 transect quadrats.	Average sward height > 10 cm in 8/8 transect quadrats.	Average sward height > 10 cm in 4/6 and one at 10cm and the other quadrat mostly saltpan.	Not measured.	Average sward height > 10 cm in 3/5 of transects and for most of area.	Average sward height > 10 cm in 4/8 transect quadrats measured.
Vegetation composition characteristic species	**Pioneer** Maintain at least one characteristic species frequent and another occasional **Mid marsh** At least one of the following dominant *Puccinella maritima Atriplex portulacoides or Salicornia*	**Pioneer:** *Spartina* spp abundant average 65%. *Puccinellia maritima, Aster tripolium* and *Salicornia* spp all rare. **Low-mid marsh:** *Puccinella maritima, Spartina spp and Aster tripolium* frequent. **Upper marsh:** *Puccinellia maritima* frequent.	**Pioneer:** *Spartina* spp abundant average 61%. *Puccinellia maritima and Salicornia* spp *occasional; Aster tripolium* and Suaeda maritima rare. **Low-mid marsh:** *Atriplex portulacoides* abundant; *Puccinellia maritima* occasional. **Upper marsh:** *Atriplex prostrata* abundant; *Elytrigia atherica* occasional.	**Pioneer:** *Spartina anglica* dominant 90%. **Low-mid marsh:** *Atriplex portulacoides and Festuca rubra* frequent; *Aster tripolium* occasional. **Mid-upper marsh:** *Atriplex portulacoides* abundant *and Elytrigia atherica* occasional.	**Pioneer:** *Sarcocornia perennis* dominant 85%. **Low-mid marsh:** *Atriplex portulacoides abundant, Sarcocornia perennis* occasional. **Mid-upper marsh:** *Puccinellia maritima* Abundant, *Triglochin maritima* and *Atriplex portulacoides* occasional.	**Pioneer:** *Spartina* spp dominant. 95%. **Lower marsh:** *Puccinella maritima Frequent; Atriplex portulacoides and Salicornia spp* occasional. **Upper marsh:** Sea club-rush abundant but **not** listed spp.	**Pioneer:** *Spartina* spp dominant. 86%. *Salicornia spp* occasional.		**Pioneer:** *Spartina anglica* frequent. 33%. *Salicornia spp* rare. **Low-mid marsh:** *Atriplex portulacoides* frequent; *Puccinella maritima and Spartina anglica occasional; Suaeda maritima, Limonium vulgare, Salicornia* spp., *aster tripolium* and *spergularia* spp rare. **Mid-upper marsh:** *Juncus gerardii* abundant; *Atriplex portulacoides* frequent; *Elytrigia*

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 West Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
	species dominant, and at least two other species frequent **Mid-upper marsh** At least one listed species abundant and three frequent								*atherica* occasional; *Limonium vulgare, Inula crithmoides and Aster tripolium* rare. **Upper marsh:** *Elytrigia atherica* dominant 100%.
Indicators of local distinctiveness	Maintain SM22 (*units 15 Pilsey only*) and lax flowered sea lavender and perennial glasswort (required at specific locations only - *unit 15 Pilsey only not surveyed*)	None	Perennial glasswort.	Lax flowered sea lavender and perennial glasswort.	Lax flowered sea lavender and perennial glasswort.	Lax flowered sea lavender and perennial glasswort.		(on walkover not transects – Lax flowered sea lavender and perennial glasswort)	Golden samphire
Negative indicator species *Spartina anglica*	<10% expansion of *Spartina* into pioneer saltmarsh in last 10 years							Pioneer community eroding but *Spartina* islands for 800m recorded.	

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 West Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
	(Baseline CASI 2002 data)								
Physical structure – creeks and pans	Realignment of creeks absent or rare. *Compared to aerial photography – CCO*	None noted on this transect.	None noted on this transect.	None noted on this transect.	None noted on this transect.	None noted on this transect.	None noted on this transect.	None noted on this transect.	None noted on this transect.
Other negative indicators	No increase in trampling, no obvious signs of pollution, no turf cutting No poaching and artificial channels or drainage affecting the drainage absent (or rare)	Previously no evidence of trampling or disturbance recorded so an increase in the mid upper/upper marsh.						Minor signs of poaching noted but only one quadrat.	
	Other signs of coastal squeeze/physical issues noted on target notes	Compressed or transition on landward edge noted.	Compressed transition on landward edge noted.	Compressed transition on landward edge noted.	Compressed transition on landward edge noted.	Compressed transition on landward edge noted.		Compressed transition on landward edge noted.	Compressed transition on landward edge noted.

Attribute	Site specific target	Unit 22 Colner Creek	Unit 23 Bosham	Unit 27 North Fishbourne	Unit 32 West Itchenor	Unit 8 Hayling island transect	Unit 8 Hayling Island Boat	Unit 8 Hayling Island Walkover	Unit 15 Thorney Island
Summary saltmarsh condition for transect/unit		Unfavourable.	Unfavourable.	Unfavourable.	Unfavourable.	Unfavourable.	Unfavourable.	Unfavourable.	Unfavourable.

Key		
Meets target for attribute	Does not meet target for attribute	Attribute not assessed or not relevant in this transect

Appendix 4 Historical mapping of opportunistic macroalgae cover

The figures below demonstrate the percentage cover of opportunistic macroalgae in Chichester Harbour east and west in 2011 and 2014.

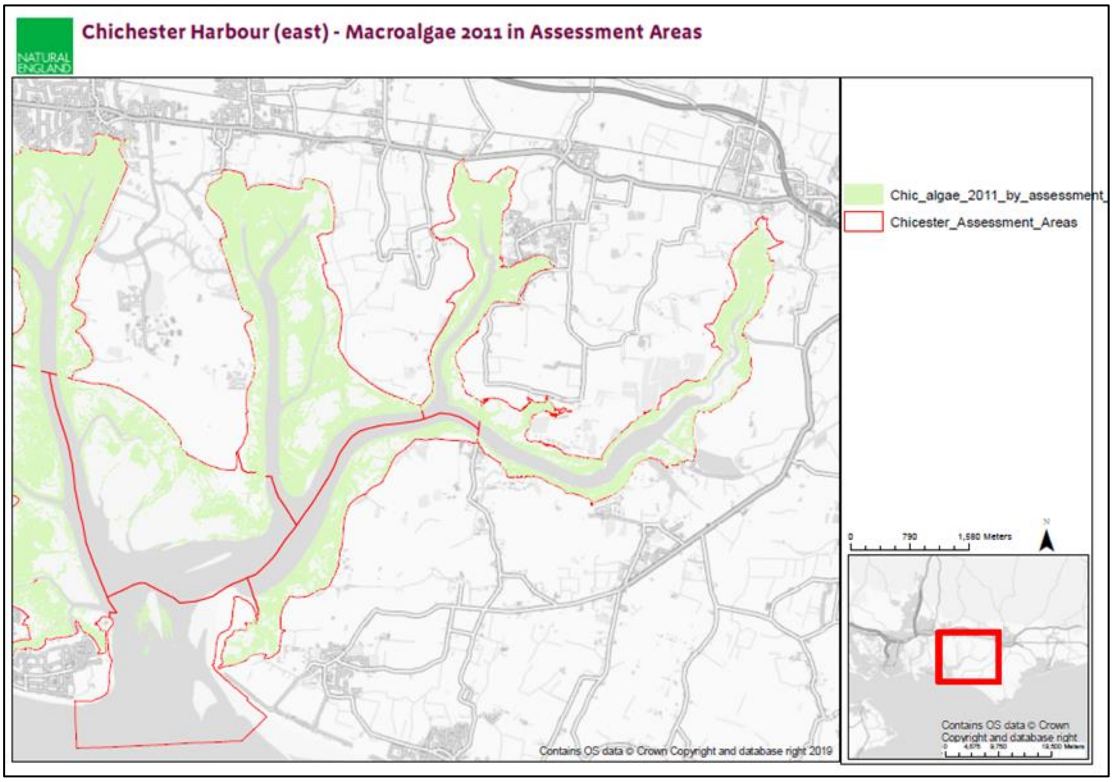


Figure A4.1 Percentage cover of opportunistic macroalgae in Chichester Harbour east in 2011

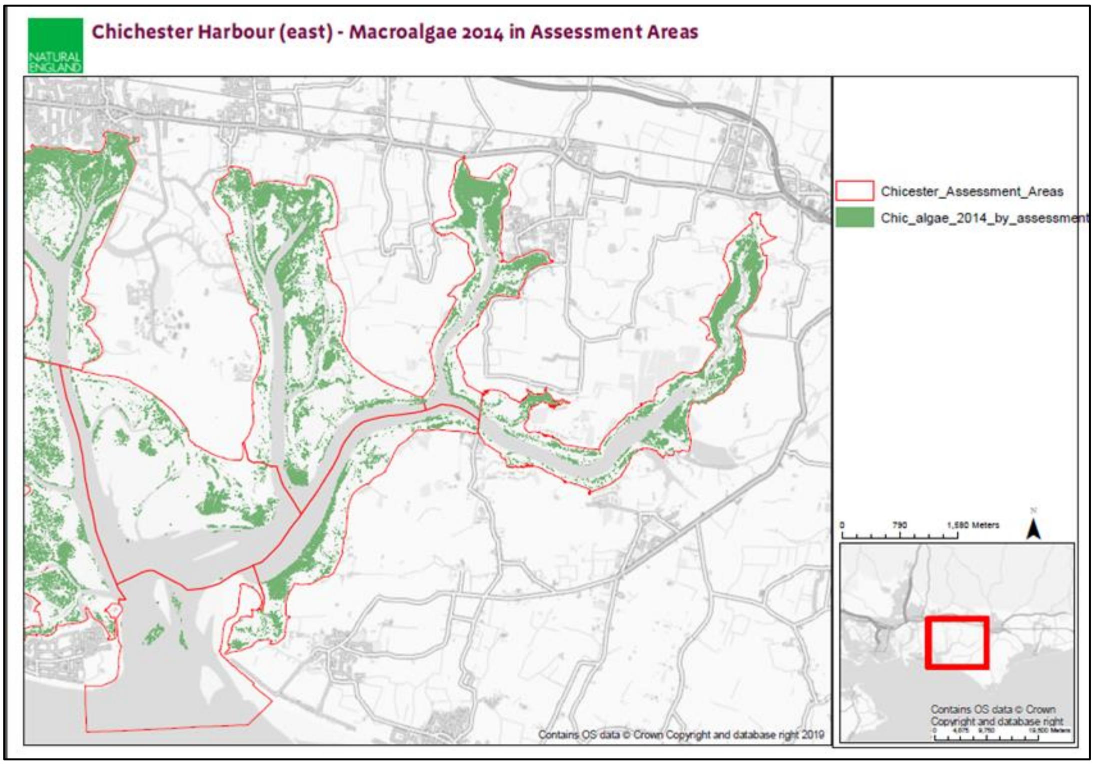


Figure A4.2 Percentage cover of opportunistic macroalgae in Chichester Harbour east in 2014

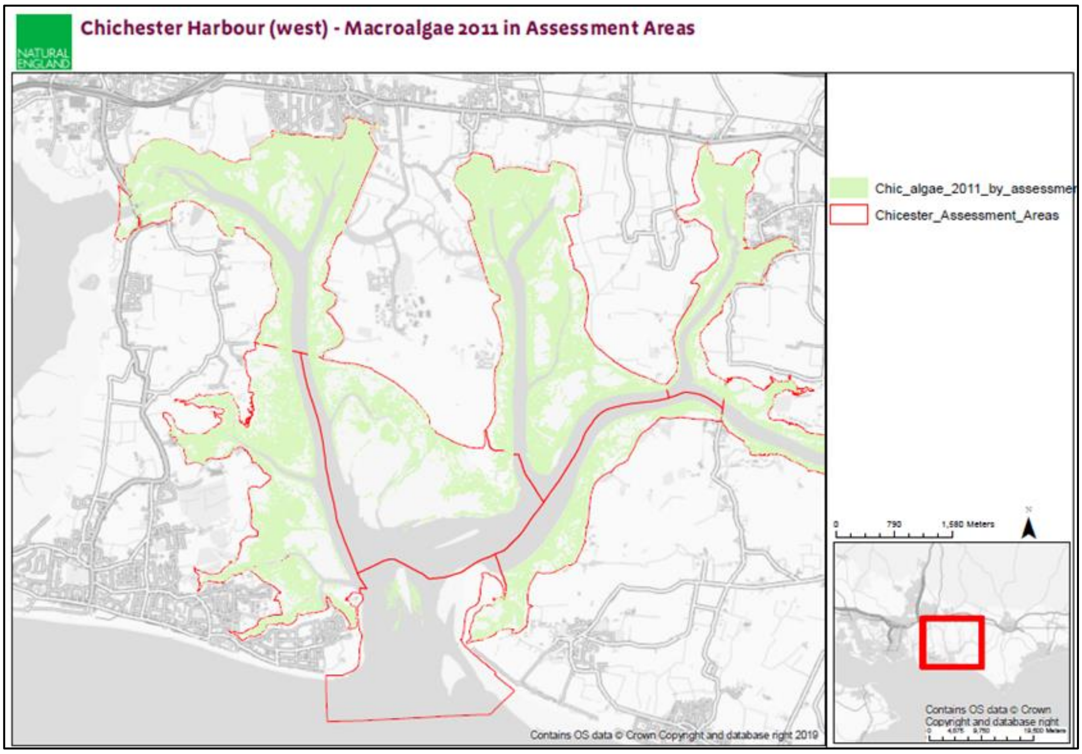


Figure A4.3 Percentage cover of opportunistic macroalgae in Chichester Harbour west in 2011

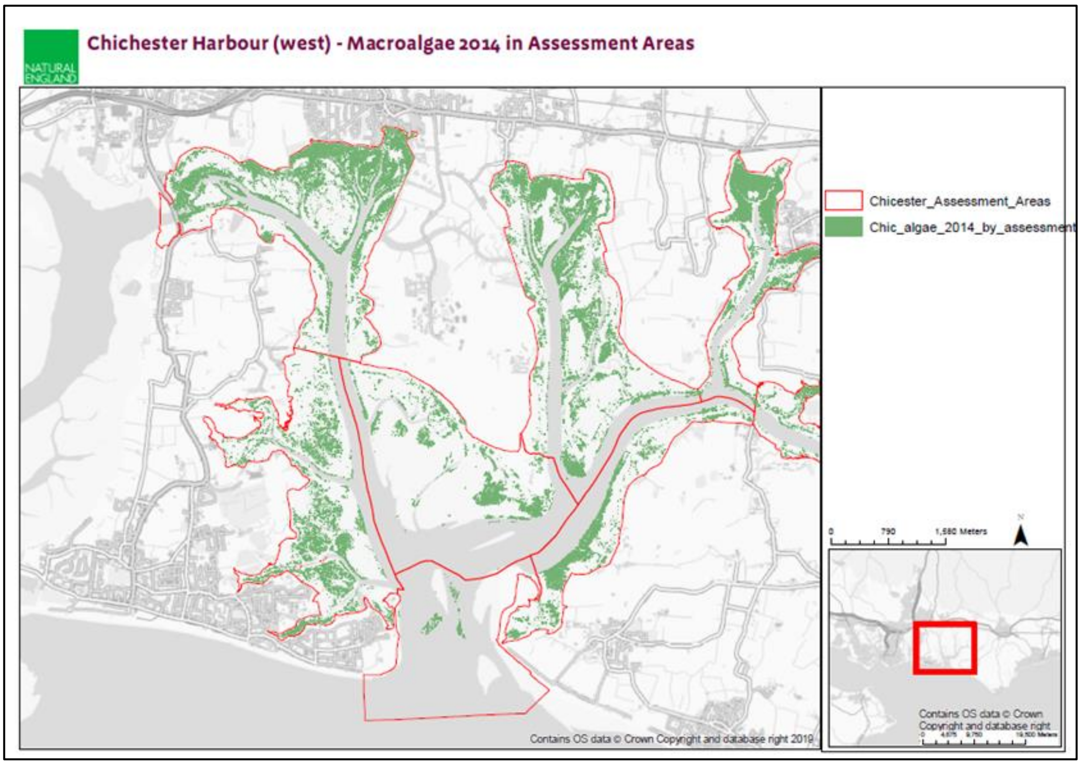


Figure A4.4 Percentage cover of opportunistic macroalgae in Chichester Harbour west in 2014

Appendix 5 Eelgrass surveys - summary of historic review

A5.1 Eelgrass surveys - summary of historic review

Table A5.1 Summary of historic seagrass extent (ha) in Chichester Harbour (1915 - 2010)

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
Pre 1995	**Circa 1915**	Extensive beds at Sweare Deep	The historian David Rudkin, writing in 1975, alluded to eelgrass decline. '*The ecological trend within Chichester Harbour has hardly been to the fisherman's favour. By an imported disease the eelgrass has been wiped out with the resultant erosion of the bed of the channel and colourisation of the water. I can avow that about 60 years ago, at Sweare Deep at low water the bottom could clearly be seen with eelgrass streaming in the tide. The bottom was firmer. The shrimpers used to walk along the Emsworth Channel pushing their nets. This could not be done now*.' (ie because of siltation of the bed).	Anecdotal and no extent	Rudkin, D.J., 1975. The Emsworth oyster fleet. Westbourne, privately published. As referenced in Tubbs, (1999) p120 and Dale & Cheswort (2013) p35
Pre 1995	**Pre 1920's ?**	Prolific meadows	Accounts from wildfowlers, fishermen and contemporary literature of prolific meadows in Chichester, Langstone and Portsmouth harbours earlier in the century.	Anecdotal and no extent	Tubbs, C. R., 1999. The Ecology, conservation and history of the Solent. Packhard Publishing Ltd, Chichester p 117, 118 119
	1920's 1930's	Decline due to wasting disease and or *Spartina anglica*	Anecdotal references of the former extent and decline of eelgrass in Chichester and Langstone Harbours. Consistent threads from the recollections were; Prolific *Zostera* beds disappeared in 1930's linked also to spread of *Spartina anglica*; The low water channel eelgrass 'forests' were important to local fisheries; The intertidal beds were the feeding ground of Brent geese and wigeon; With the demise of the beds there was extensive erosion of the mudflats,	Anecdotal and no extent (Except for Langstone Harbour where maps are provided)	Tubbs, C. R., 1999. The Ecology, conservation and history of the Solent. Packhard Publishing Ltd, Chichester p119

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
			lowering of the intertidal profile, increase siltation of channels and an increase in load of suspended sediment carried by harbour waters.		
Pre 1995	**1932**		First report of wasting disease in Britain to Ministry of Agriculture. Tubbs reports eelgrass had been declining widely for some years previously.	No extent	Tubbs, C. R., 1999. The Ecology, conservation and history of the Solent. Packhard Publishing Ltd, Chichester p118
Pre 1995	**1933**	Two small beds	In Chichester Harbour only two small beds were reported by Butcher (1934), one south of Thorney Island and one at West Wittering. Butcher undertook a rapid survey for Ministry of Fisheries of the south and east coasts of England and found widespread losses of eelgrass. In the Solent he describes only small isolated patches where once there were very large and abundant areas.	No extent but approximate location	Butcher, R.W. (1934) *Zostera*. Report on the present condition of eelgrass on the coasts of England. *J. Cons. Perm.int. Explor. Mer.* ,**9,** 49-65. As referenced in Tubbs (1999) p119 and in Dale & Chesworth (2013) Section One: Report. Hampshire and Isle of Wight Wildlife Trust. p35
Pre 1995	**1972**	0	In Chichester Harbour, Tittensor (1973) found no *Zostera* in 1972.	No details about survey locations	Tittensor, R.M. (1973) A Botanical Survey of the intertidal zone of Chichester Harbour. Sussex Ornithological Society. As referenced in Tubbs, 1999 p120
Pre 1995	**1974**	2 small beds	Tubbs and Tubbs surveyed *Zostera* in Chichester Harbour in 1974, 1979, 1987 and 1988. Surveys were carried out from the shore, plotting the visible limits of the *Zostera* beds on 1:10000 scale maps using intertidal features as reference points. In 1974 they found small beds in two areas.	No extent, no location was provided in reference	Tubbs, C. R. and Tubbs, J.M., 1983. The distribution of *Zostera* and its exploitation by wildfowl in the Solent, Southern England. Aquatic Botany, 15, 223-239
Pre 1995	**1979**	**130**	Tubbs and Tubbs surveyed *Zostera* in Chichester Harbour in 1974, 1979, 1987 and 1988. Surveys were carried out from the shore, plotting the visible limits of	Visual estimate of extent surveyed from shoreline	Tubbs, C. R. and Tubbs, J.M., 1983. The distribution of *Zostera* and its exploitation by

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
			the *Zostera* beds on 1:10000 scale maps using intertidal features as reference points. In 1974 they found small beds in two areas, in 1979 they estimated 130ha of *Zostera* in Chichester.	Likely to be an underestimate. Refer to primary source for location information	wildfowl in the Solent, Southern England. Aquatic Botany, 15, 223-239
Pre 1995 **The 2011 HIWWT inventory maps all pre 1995 data together in one map layer (green).**	**1980**	44.61	Coastal vegetation was mapped using airborne infrared sensors as part of an ongoing programme. Distinguishing between *Zostera* and *Enteromorpha* was found to be problematic and so **the area estimates of 44.61ha is not an accurate estimate of *Zostera*.** **Note1:** In 2011 CHC used the data from Portsmouth University surveys to produce a map showing separate areas for *Zostera* and Zostera and *Enteromorpha* for 1980 as 22.81ha (*Zostera*) and 21.70ha (*Zostera* and *Enteromorpha*) **Note 2:** In 2003 Jackie Middleton undertook analysis of the 1980 and 1996 Portsmouth University data for EN presented in an excel spreadsheet giving ha of seagrass habitat per SSSI unit. Total extent for 1996 was **23.17ha** (*Zostera)* and **24.02ha** ***(****Zostera* and *Enteromorpha)*. This data is used by NE to determine the baseline extent for seagrass beds for Chichester Harbour SSSI in the FCT. The baseline figure for 1980 is **47.20ha.**	Methodology unable to accurately distinguish between seagrass and green algae. Different methodology used for Portsmouth University surveys and in Tubbs and Tubbs resulting in significantly different extent data	Portsmouth University, 1980. Infrared survey of green weed cover within the harbours of the South coast. Reports to Environment Agency, Waterlooville, Hampshire. As referenced in Dale, Chesworth & Leggett (2011).
Pre 1995	**1988**	**220**	In an update to Tubbs and Tubbs (1983), Chichester harbour was resurveyed for *Zostera* in 1988, with 220ha of *Zostera* beds being estimated.	Visual estimate of extent surveyed from shoreline Need to refer to primary source for location information	Tubbs, C. R., 1999. The Ecology, conservation and history of the Solent. Packhard Publishing Ltd, Chichester p120
Pre 1995	**1988-1989**	**Decline due to**	Tubbs estimate of when a new episode of wasting disease occurred in the Solent harbours.	No extent	Tubbs, C. R., 1999. The Ecology, conservation and

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
		wasting disease	Tubbs notes that due to a lack of monitoring the precise chronology of events is hard to establish.		history of the Solent. Packhard Publishing Ltd, Chichester p122
Pre 1995	**1993**	**Decline due to wasting disease**	Tubbs writes that by 1993 former extensive meadows in the Nutbourne inlet (Thorney Channel) and on the east side of Emsworth Channel in Chichester Harbour had been reduced to small, albeit numerous patches. Where formerly there had been dark green meadows covering the flats there now gleaming mud, broken by mainly low-density patches of green algae.	No extent	Tubbs, C. R., 1999. The Ecology, conservation and history of the Solent. Packhard Publishing Ltd, Chichester p122
Pre 1995	**1994**	**24.9**	Coastal vegetation was mapped using airborne infrared sensors as part of an ongoing programme. Distinguishing between *Zostera* and *Enteromorpha* was found to be problematic and so **the area estimates of 24.9ha is not an accurate estimate of *Zostera*.** Note: In 2011 CHC used the data from Portsmouth University surveys to produce a map showing separate areas for *Zostera* and *Zostera* and *Enteromorpha* for 1994 as 5.45ha (*Zostera*) and 19.47ha (*Zostera* and *Enteromorpha)*	Methodology unable to accurately distinguish between seagrass and green algae. Not possible to identify individual dataset locations (particularly Tubbs and Tubbs and Portsmouth University)	Portsmouth University, 1994. Infrared survey of green weed cover within the harbours of the South coast. Reports to Environment Agency, Waterlooville, Hampshire. As referenced in Dale, Chesworth & Leggett (2011). And CHC maps provided to NE (2011)
1995 to 2005	**1995**	**58.8**	Coastal vegetation was mapped using airborne infrared sensors as part of an ongoing programme. Distinguishing between *Zostera* and *Enteromorpha* was found to be problematic and so **the area estimates of 58.8ha is not an accurate estimate of *Zostera*.** Note: In 2011 CHC used the data from Portsmouth University surveys to produce a map showing separate areas for *Zostera* and *Zostera* and *Enteromorpha* for 1995 as **25.47ha** (*Zostera*) and **33.37ha** (*Zostera* and *Enteromorpha*).	Methodology unable to accurately distinguish between seagrass and green algae.	Portsmouth University, 1995. Infrared survey of green weed cover within the harbours of the South coast. Reports to Environment Agency, Waterlooville, Hampshire. As referenced in Dale, Chesworth & Leggett (2011).

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
1995 to 2005 **The 2011 HIWWT inventory maps all data from 1995 to 2005 in one map layer (yellow) extent figures are rolling totals**	**1996**	**70.1**	Coastal vegetation was mapped using airborne infrared sensors as part of an ongoing programme. . Distinguishing between *Zostera* and *Enteromorpha* was found to be problematic and so **the area estimates of 70.1ha is not an accurate estimate of *Zostera*.** Note1: In 2011 CHC used the data from Portsmouth University surveys to produce a map showing separate areas for *Zostera* and *Zostera* and *Enteromorpha* for 1996 as **28.77ha** *(Zostera)* and **41.32ha** *(Zostera* and *Enteromorpha)* **Note 2:** In 2003 Jackie Middleton undertook analysis of the 1980 and 1996 Portsmouth University data for EN giving ha of seagrass habitat per SSSI unit. Total extent for 1996 was **28.79ha** *(Zostera*) and **41.29ha** (*Zostera* and *Enteromorpha).* The 1996 data is used to determine seagrass extent in Chichester Harbour for the Solent Maritime SAC. The FCT states that **70.10ha** is the SAC baseline.	Methodology unable to accurately distinguish between seagrass and green algae.	Portsmouth University, 1996*.* Infrared Survey of green weed cover within the harbours of the South coast. Reports to Environment Agency, Waterlooville, Hampshire. As referenced in Dale, Chesworth & Leggett (2011).
1995 to 2005	**2001**	**?**	As part of a student dissertation, *Zostera* beds were mapped. *Z. marina* was located at Gutner, to the west of Emsworth Channel and Oar Rythe *Z. noltii* were located at Fowley towards the north of Emsworth Channel Verner to the west and Mengham at the southern end, West Wittering and West Itchenor, close to Chichester Channel and Chidham, east of Thorney Channel. Co-ordinates are provided but no estimate of extent.	No extent	Mieszkowska, N., 2001. Antifouling Booster Biocides in Chichester Harbour and their Potential Impact on *Zostera marina* and *Zostera noltii* species of Seagrass. Report to CHC, Chichester. As referenced in Dale, Chesworth & Leggett (2011).
1995 to 2005	**2005**	**6.8?**	This survey was conducted in June 2005 as part the Conservancy's ongoing survey programme. The seagrass beds were viewed from the shore and the area locations sketched approximately onto GIS. Due to the limitations of the survey	possible typing error in 2011 inventory report	Rowsell, E., 2005. Chichester Harbour Seagrass survey. Chichester Harbour Conservancy, Chichester.

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
			method, the seagrass was not identified to species level. The records also note areas where *Enteromorpha* sp. and *Zostera* sp. are found mixed together.		As referenced in Dale, Chesworth & Leggett (2011).
1995 to 2005	**2005**	**6.8**	As part of a Solent wide survey, in September 2005 the consultants ERT conducted 10 400m wide belt transects in Chichester Harbour. They were carried out using hovercrafts with surveyors zigzagging down the transect. They found *Z. noltii* on one of the transects, on the east coast of Hayling Island, near Mengham at GR SZ743997. It was calculated to be 6.8ha. The ERT report documents intertidal sediment and associated benthic fauna surveys. Biotopes associated with dwarf seagrass (*Zostera noltii*; Ls.LMp.LSgr.Znor) were recorded as part of the study.	Surveys limited to 10 transects.	ERT (Scotland) Ltd., 2005. Solent intertidal survey, August to September. Report to English Nature FIN/T05/02. As referenced in Dale, Chesworth & Leggett (2011).
2006 to 2009	**2008**	**?**	The Botanical Society of the British Isles (BSBI) holds field observations of *Zostera* in Hampshire. Much of the data has only coarse resolution location information and only points with 6 figure grid references were mapped by HIWWT.	No extent	Botanical Society of the British Isles, 2008. Field observations submitted to the Botanical Society of the British Isles, London. As referenced in Dale, Chesworth & Leggett (2011).
2006 to 2009	**2008**	**10.5** (this includes CHC 2008 surveys listed below)	An on-going survey conducted in association with the CHC, the seagrass bed edges were measured by walking around the edges of the intertidal beds using hand-held GPS to record locations. The seagrass species were identified, and records of *Ruppia* sp. are included in this survey.	Field surveys	HIWWT, 2008. Chichester Harbour intertidal Seagrass survey. HIWWT, Hampshire. As referenced in Dale, Chesworth & Leggett (2011).
2006 to 2009	**2008**		This survey was conducted in September 2008 as part the Conservancy's ongoing survey programme. The seagrass beds were viewed from the shore and the area locations sketched	Field surveys	Rowsell, E., 2008. Chichester Harbour Seagrass survey, 2008. Chichester

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
			approximately onto GIS. Due to the limitations of the survey method, the seagrass was not identified to species level.		Harbour Conservancy, Chichester. As referenced in Dale, Chesworth & Leggett (2011).
2006 to 2009	**2009**	**24.3**	The survey was conducted in May, July, August and October 2009, using hand-held GPS to record locations. The presence or absence of seagrass and species types were determined on foot and documented using a waterproof handheld camera.	The HIWWT 2011 inventory maps 2006 to 2009 data (red) as one map layer. Extent figures are rolling totals updated each year. Unable to identify location of each survey area.	HIWWT, 2009. Solent Seagrass Project Chichester Harbour intertidal seagrass survey. HIWWT, Hampshire. As referenced in Dale, Chesworth & Leggett (2011).
2006 to 2009	**2009**	**3.0**	This survey of a *Zostera noltii* and *Z. angustifolia* patch in Chidham was carried out on 9th July 2009. Thirty quadrats were taken within the patch to assess seagrass species composition. Half the quadrats only contained *Z. noltii*, with a further eleven quadrats containing both species. Percentage cover ranged from 20-100 %. *Enteromorpha* covered *Zostera* plants in two quadrats and many quadrats contained plants with brown leaves.	Local surveys at Chidham only	Environment Agency. 2009. Solent Seagrass Project Chichester Harbour intertidal seagrass survey. Unpublished data. As referenced in Dale, Chesworth & Leggett (2011)
	2010	**100.65 This figure is given as the extent using data from 2006 to 2010**	Surveys were conducted on foot in June 2010, using hand-held GPS to record locations. Access to beds was obtained by kayak or small craft. The presence or absence of seagrass and species types were determined on foot and documented using a waterproof handheld camera. Both *Zostera noltii* and *Z. angustifolia* were found, and cover was generally patchy but with some dense areas. The boundary for the large bed southwest of Mengham Rithe (Map 9e) and north of Mill Rithe (Map 9c) includes saltmarsh	Areas surveyed on foot. The HIWWT 2011 inventory extent figures are rolling totals updated annually. Different survey methodologies used by Portsmouth University and	HIWWT, 2010. Solent Seagrass Project Chichester Harbour intertidal seagrass survey. HIWWT, Hampshire. As referenced in Dale, Chesworth & Leggett (2011)

HIWWT mapped time periods	Date	Area/ha	Description	Data limitations	Reference
			habitat. Much of the seagrass observed was growing in channels and within saltmarsh, preventing a seagrass-only boundary being traced. Damage to seagrass by moorings was observed at Mengham Rithe where there were holes in seagrass beds caused by the dragging of mooring chains as boats swing round on the tide.	HIWWT does not make for meaningful comparison between the 1995-2005 and the 2006-2009/2010 datasets. No HIWWT surveys were carried out in 2006 and 2007 for Chichester Harbour. Only some of the data from 2008 botanical surveys is included in the extent. Area surveyed at Mill Rithe in 2010 was resurveyed in 2015	

Appendix 6 Environment Agency survey methodology and datasets

A6.1 Environment Agency methodology for calculating opportunistic macroalgae approach

1) Opportunistic Macroalgal Blooming Tool (OMBT)

The OMBT enables an assessment of the condition of the quality element, 'opportunistic macroalgae', as listed in Tables 1.2.3 and 1.2.4 of Annex V to the WFD (2000/60/EC). The WFD requires that the assessment of the opportunistic macroalgal quality element considers composition, opportunistic macroalgal cover, abundance and disturbance-sensitive taxa.

The OMBT is a multimeric index composed of five metrics:

(i) Percentage cover of the available intertidal habitat (AIH)

(ii) Total extent of area covered by algal mats (affected area (AA)) **or** affected area as a percentage of the AIH (AA/AIH, %)

(iii) Biomass of AIH (g m_2)

(iv) Biomass of AA (g m_2)

(v) Presence of entrained algae (percentage of quadrats)

The metrics are equally weighted and combined within the multimeric, in order to best describe the changes in the nature and degree of opportunistic macroalgae growth on sedimentary shores due to nutrient pressure.

An assessment of opportunistic macroalgae was reported for the first River Basin Management Plans (2009) however, the option to use either the total extent of area covered by algal mats (affected area (AA)) **or** affected area as a percentage of the AIH (AA/AIH, %) is a new modification of the tool.

The OMBT operates over a range from zero (major disturbance) to one (reference/minimally disturbed). The four class boundaries are:

- High/Good = 0.8
- Good/Moderate = 0.6
- Moderate/Poor = 0.4
- Poor/Bad = 0.2

To calculate the OMBT, the percentage cover, biomass and presence of entrained opportunistic algae within a known area of sedimentary shore are required. Samples have to be defined by sampling (eg area of patch) and processing (eg wet weight) methodologies.

Where several surveys are carried out within a reporting period, the EQR is averaged.

2) Applicability

Where: The OMBT is suitable for use in UK transitional and coastal waters which have intertidal areas of soft sedimentary substratum (ie areas of AIH for opportunistic macroalgal growth). The tool is not currently used for assessing saline lagoons due to the particular challenges in setting suitable reference conditions for these water bodies.

When: The OMBT has been developed to classify data over the maximum growing season so sampling should target the maximum potential growth of the algal bloom. The peak bloom is generally monitored in summer (June to September), although peaks in opportunistic algal growth can occur during the spring and rarely 'secondary' peaks may be seen in the late summer or early autumn. Peak timing may vary among water bodies, so local knowledge is used (Practitioners Guide to the Opportunistic Macroalgal Blooming Tool Version 08. 071212 Page 3 of 20).

Required to identify the maximum growth period, sampling is not recommended outside the summer period due to seasonal variations that could affect the outcome of the tool and possibly lead to misclassification. Blooms may become disrupted by stormy autumn weather and often there is die back in winter. Sampling should be carried out during spring low tides in order to access the maximum area of the intertidal.

Response to Pressure: The OMBT has been designed to identify the impact on opportunistic macroalgae from nutrients and organic enrichment and should detect signs of eutrophication.

A6.2 Water quality datasets

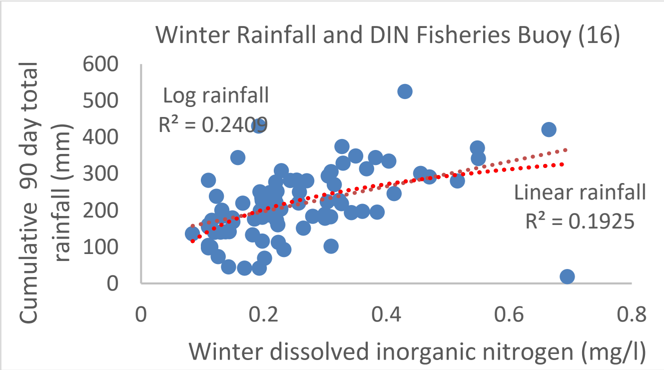
Table A6.1 Data sets, date and parameter type

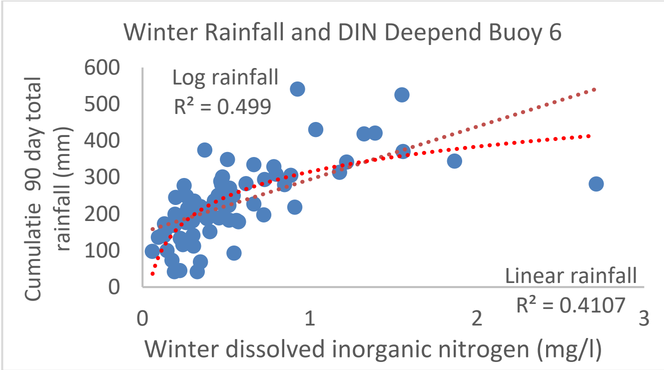
Parameter	Measures/derived	Dates
Ammoniacal Nitrogen as N **Ammonia un-ionised as N**	Measured Parameters	Data set provided starts 1977 Data set provided starts 1980
Nitrate as N	Measured Parameter	Data set provided starts 1977 but not available consistently
Nitrite as N	Measured Parameter	Data set provided starts 1977 Not available at all sites consistently
Nitrogen, Total Oxidised as N	Is a derived parameter ie nitrate + nitrite	Data set provided starts 1984
Nitrogen, Dissolved Inorganic as N	Is a derived parameter TON + Ammoniacal N (NH3-N)	Data set provided starts 2010 at limited number of sites
Nitrogen, Total as N	Is a derived parameter Organic N + Ammoniacal N + TON	Data set provided starts 2010 at very limited number of sites

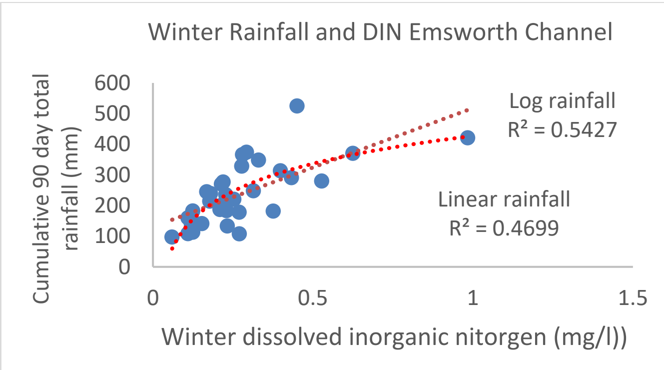
Table A6.2 Water quality sampling points

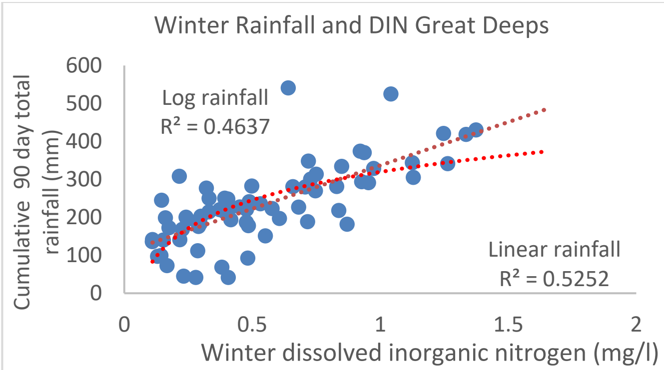
Habitat Type	Names	**Location**
Freshwater - Rivers	CHICHESTER CANAL BYPASS BRIDGE - A27	SU8591003710
	CHICHESTER CANAL BELOW BIRDHAM WEIR	SU8376001070
	HAMBROOK FARM LANE FORD NUTBOURNE	SU8376001070
	RIVER EMS A259 ROAD BRIDGE	SU7768005390
	SOUTHLEIGH STREAM AT SOUTH LEIGH	SU7473106223
	WARBLINGTON STREAM NO 1	SU7381705665
	WARBLINGTON STREAM NO 2	SU7355105285
	WARBLINGTON STREAM NO 3	SU7310205393
Freshwater - unspecified	BOSHAM STREAM D/S MAINE ROAD BRIDGE	SU8075205296
	BOSHAM STREAM DISCHARGE TO HARBOUR	SU8041003780
	RIVER LAVANT APULDRAM LANE ROAD BRIDGE	SU8441003740
Saline - shellfish waters	CHICHESTER CHANNEL AT BIRDHAM BEACON	SU8196001310
	EMSWORTH CHANNEL- AT MILL RYTHE BUOY	SU7466000610
	THORNHAM CHANNEL AT CAMBER BUOY	SU7755000410
Saline – estuarine waters	(16) AT FISHERY BUOY	SZ7533099380
	(20) EAST BRANCH OF CHANNEL	SU7442003780
	(6) AT DEEPEND BUOY	SU7950001860
	(7) AT COBNOR BUOY	SU7943002410
		SU7692003810
	(9) ABOVE GREAT DEEPS	SU8341002880
		SU8376004350
	DELL QUAY	SU7724001000
	POINT G AT FISHBOURNE	SU7980015300
	(12) BEACON MARKING PILES PILSEA ISLAND	
	(5 AND K) OFF JETTY AT ITCHENOR HARD	SU8412404618
	FISHBOURNE STREAM - D/S OF FOOTBRIDGE	
	LANGSTONE BRIDGE SAMPLING POINT	SU7180004300

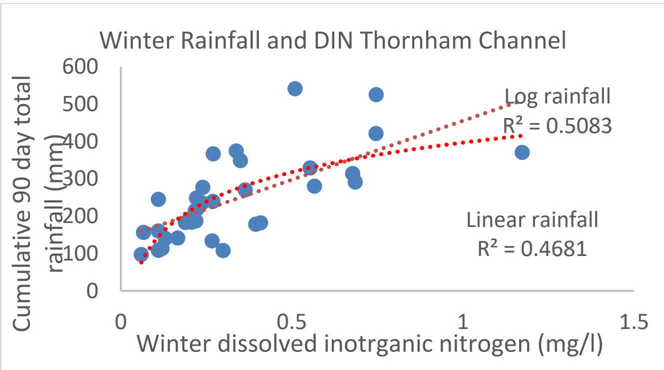
A6.3 Rainfall and DIN data

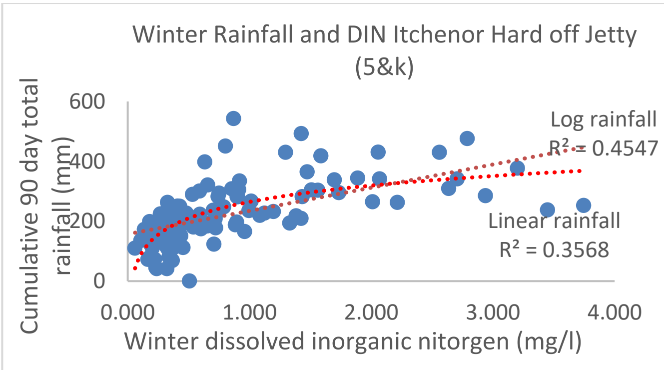


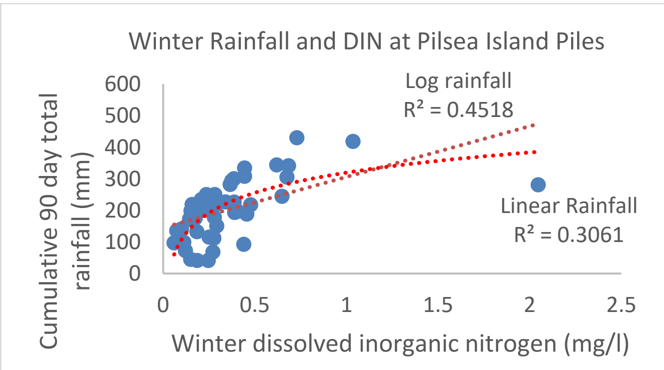


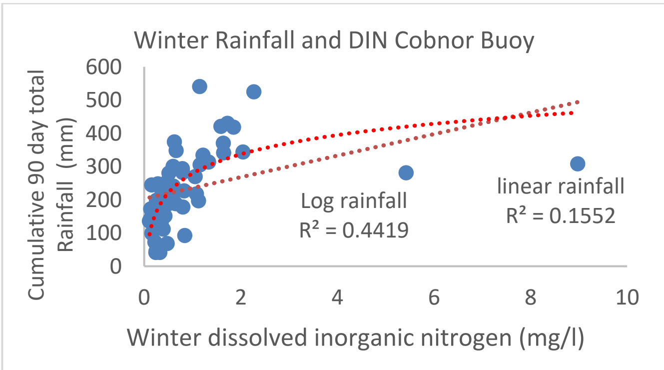












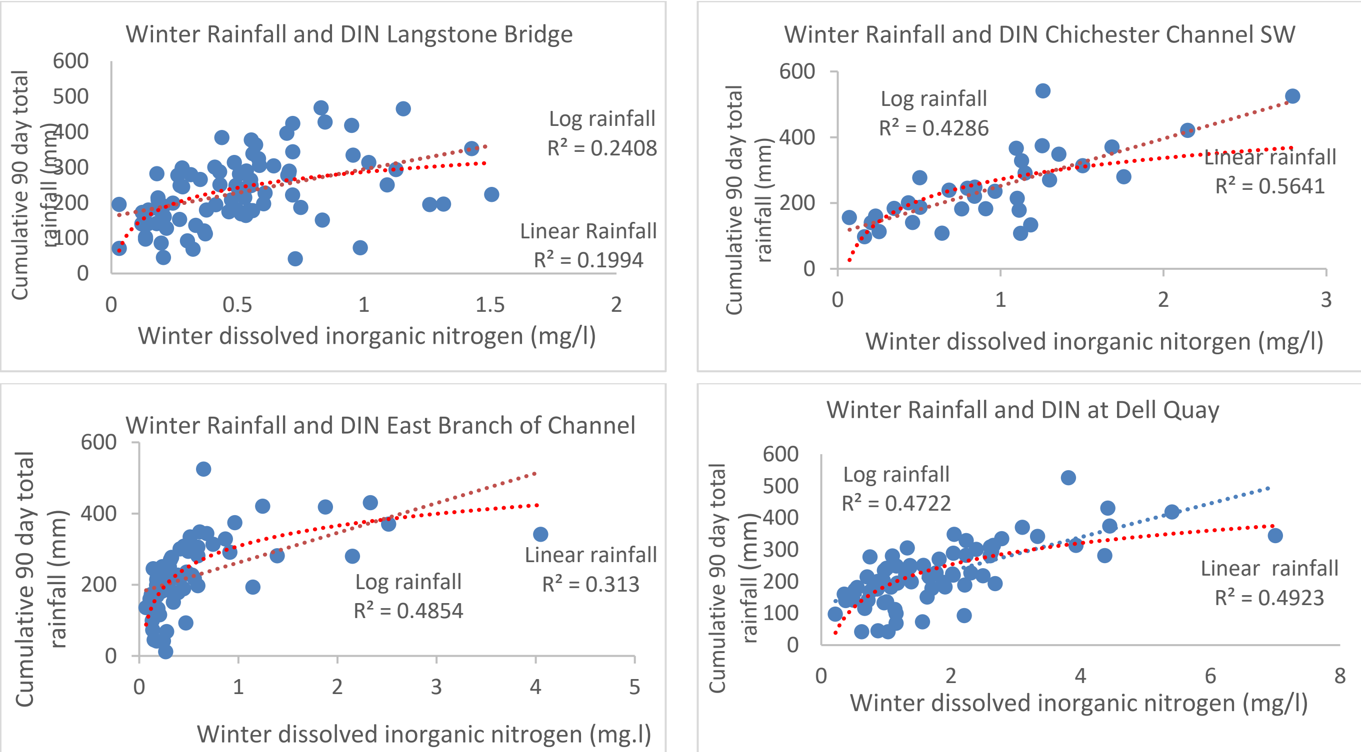
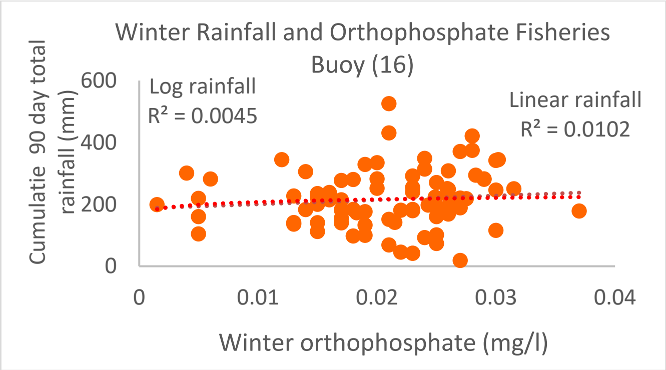
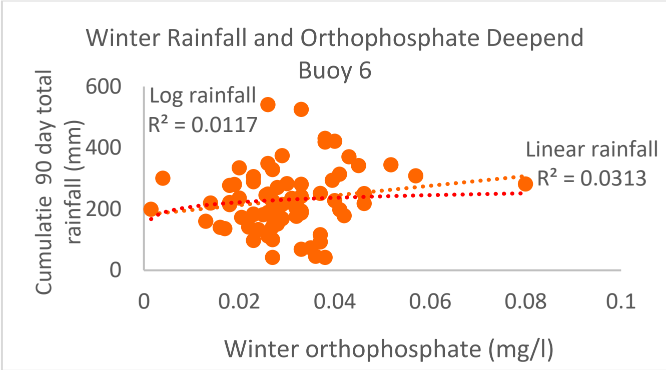
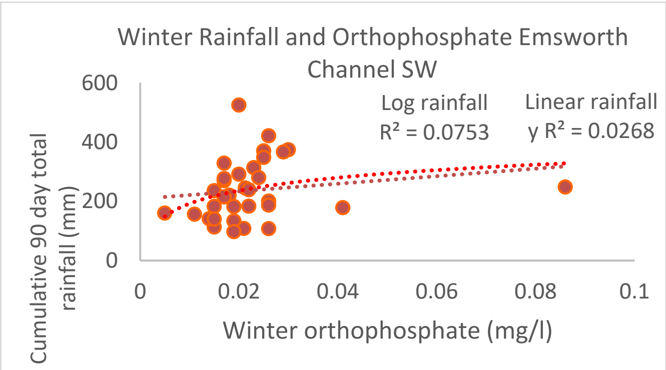


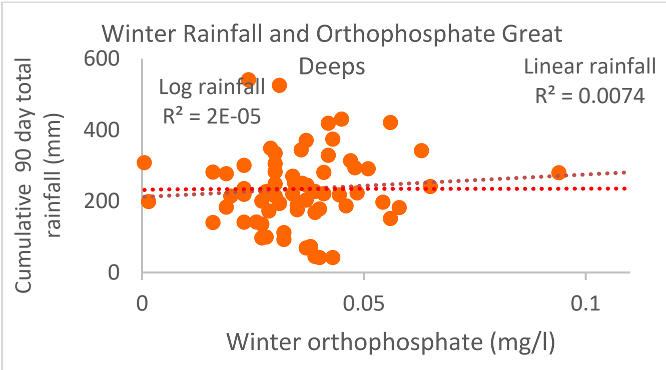
Figure A6.1 Cumulative 90-day total rainfall and DIN Chichester Harbour

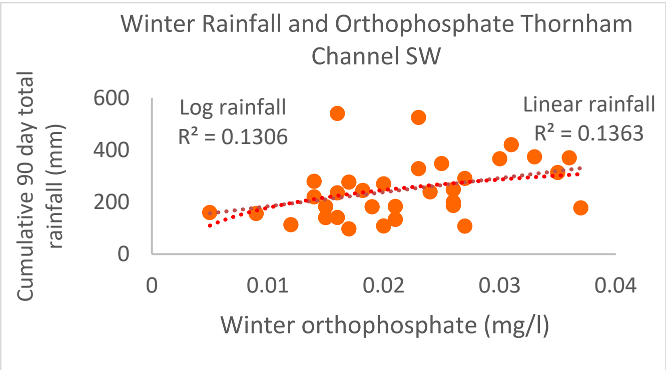
A6.4 Rainfall and orthophosphate data

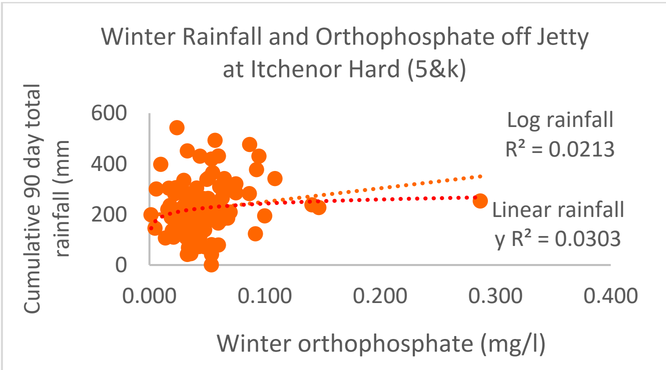


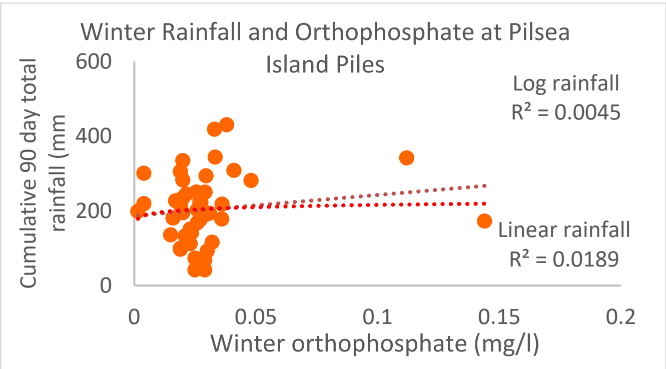


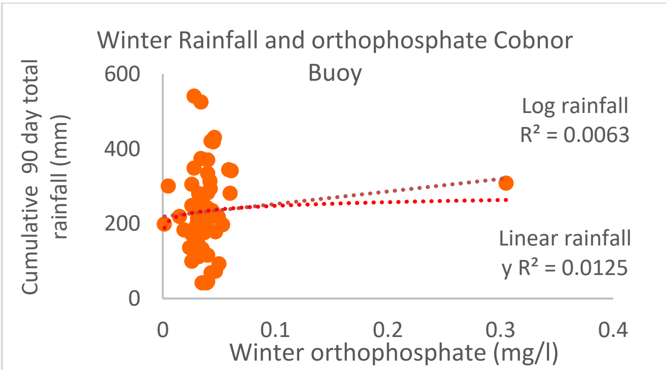












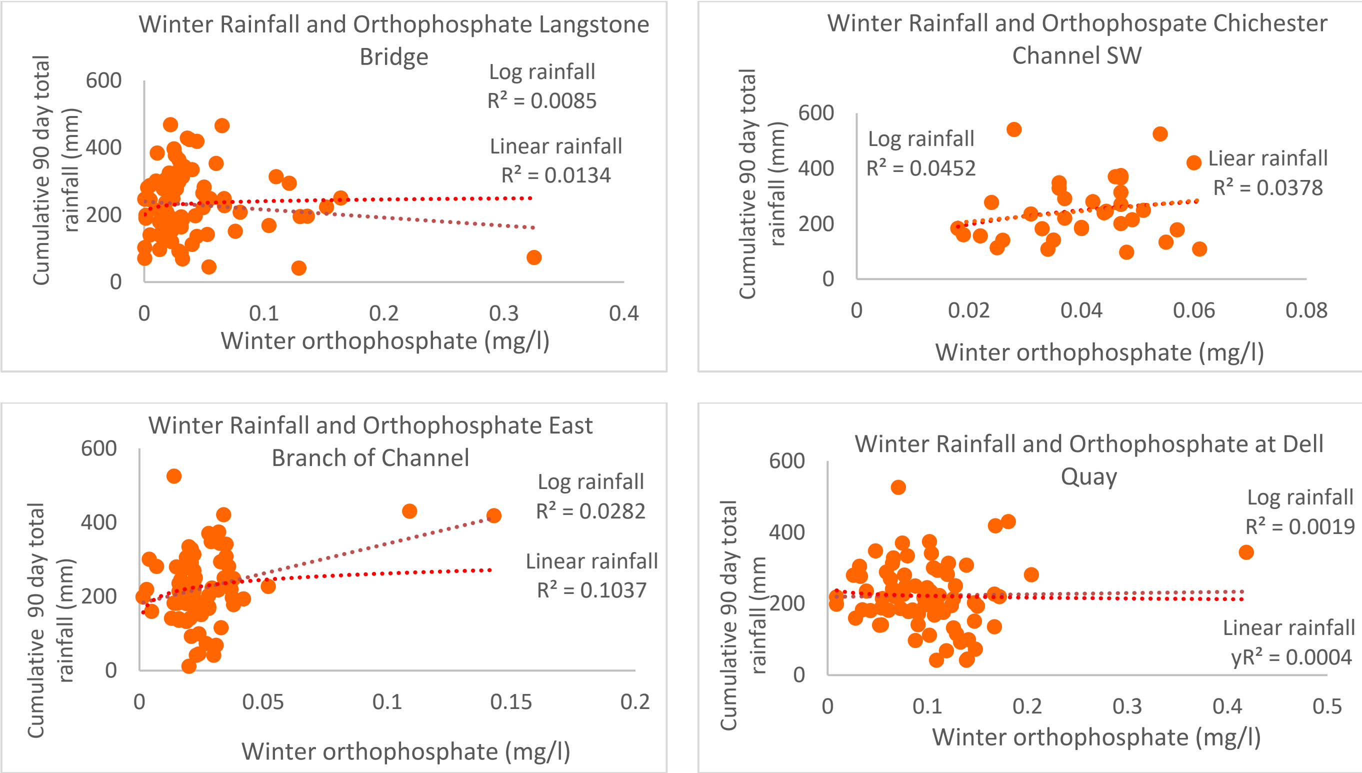
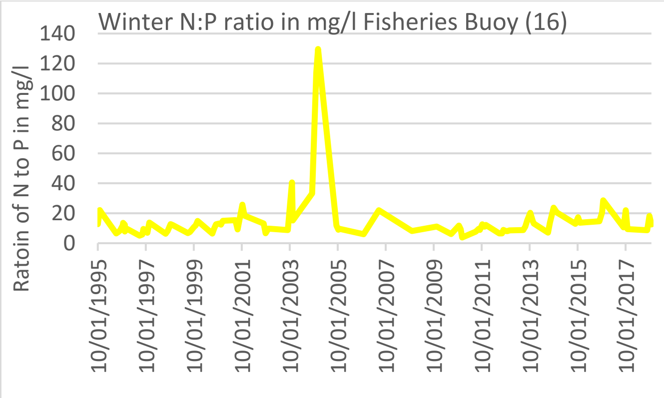
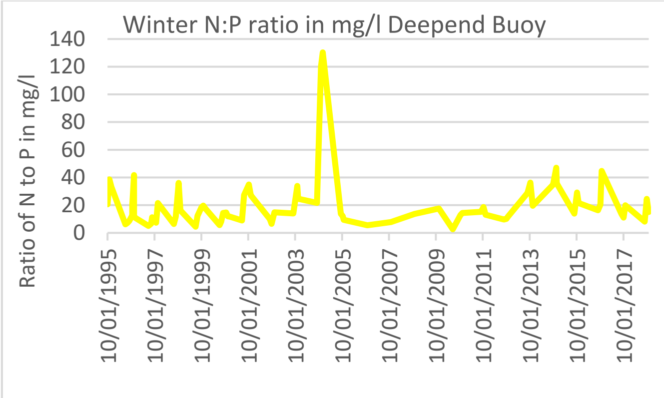
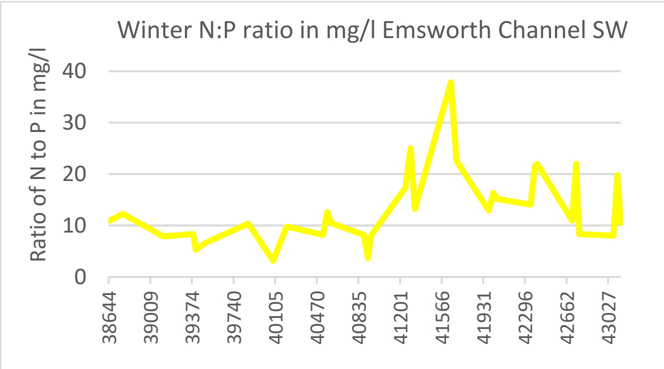


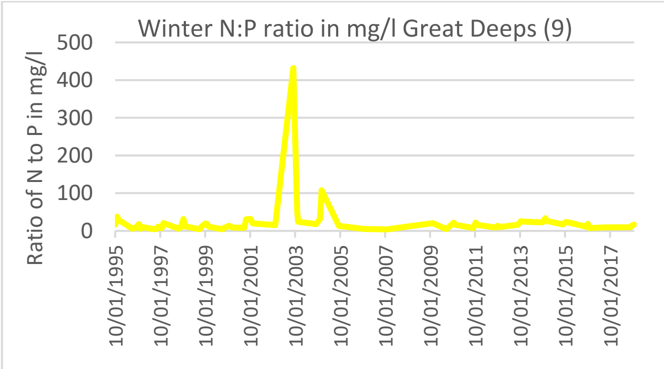
Figure A6.2 Cumulative 90-day total rainfall and orthophosphate Chichester Harbour

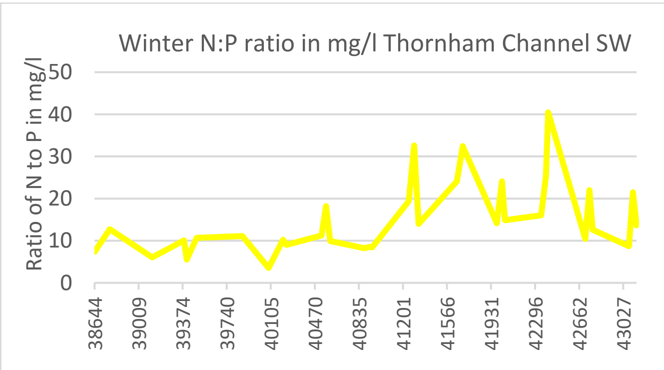
A6.5 Winter N:P ratio data

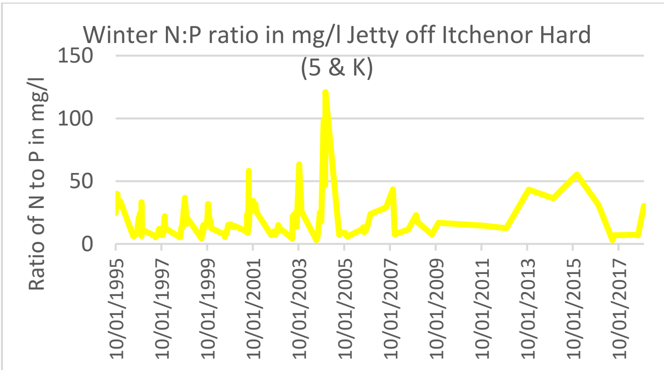


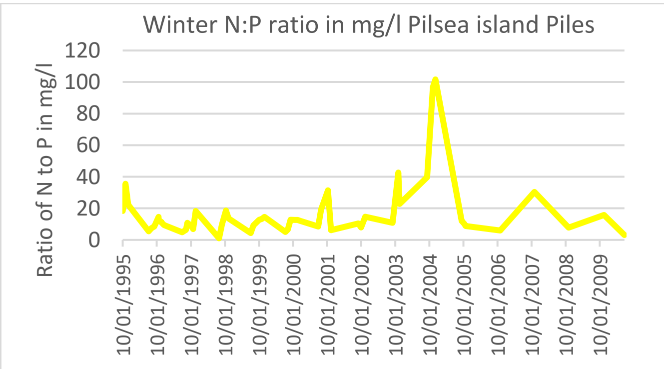


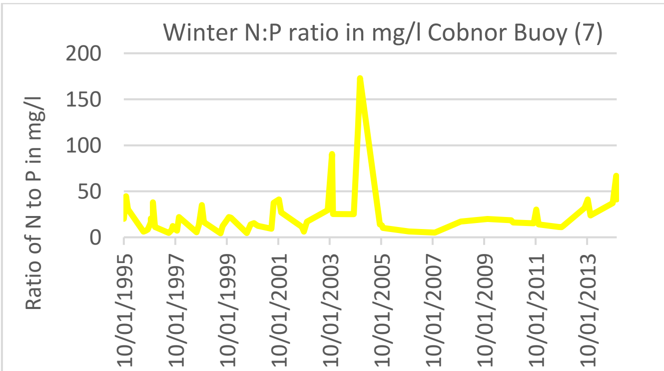












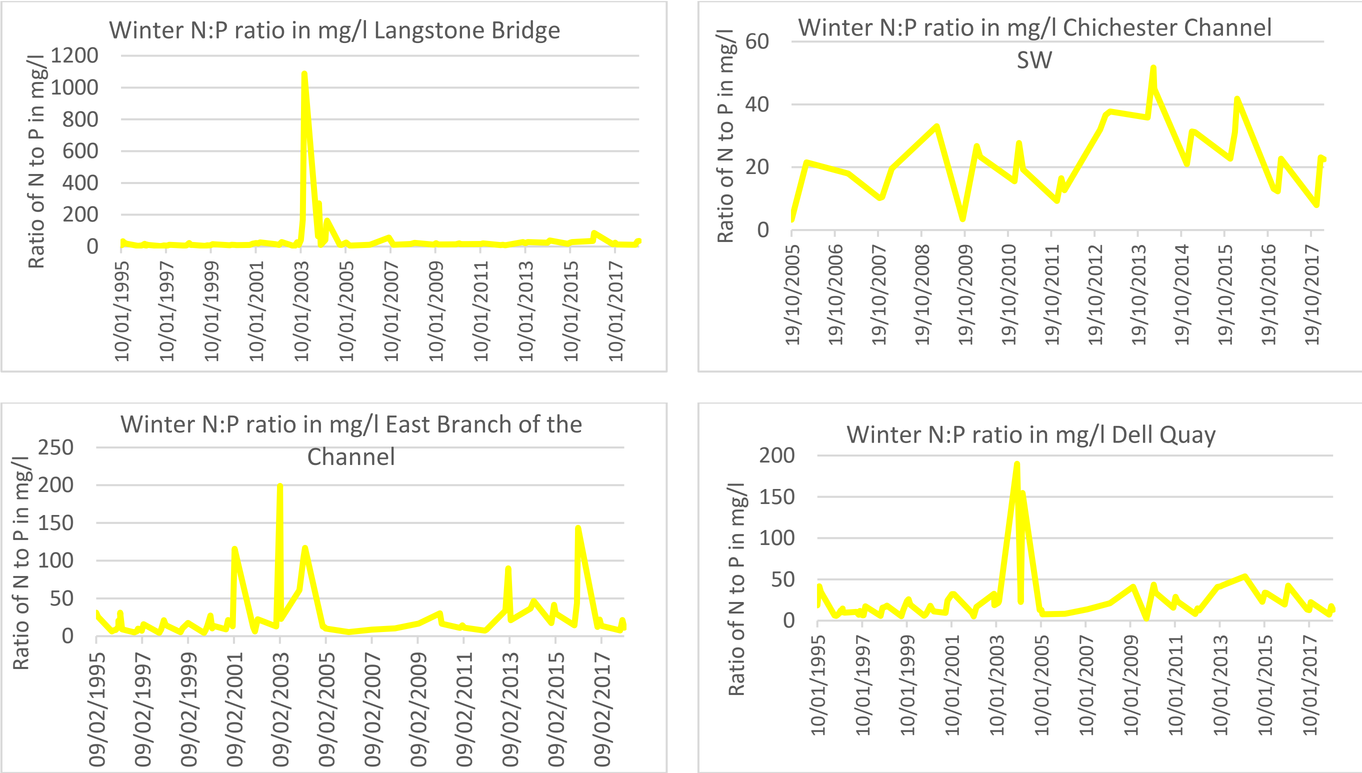
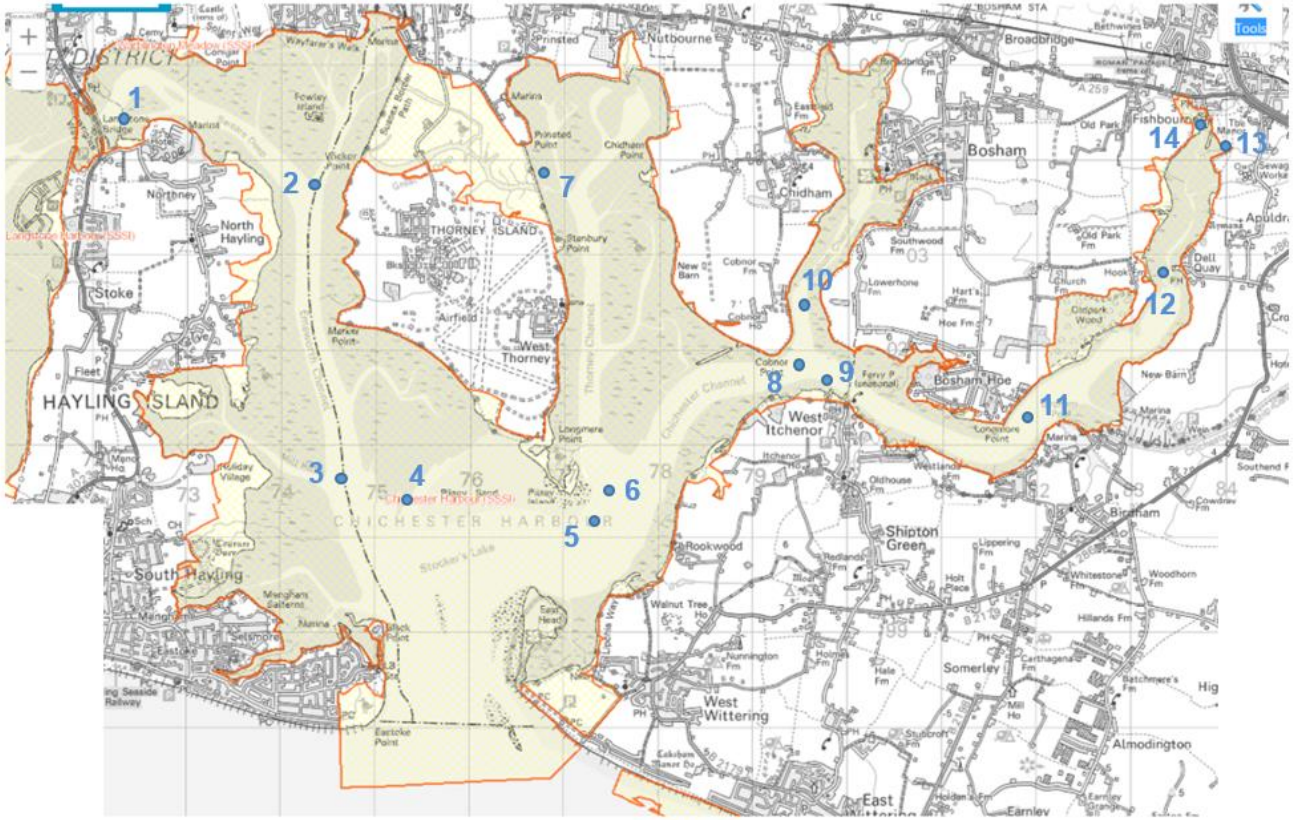
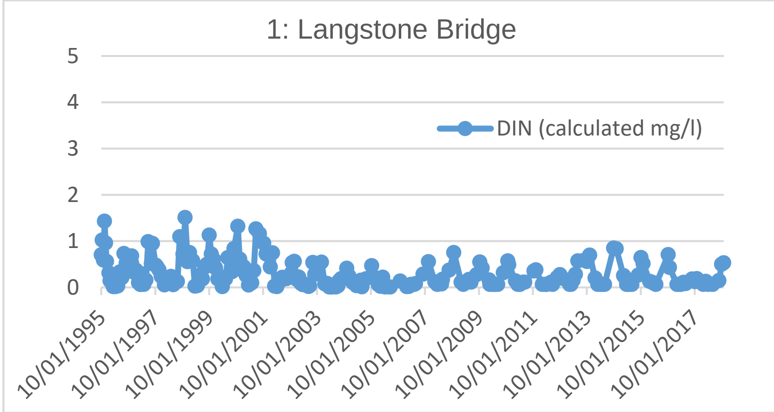
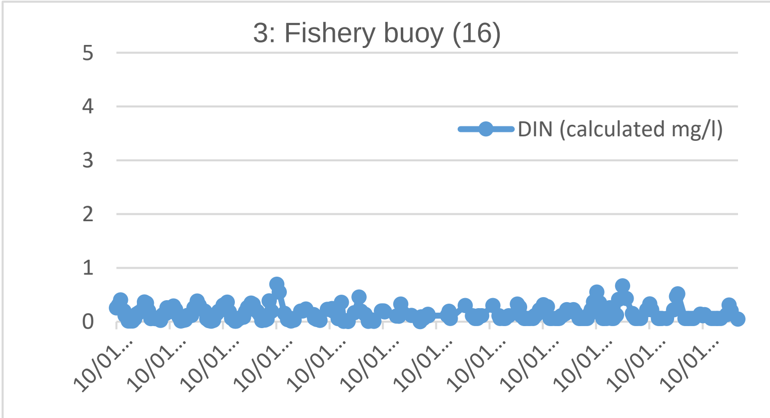


Figure A6.3 Nitrogen and phosphorus ratio Chichester Harbour

A6.6 Water Quality Maps







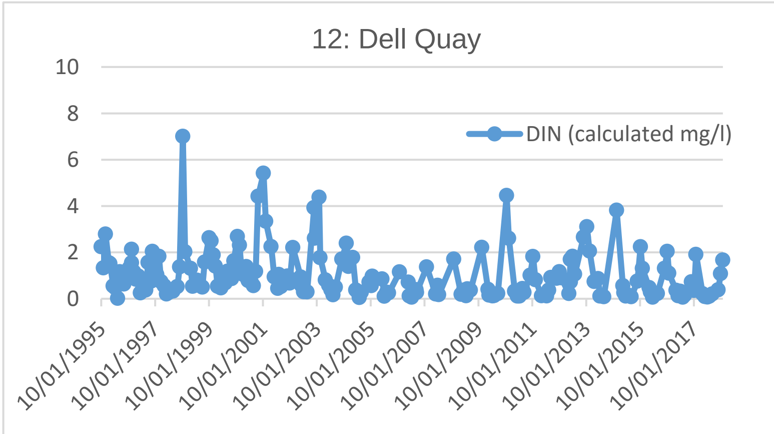
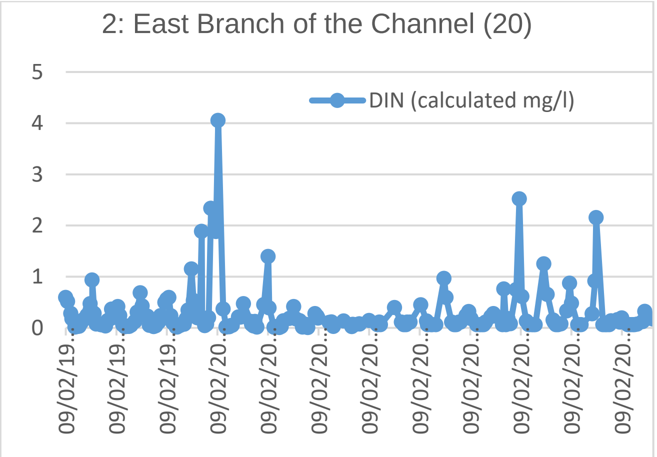
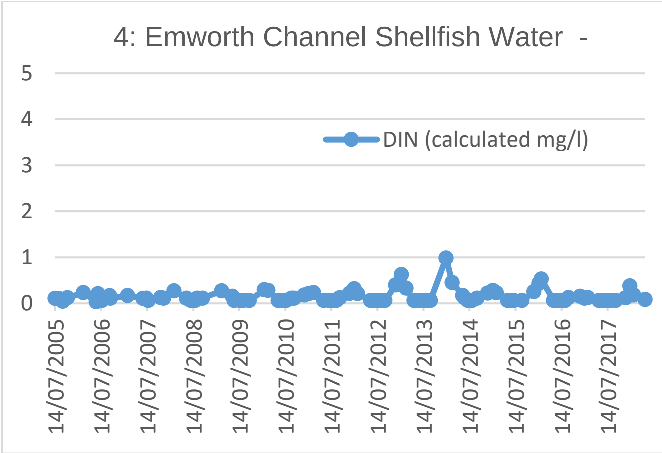
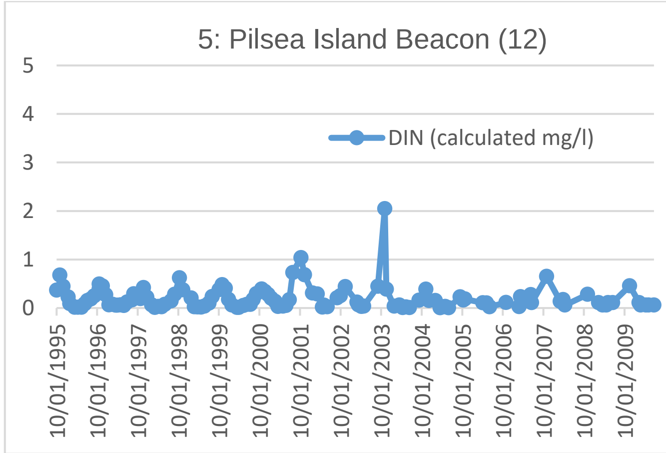
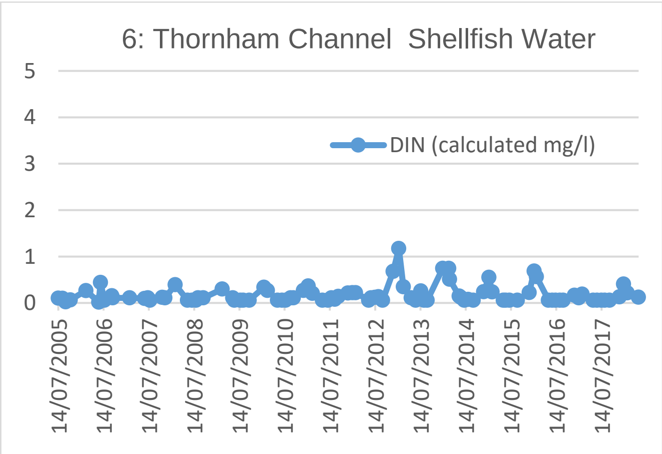


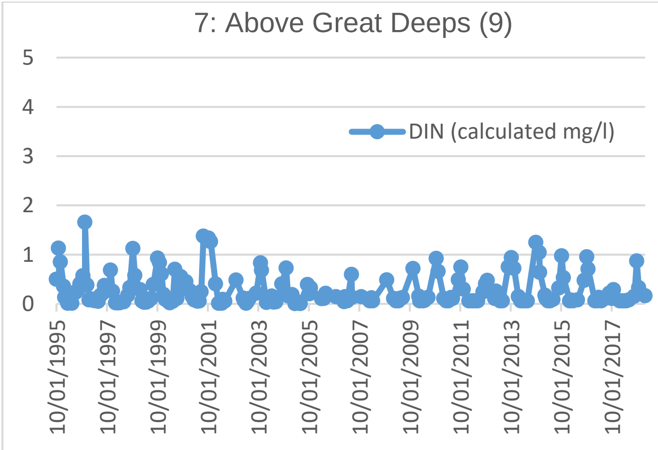
Figure A6.4 Dissolved Inorganic Nitrogen Chichester Harbour (Note scale set at either 5 or 10 mg/l)

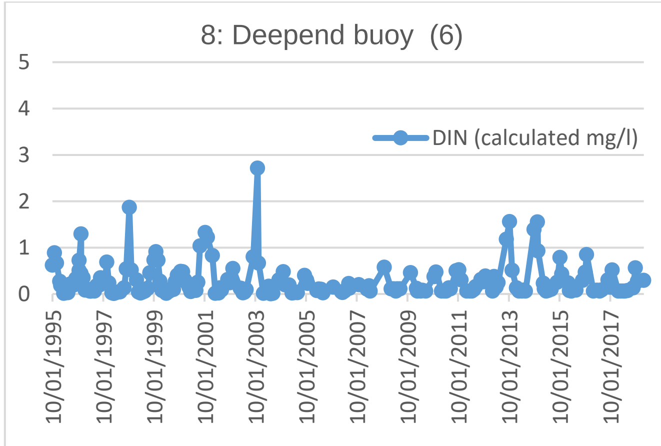

2: East Branch of the Channel (20)
DIN (calculated mg/l)
0
1
2
3
4
5
09/02/19…
09/02/20…

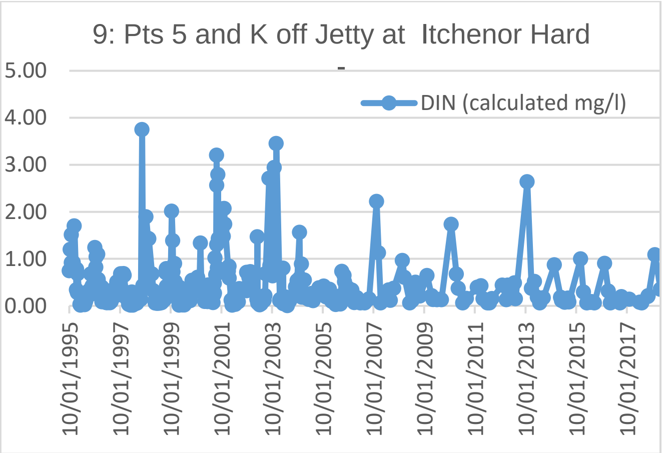

4: Emworth Channel Shellfish Water -
DIN (calculated mg/l)
0
1
2
3
4
5
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017

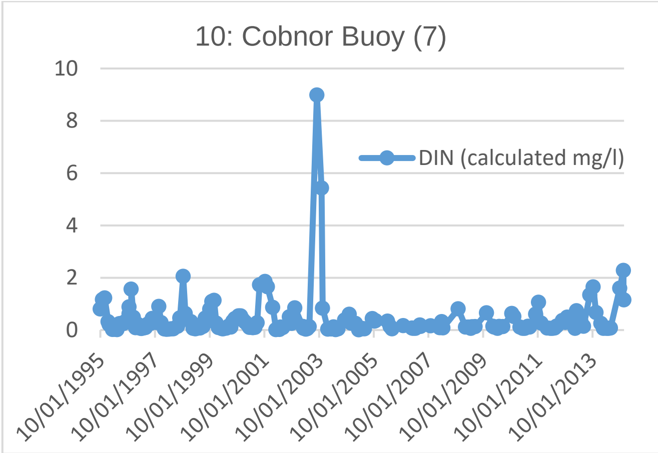

5: Pilsea Island Beacon (12)
DIN (calculated mg/l)
0
1
2
3
4
5
10/01/1995
10/01/1996
10/01/1997
10/01/1998
10/01/1999
10/01/2000
10/01/2001
10/01/2002
10/01/2003
10/01/2004
10/01/2005
10/01/2006
10/01/2007
10/01/2008
10/01/2009

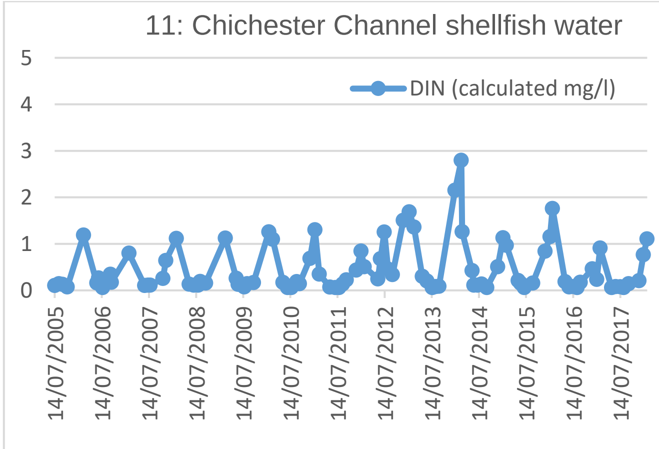

6: Thornham Channel Shellfish Water
DIN (calculated mg/l)
0
1
2
3
4
5
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017

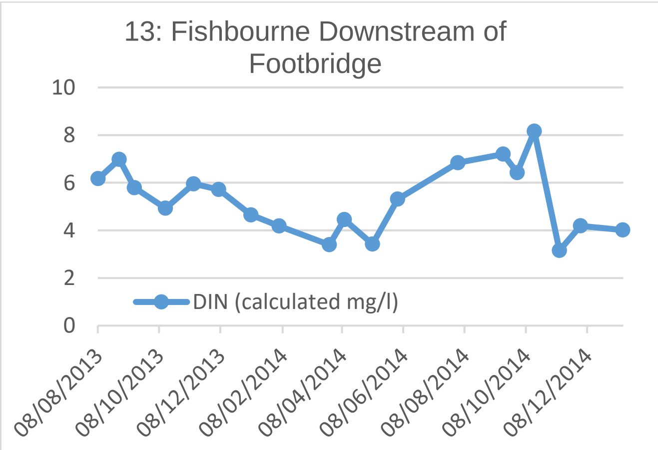

7: Above Great Deeps (9)
DIN (calculated mg/l)
0
1
2
3
4
5
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

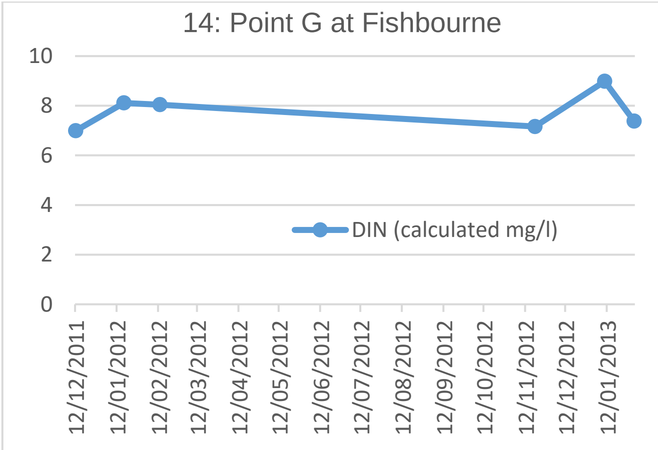

8: Deepend buoy (6)
DIN (calculated mg/l)
0
1
2
3
4
5
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

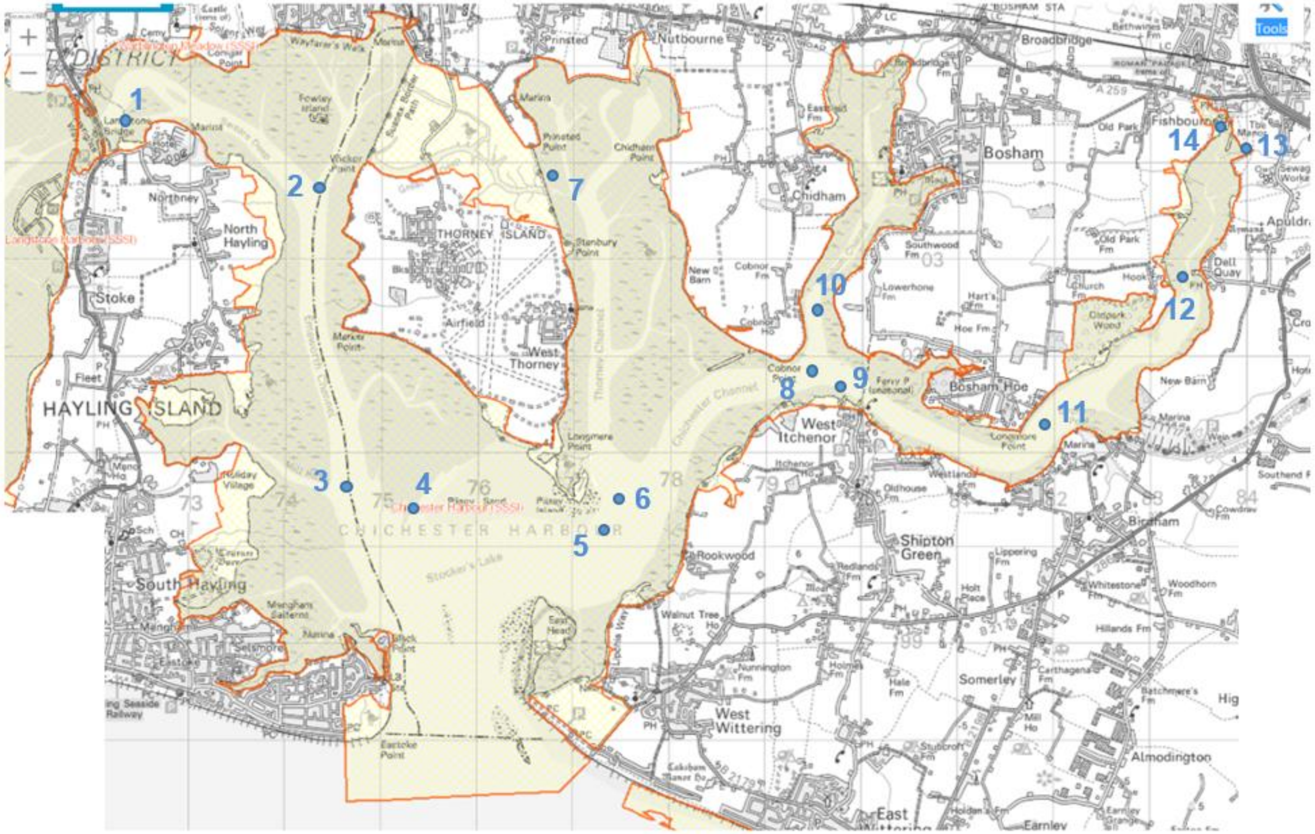

9: Pts 5 and K off Jetty at Itchenor Hard
DIN (calculated mg/l)
5.00
4.00
3.00
2.00
1.00
0.00
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

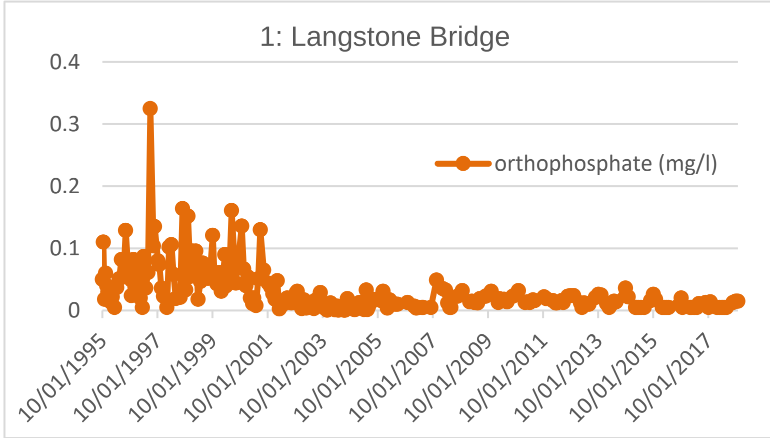

10: Cobnor Buoy (7)
DIN (calculated mg/l)
10
8
6
4
2
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013

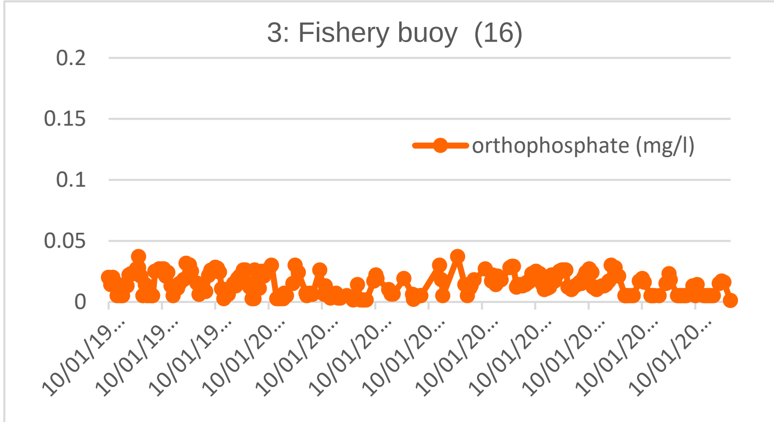

11: Chichester Channel shellfish water
DIN (calculated mg/l)
5
4
3
2
1
0
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017


13: Fishbourne Downstream of Footbridge
DIN (calculated mg/l)
10
8
6
4
2
0
08/08/2013
08/10/2013
08/12/2013
08/02/2014
08/04/2014
08/06/2014
08/08/2014
08/10/2014
08/12/2014


14: Point G at Fishbourne
DIN (calculated mg/l)
10
8
6
4
2
0
12/12/2011
12/01/2012
12/02/2012
12/03/2012
12/04/2012
12/05/2012
12/06/2012
12/07/2012
12/08/2012
12/09/2012
12/10/2012
12/11/2012
12/12/2012
12/01/2013







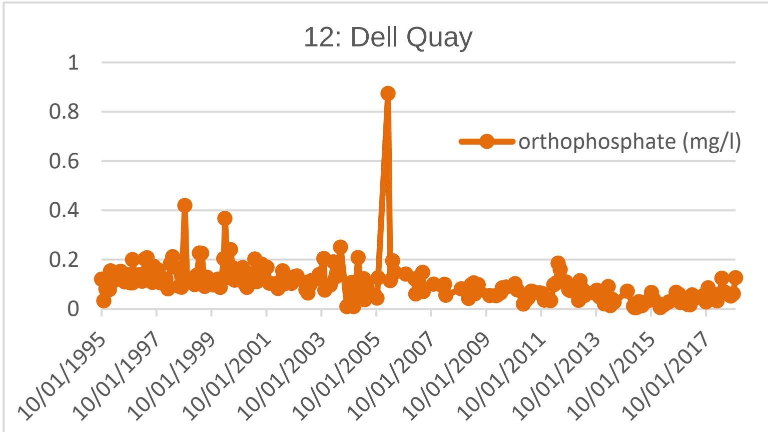
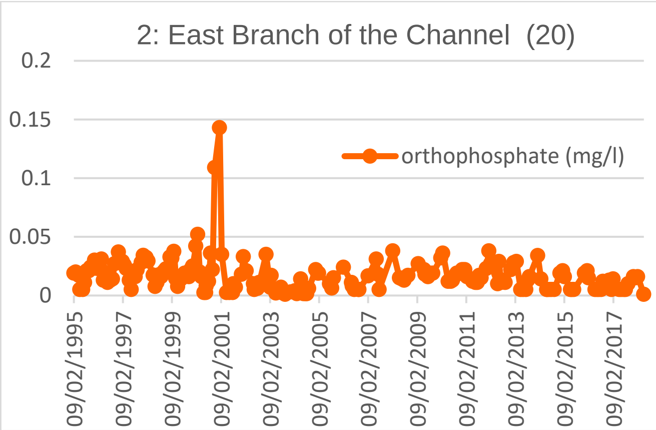
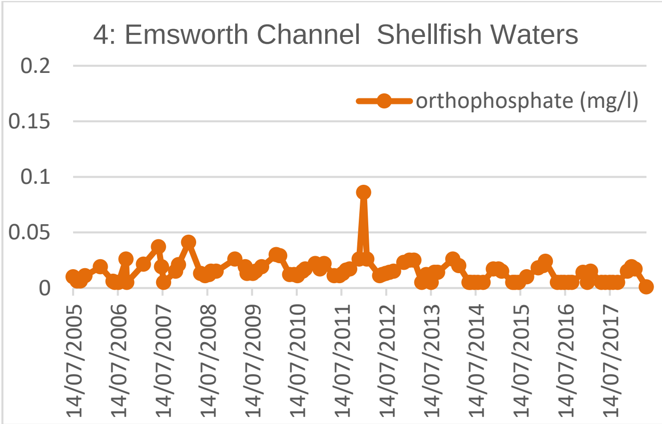
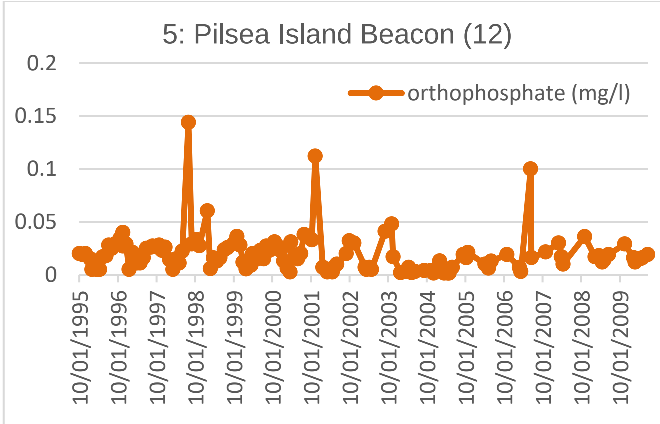
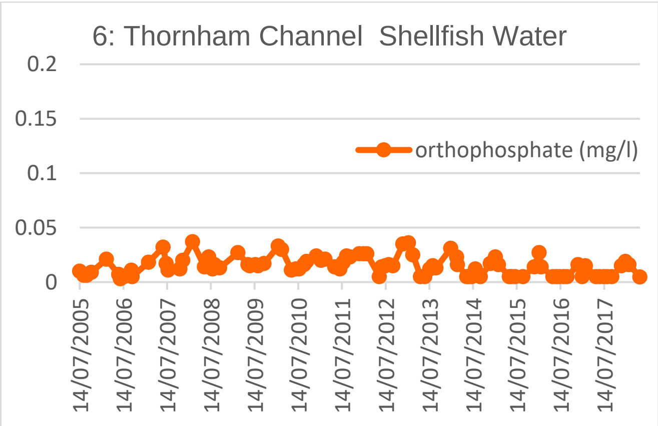


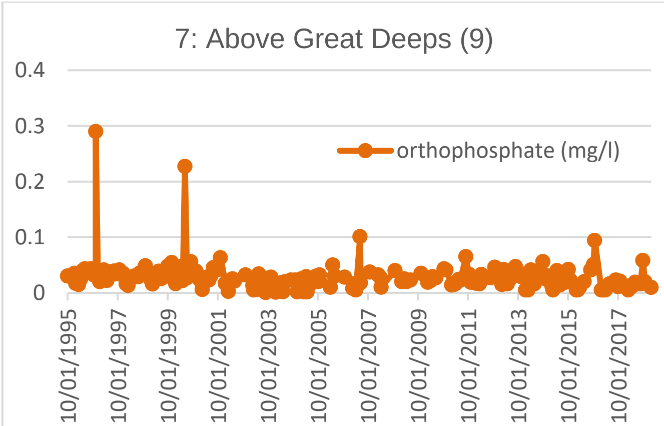
Figure A6.5 Orthophosphate Chichester Harbour (note scale set at either 0.2 mg/l or if above set by data so varies between graphs)

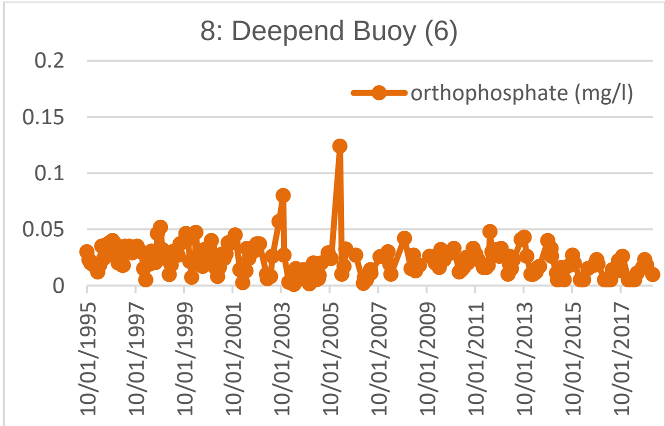

2: East Branch of the Channel (20)
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
09/02/1995
09/02/1997
09/02/1999
09/02/2001
09/02/2003
09/02/2005
09/02/2007
09/02/2009
09/02/2011
09/02/2013
09/02/2015
09/02/2017

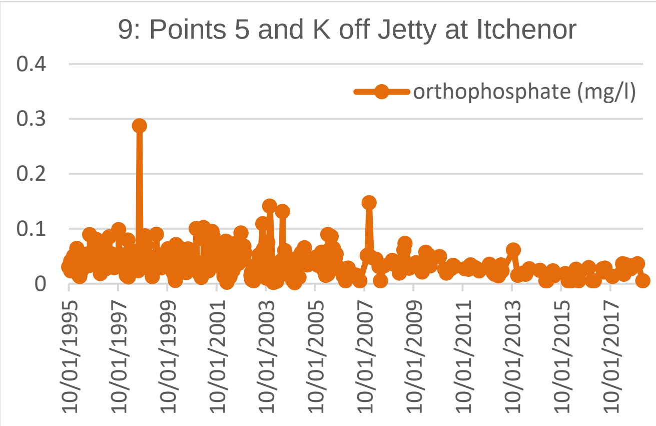

4: Emsworth Channel Shellfish Waters
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017

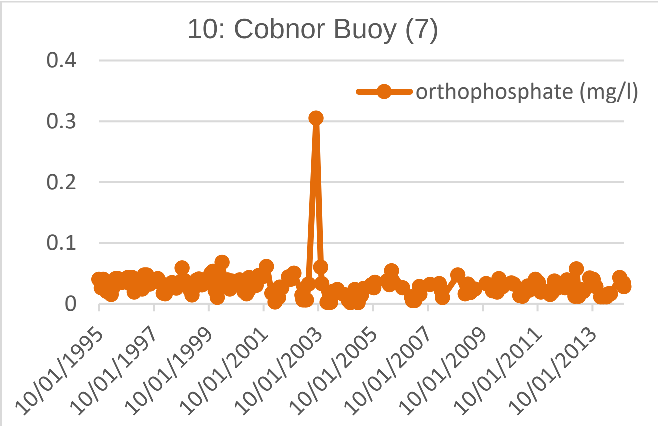

5: Pilsea Island Beacon (12)
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
10/01/1995
10/01/1996
10/01/1997
10/01/1998
10/01/1999
10/01/2000
10/01/2001
10/01/2002
10/01/2003
10/01/2004
10/01/2005
10/01/2006
10/01/2007
10/01/2008
10/01/2009

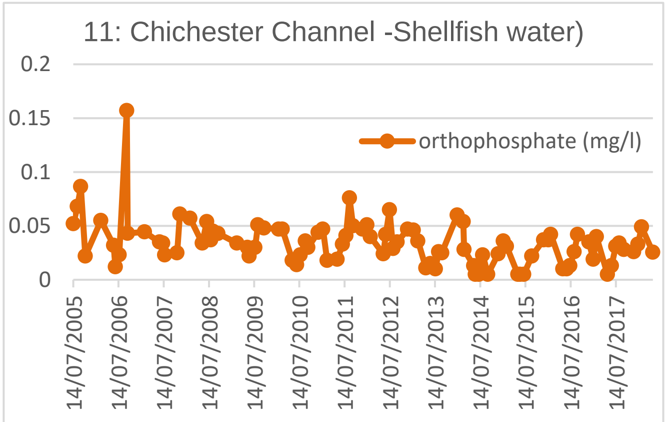

6: Thornham Channel Shellfish Water
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017

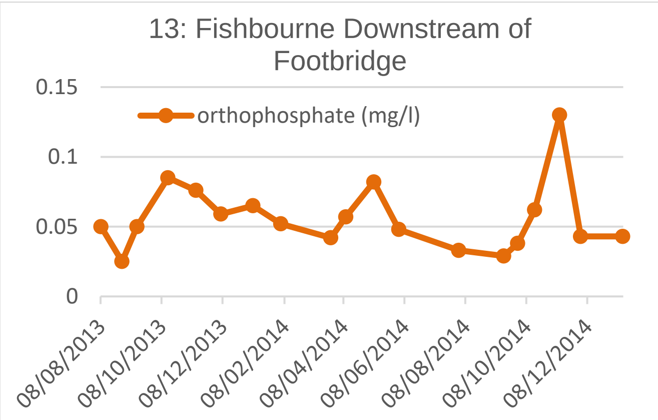

7: Above Great Deeps (9)
orthophosphate (mg/l)
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

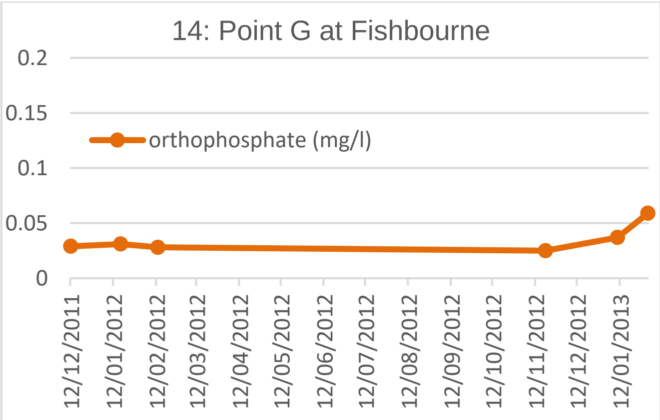

8: Deepend Buoy (6)
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

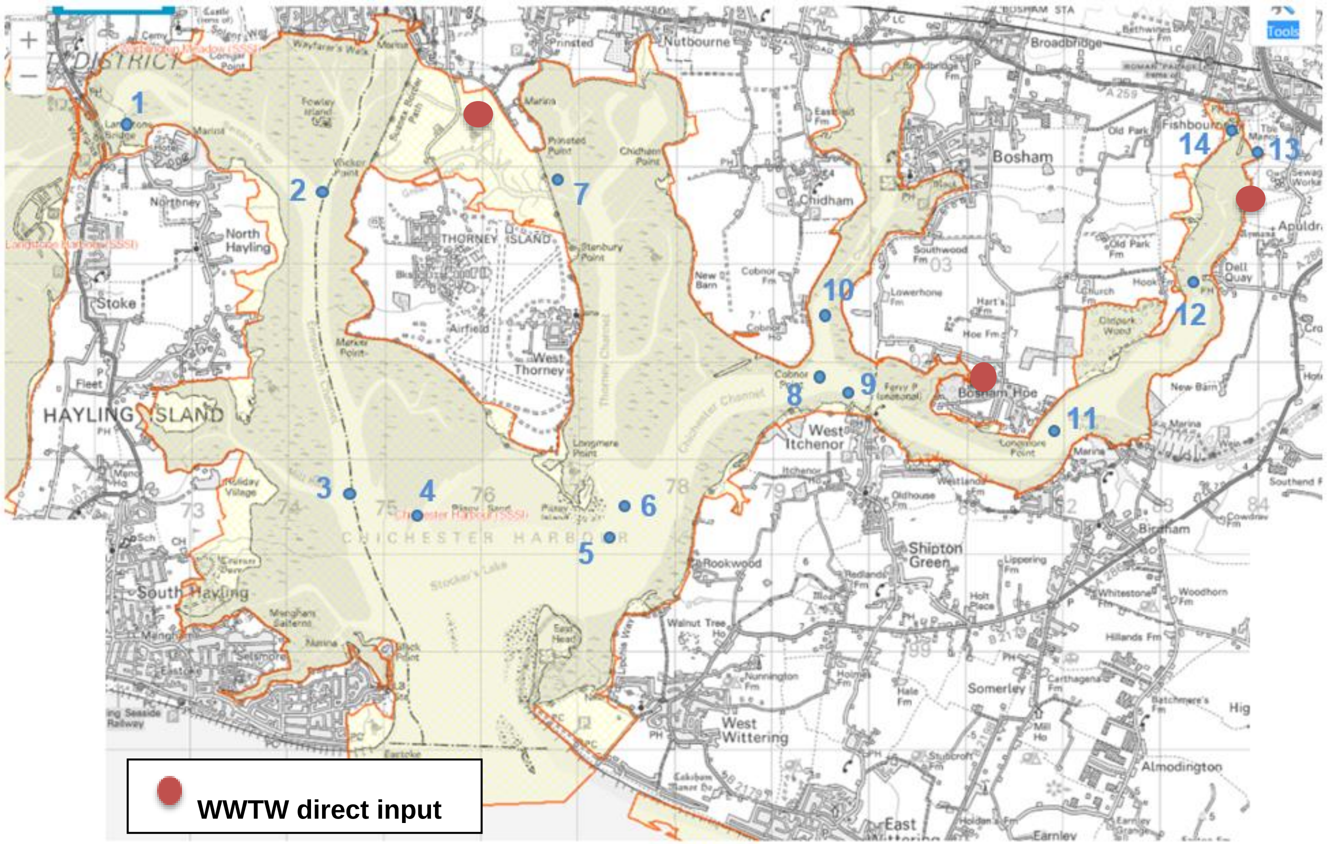

9: Points 5 and K off Jetty at Itchenor
orthophosphate (mg/l)
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

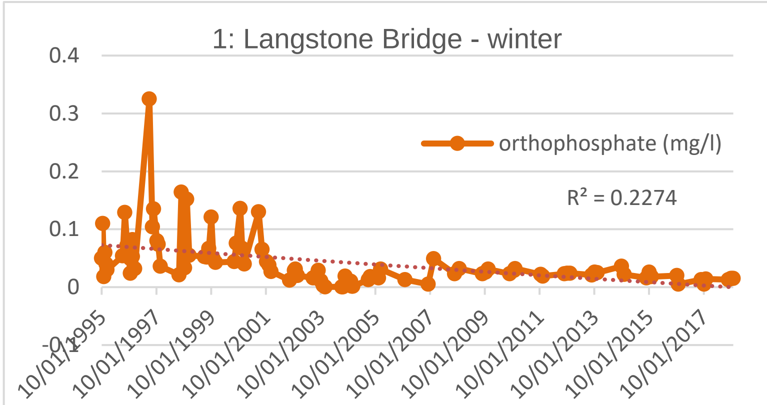

10: Cobnor Buoy (7)
orthophosphate (mg/l)
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013

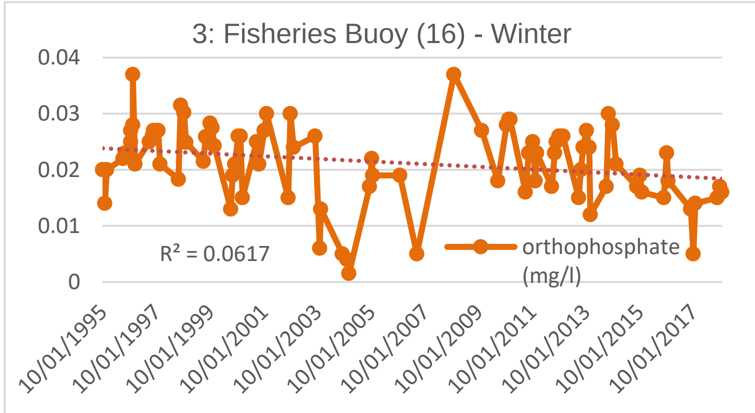

11: Chichester Channel -Shellfish water)
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017


13: Fishbourne Downstream of Footbridge
orthophosphate (mg/l)
0.15
0.1
0.05
0
08/08/2013
08/10/2013
08/12/2013
08/02/2014
08/04/2014
08/06/2014
08/08/2014
08/10/2014
08/12/2014


14: Point G at Fishbourne
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
12/12/2011
12/01/2012
12/02/2012
12/03/2012
12/04/2012
12/05/2012
12/06/2012
12/07/2012
12/08/2012
12/09/2012
12/10/2012
12/11/2012
12/12/2012
12/01/2013







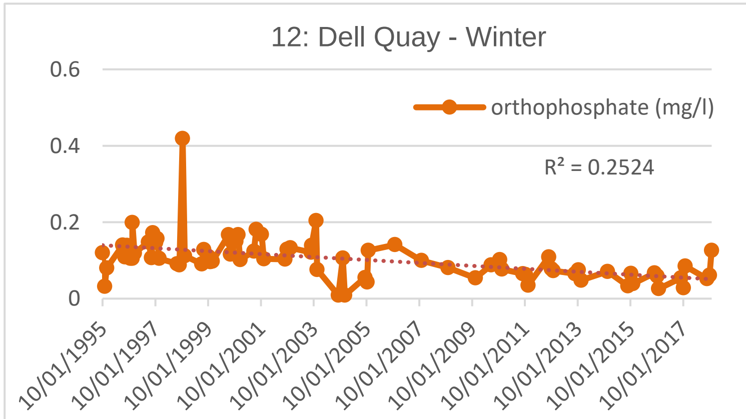
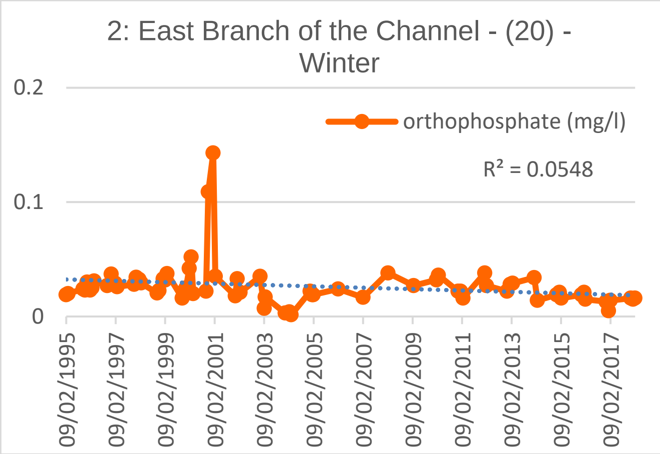
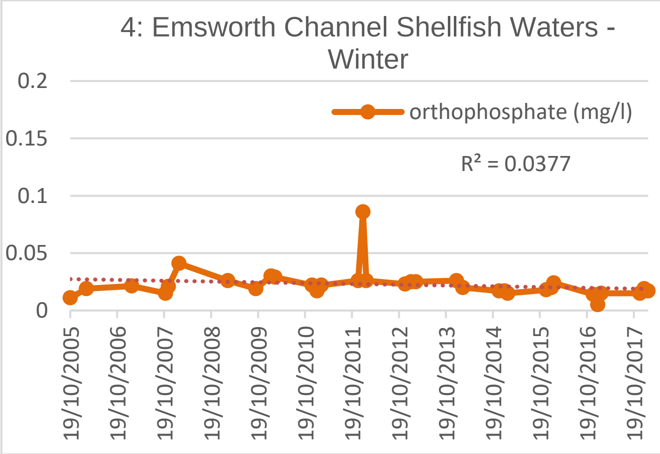
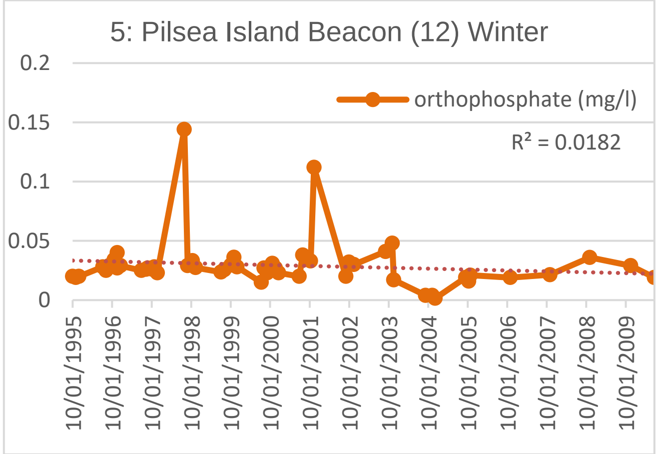
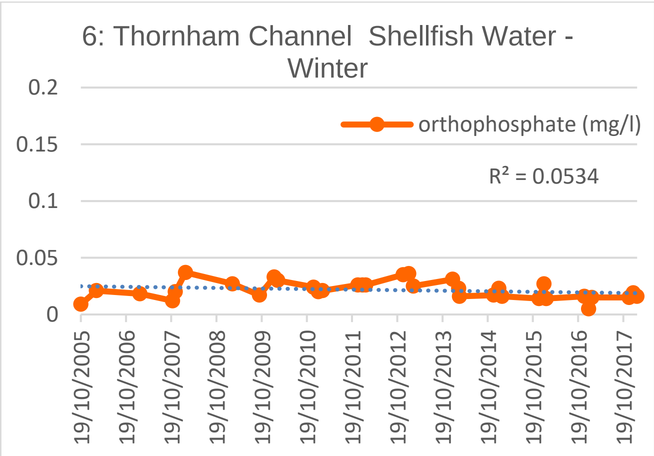


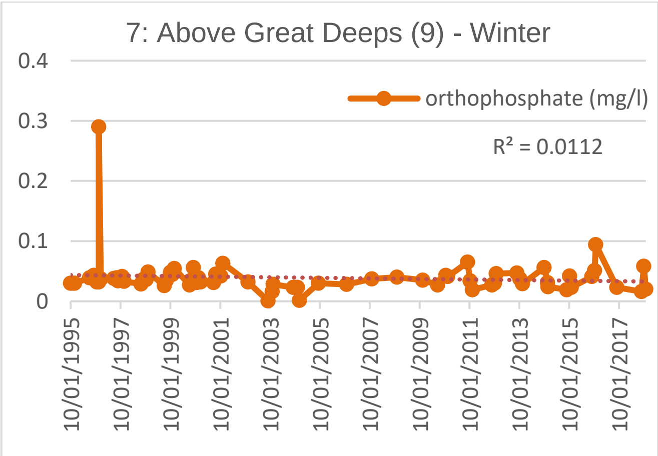
Figure A6.6 Winter Orthophosphate - Chichester Harbour (note scale set at either 0.2 mg/l or if above set by data so varies between graphs)

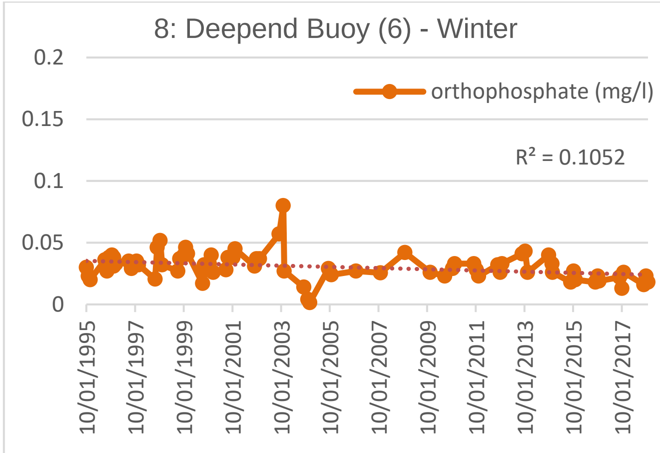

2: East Branch of the Channel - (20) - Winter
orthophosphate (mg/l)
R² = 0.0548
0.2
0.1
0
09/02/1995
09/02/1997
09/02/1999
09/02/2001
09/02/2003
09/02/2005
09/02/2007
09/02/2009
09/02/2011
09/02/2013
09/02/2015
09/02/2017

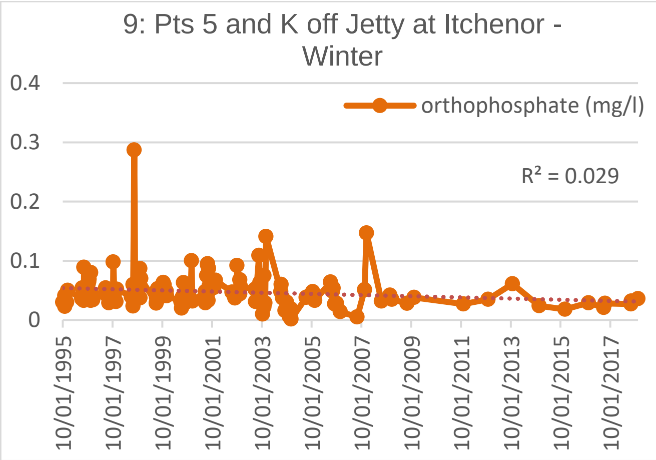

4: Emsworth Channel Shellfish Waters - Winter
orthophosphate (mg/l)
R² = 0.0377
0.2
0.15
0.1
0.05
0
19/10/2005
19/10/2006
19/10/2007
19/10/2008
19/10/2009
19/10/2010
19/10/2011
19/10/2012
19/10/2013
19/10/2014
19/10/2015
19/10/2016
19/10/2017

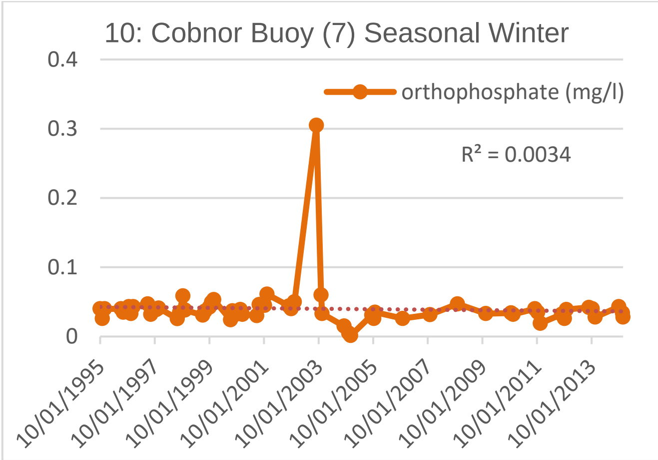

5: Pilsea Island Beacon (12) Winter
orthophosphate (mg/l)
R² = 0.0182
0.2
0.15
0.1
0.05
0
10/01/1995
10/01/1996
10/01/1997
10/01/1998
10/01/1999
10/01/2000
10/01/2001
10/01/2002
10/01/2003
10/01/2004
10/01/2005
10/01/2006
10/01/2007
10/01/2008
10/01/2009

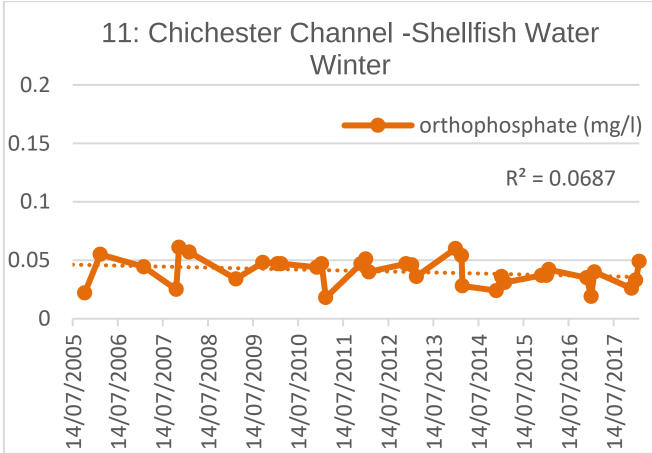

6: Thornham Channel Shellfish Water - Winter
orthophosphate (mg/l)
R² = 0.0534
0.2
0.15
0.1
0.05
0
19/10/2005
19/10/2006
19/10/2007
19/10/2008
19/10/2009
19/10/2010
19/10/2011
19/10/2012
19/10/2013
19/10/2014
19/10/2015
19/10/2016
19/10/2017

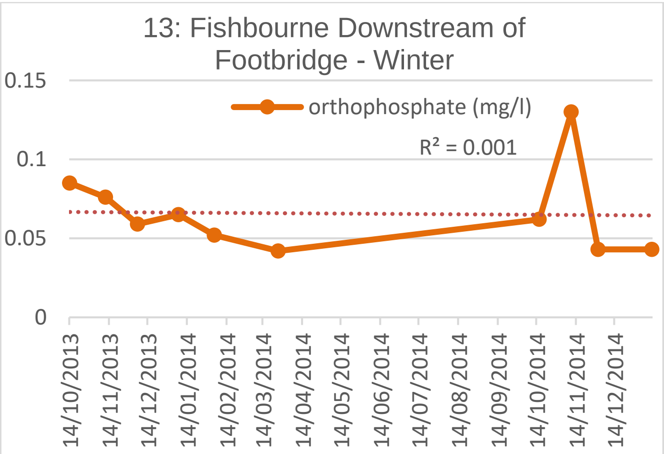

7: Above Great Deeps (9) - Winter
orthophosphate (mg/l)
R² = 0.0112
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

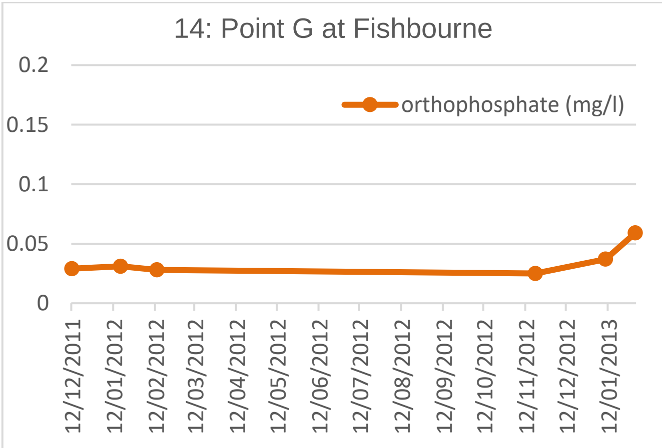

8: Deepend Buoy (6) - Winter
orthophosphate (mg/l)
R² = 0.1052
0.2
0.15
0.1
0.05
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

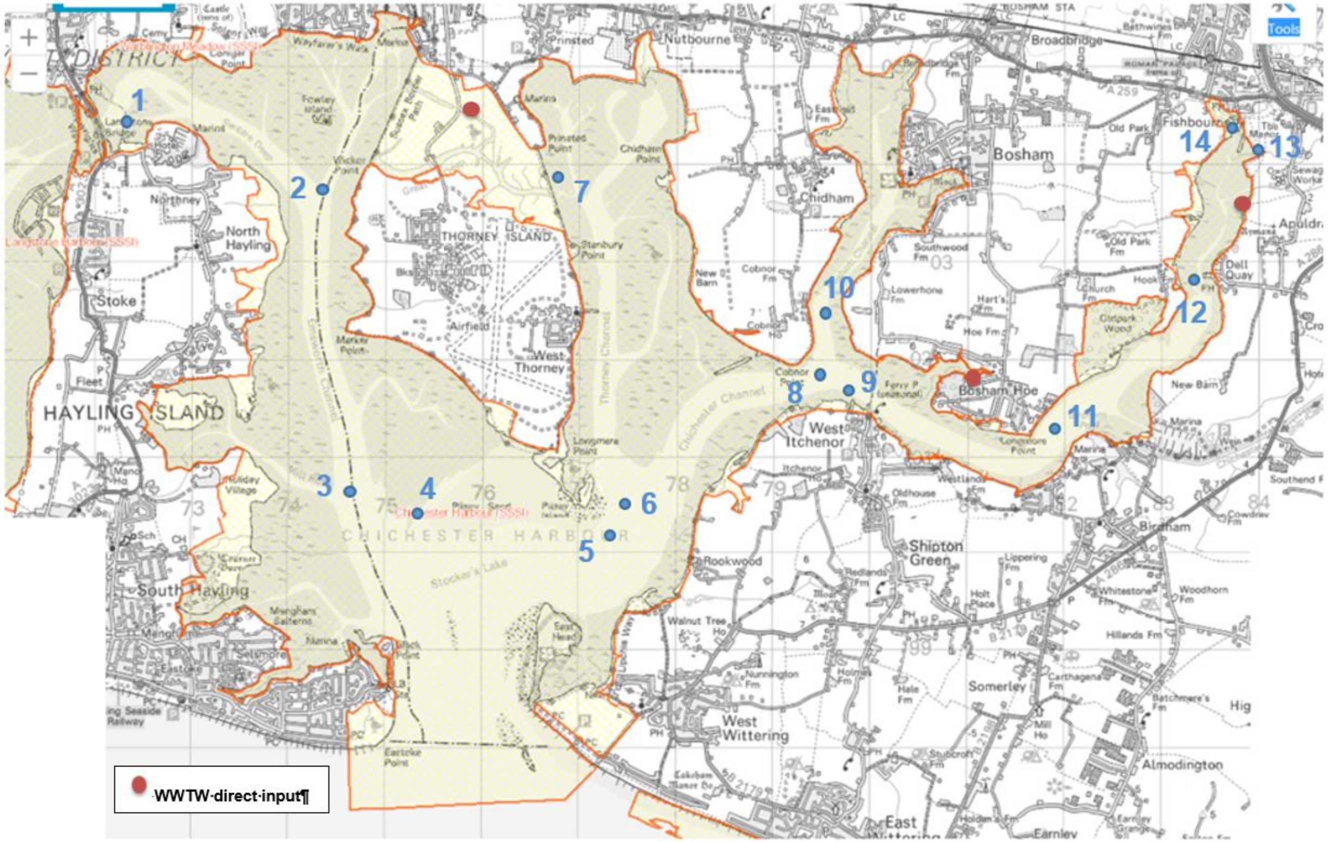

9: Pts 5 and K off Jetty at Itchenor - Winter
orthophosphate (mg/l)
R^2 = 0.029
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017

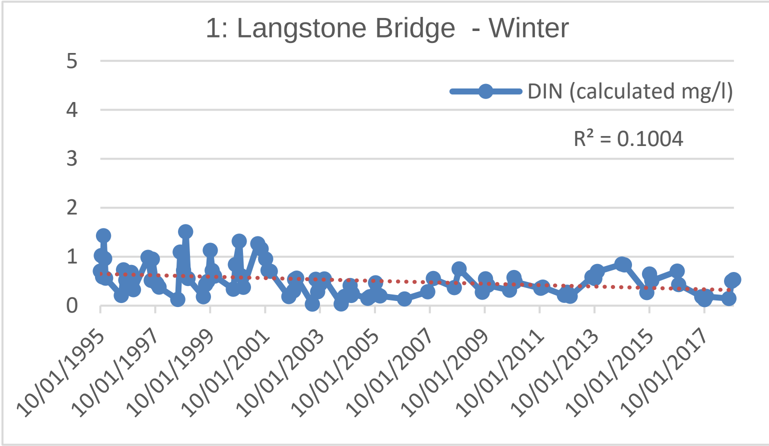

10: Cobnor Buoy (7) Seasonal Winter
orthophosphate (mg/l)
R^2 = 0.0034
0.4
0.3
0.2
0.1
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013

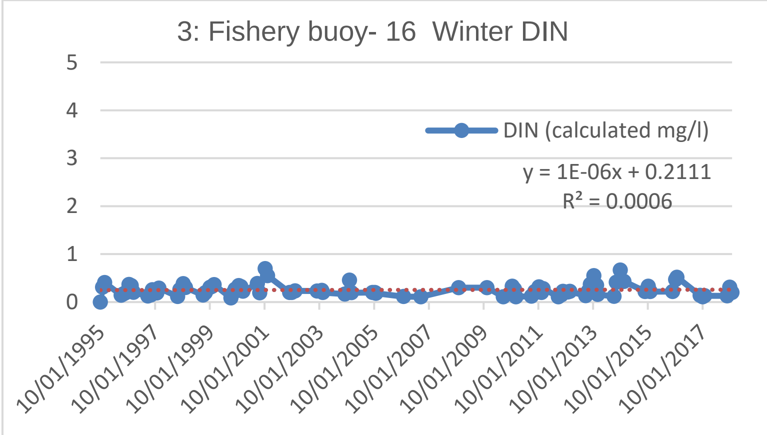

11: Chichester Channel -Shellfish Water Winter
orthophosphate (mg/l)
R^2 = 0.0687
0.2
0.15
0.1
0.05
0
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017


13: Fishbourne Downstream of Footbridge - Winter
orthophosphate (mg/l)
R^2 = 0.001
0.15
0.1
0.05
0
14/10/2013
14/11/2013
14/12/2013
14/01/2014
14/02/2014
14/03/2014
14/04/2014
14/05/2014
14/06/2014
14/07/2014
14/08/2014
14/09/2014
14/10/2014
14/11/2014
14/12/2014


14: Point G at Fishbourne
orthophosphate (mg/l)
0.2
0.15
0.1
0.05
0
12/12/2011
12/01/2012
12/02/2012
12/03/2012
12/04/2012
12/05/2012
12/06/2012
12/07/2012
12/08/2012
12/09/2012
12/10/2012
12/11/2012
12/12/2012
12/01/2013







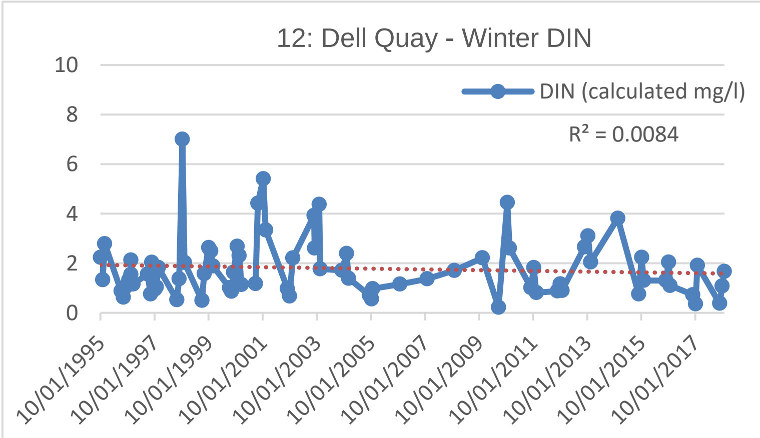
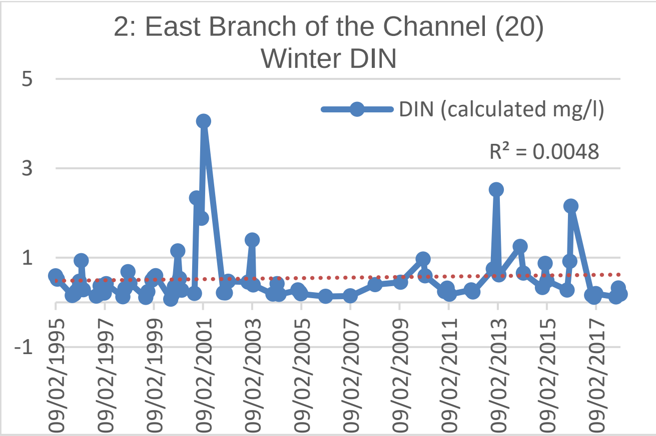
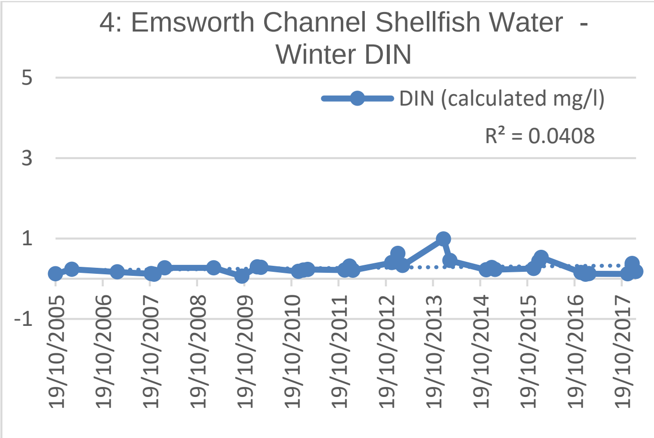
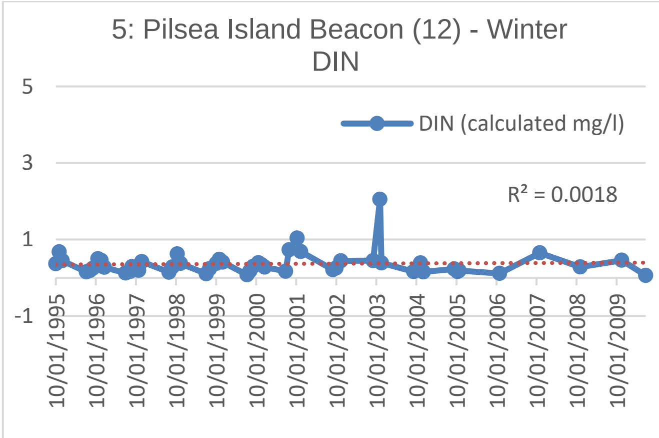
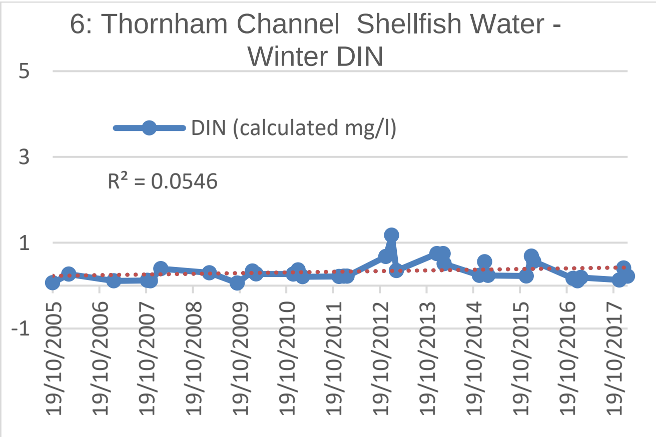


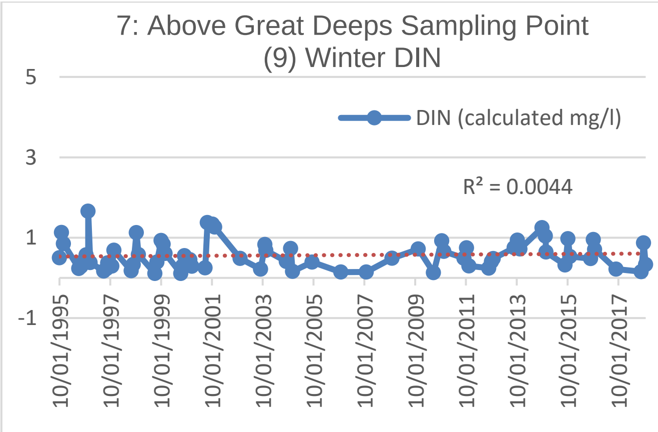
Figure A6.7 Winter Dissolved Inorganic Nitrogen - Chichester Harbour (note scale set at either 5 mgl-1 or 10mgl-1 so trends can be seen)

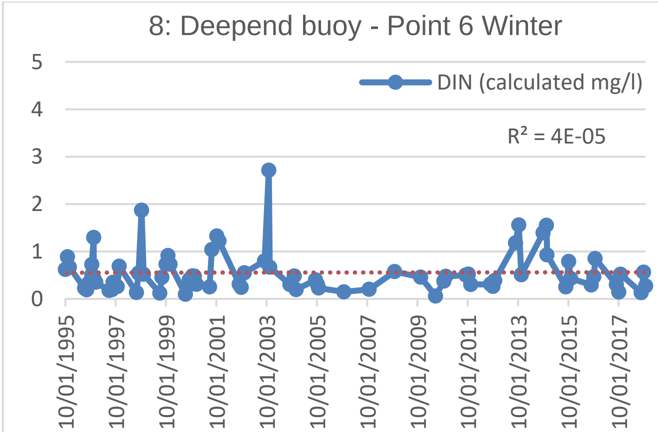

2: East Branch of the Channel (20) Winter DIN
DIN (calculated mg/l)
R² = 0.0048

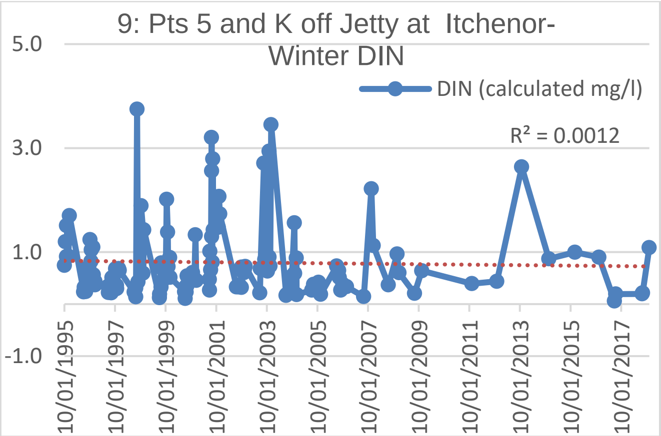

4: Emsworth Channel Shellfish Water - Winter DIN
DIN (calculated mg/l)
R² = 0.0408

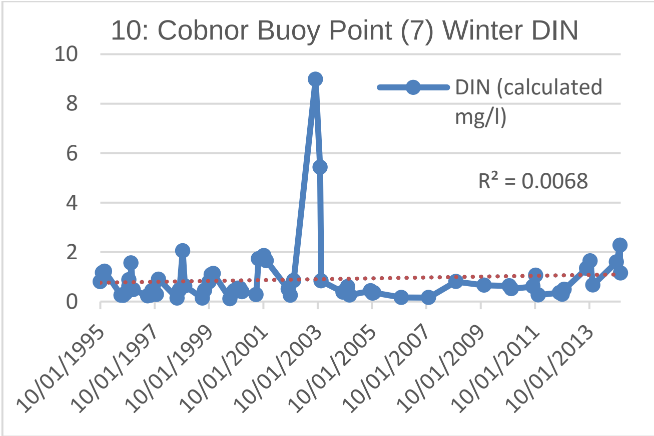

5: Pilsea Island Beacon (12) - Winter DIN
DIN (calculated mg/l)
R² = 0.0018

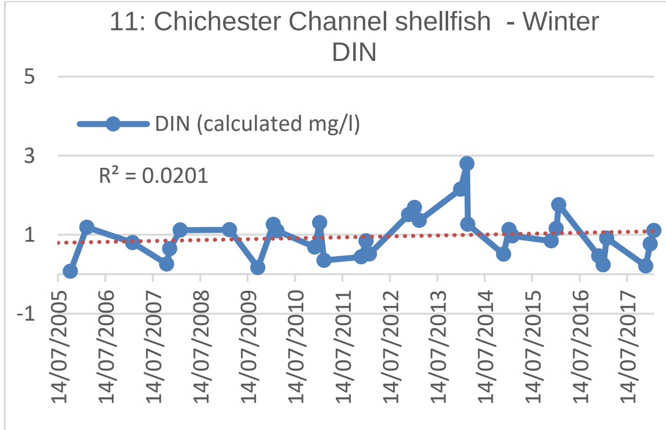

6: Thornham Channel Shellfish Water - Winter DIN
DIN (calculated mg/l)
R² = 0.0546

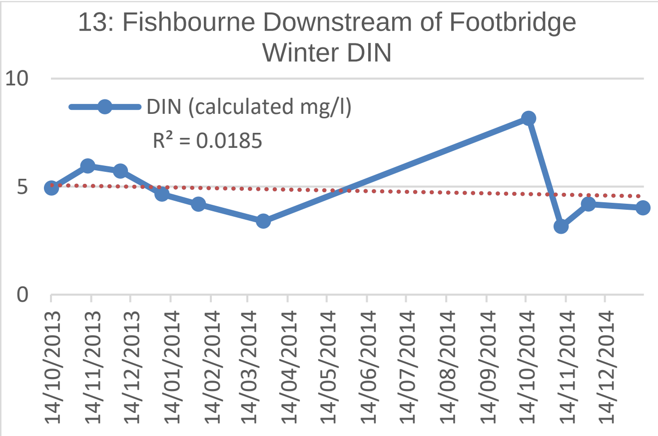

7: Above Great Deeps Sampling Point (9) Winter DIN
DIN (calculated mg/l)
R² = 0.0044

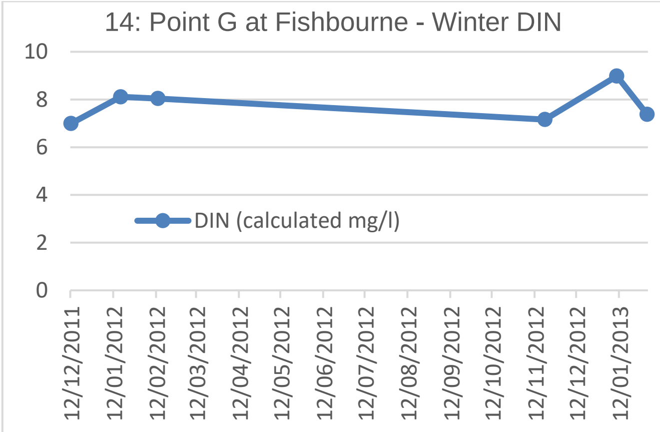

8: Deepend buoy - Point 6 Winter
DIN (calculated mg/l)
R² = 4E-05


9: Pts 5 and K off Jetty at Itchenor- Winter DIN
DIN (calculated mg/l)
R² = 0.0012
5.0
3.0
1.0
-1.0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013
10/01/2015
10/01/2017


10: Cobnor Buoy Point (7) Winter DIN
DIN (calculated mg/l)
R² = 0.0068
10
8
6
4
2
0
10/01/1995
10/01/1997
10/01/1999
10/01/2001
10/01/2003
10/01/2005
10/01/2007
10/01/2009
10/01/2011
10/01/2013


11: Chichester Channel shellfish - Winter DIN
DIN (calculated mg/l)
R² = 0.0201
5
3
1
-1
14/07/2005
14/07/2006
14/07/2007
14/07/2008
14/07/2009
14/07/2010
14/07/2011
14/07/2012
14/07/2013
14/07/2014
14/07/2015
14/07/2016
14/07/2017


13: Fishbourne Downstream of Footbridge Winter DIN
DIN (calculated mg/l)
R² = 0.0185
10
5
0
14/10/2013
14/11/2013
14/12/2013
14/01/2014
14/02/2014
14/03/2014
14/04/2014
14/05/2014
14/06/2014
14/07/2014
14/08/2014
14/09/2014
14/10/2014
14/11/2014
14/12/2014


14: Point G at Fishbourne - Winter DIN
DIN (calculated mg/l)
10
8
6
4
2
0
12/12/2011
12/01/2012
12/02/2012
12/03/2012
12/04/2012
12/05/2012
12/06/2012
12/07/2012
12/08/2012
12/09/2012
12/10/2012
12/11/2012
12/12/2012
12/01/2013