Overview of Solent Eutrophication and Recovery

Preface

Report signals hope for the recovery of the Solent

Eutrophication occurs where increased nutrients in the water result in excessive plant growth, seen in the Solent as green macroalgal mats which cover intertidal mudflats, negatively affecting the ecology and the designations.

This report shows, at the larger waterbody scale for the purposes of the Water Framework Directive, a reduction in the amount of macroalgae within the estuaries of the Solent, compared to the last two decades. The report concludes that recovery from eutrophication in parts of the Solent area is well underway. These changes are the result of a range of nutrient reduction measures introduced at wastewater treatment works and through changes in agricultural practice over the last 20 years.

Looking at more local (feature) scale for the purposes of the Habitats Directive we still see the impacts on designated features from nutrients, as featured in Natural England's condition assessments. Within Chichester Harbour, areas of macroalgae are still common at the top reaches of the Harbour arms where there are shallow and sheltered waters being fed by nutrients from local streams.

This report and Natural England's Condition Assessments for Chichester Harbour sites identify the need to continue work to reduce these nutrient inputs further and address the localised areas of macroalgae coverage. However, this report provides hope for the future of the Solent and its harbours by demonstrating that investment in nutrient reduction measures can, with time, result in positive changes for the environment.

Working in partnership with groups such as the Harbours Summit, Chichester Harbour Protection and Recovery of Nature (CHaPRoN), Solent Forum and the Solent Seascape Project presents an opportunity to direct more funding and action to support further improvements in the Solent environment to increase resilience and aid nature recovery across its designated sites. The Environment Agency and Natural England will continue to work together with our partners to achieve this recovery.

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1. Background

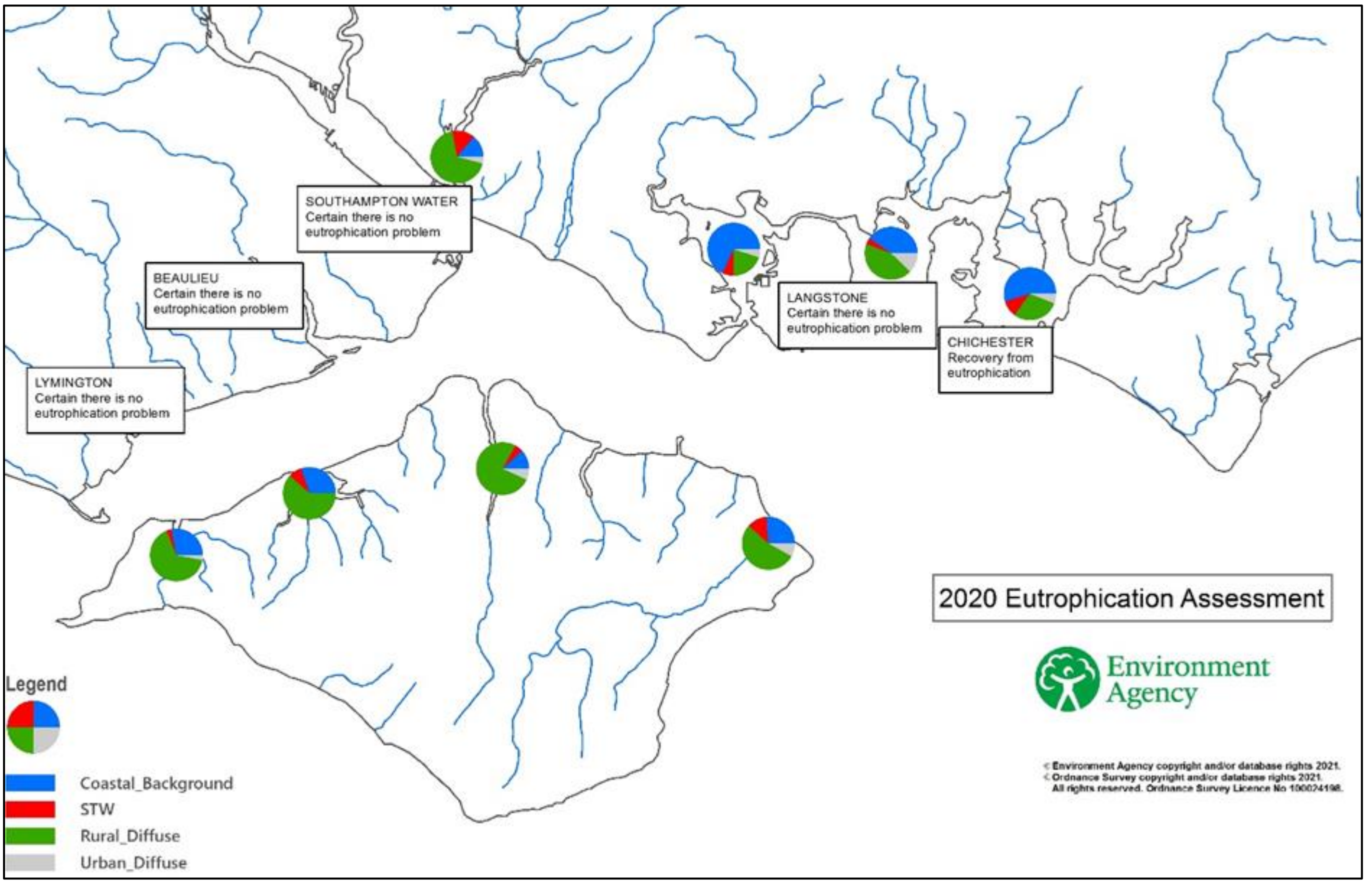
Nitrogen enrichment (especially nitrate) in some Solent estuaries has contributed to the excessive growth of green macroalgae on intertidal mudflats (Figure 1) which can have adverse effects on ecology, eg impacts on birds. This process is known as eutrophication.

Figure 1 Green macroalgae (Chichester Harbour)

Levels of nitrate in the Solent are not high but they are sufficiently elevated to stimulate plant growth in some locations, adversely affecting the ecology. There are much higher nitrate levels elsewhere around the UK (eg Thames estuary) with no adverse effect on ecology. The Solent does not suffer from problem phytoplankton blooms.

Source apportionment work has confirmed that the main sources of nitrogen (N) to Solent estuaries are diffuse sources from agriculture (on average about 50% N is from agriculture, often via rivers) and point sources from sewage discharges (on average about 10% N is from sewage). The remainder includes coastal background and urban sources. The exact proportions vary between different estuaries. Figure 2 shows the proportion of N sources in estuaries around the Solent and highlights the estuaries where there are no eutrophication impacts at waterbody scale, as levels of macroalgae achieve Good status under the Water Framework Directive (WFD).

Figure 2 Sources of Nitrogen into Solent Estuaries



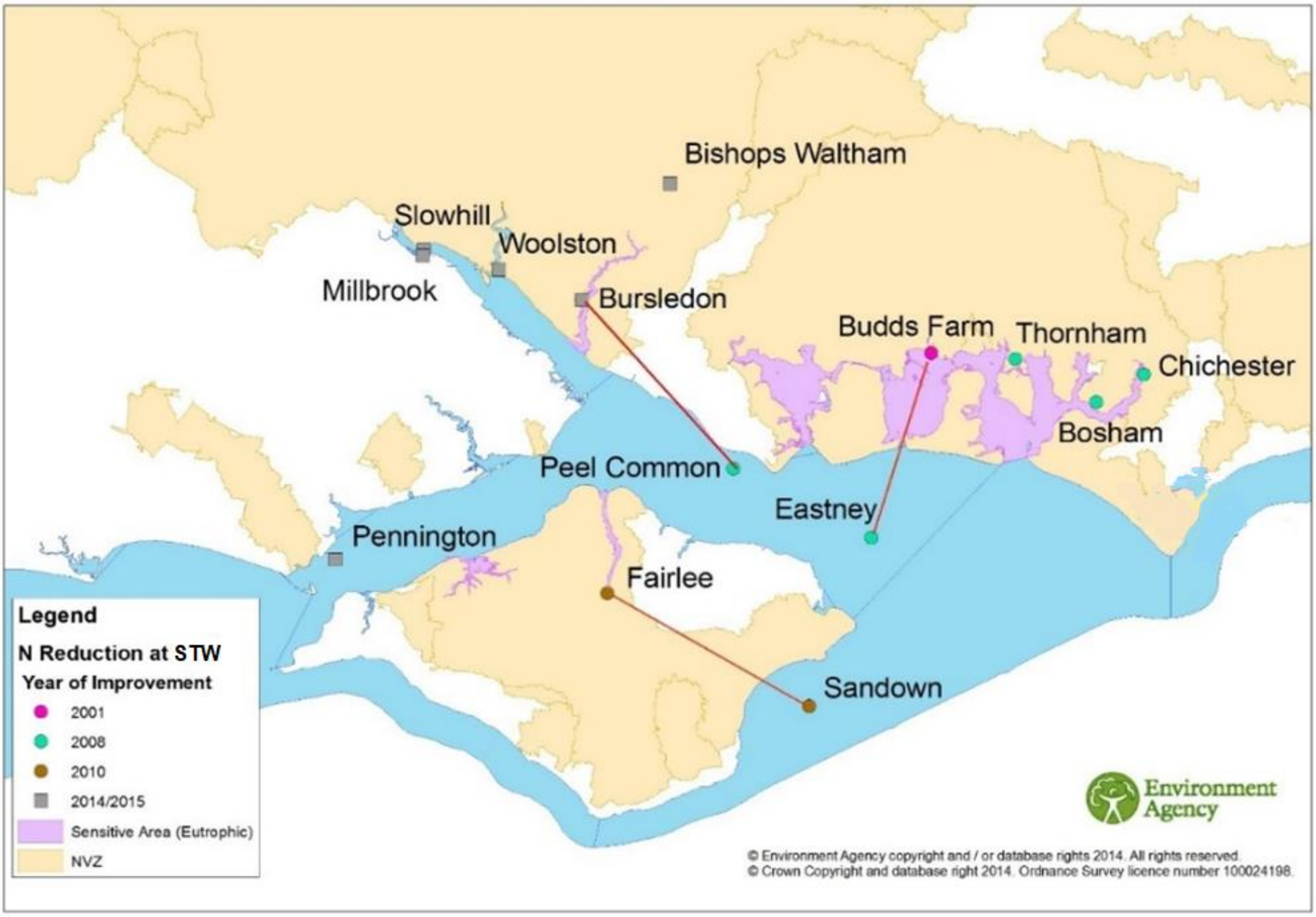
Notes: *STW = Sewage Treatment Works*
Boxes show estuaries with no eutrophication impacts, based on the 2020 EA Weight of Evidence Eutrophication Assessment
Where stated 'no eutrophication problem', this is assessed at waterbody scale

2. Nutrient reductions

2.1 Nutrient reduction measures

The Environment Agency has been aware for several decades of eutrophication in some Solent estuaries. Consequently, during this time we have undertaken a series of eutrophication reviews and used regulatory means to reduce nitrogen inputs (see Appendices 1 & 2). These have included putting in place permits that require N reductions from both marine and riverine sewage discharges (via the Urban Waste Water Treatment Directive [UWWTD] and Habitats Directive) and reducing N inputs from agriculture (via the Nitrates Directive, which enabled designation of Nitrate Vulnerable Zones [NVZ] and subsequent actions required by farmers). Figure 3 summarises the designated eutrophic areas in the Solent and the regulatory measures that have been used to reduce N inputs.

Figure 3 Solent designated Sensitive Areas (Eutrophic) and locations of regulatory Nitrogen reductions



Notes: STW = Sewage Treatment Works
The Eastern Yar (Bembridge Harbour) also has a eutrophication designation – it is a Polluted Water (Eutrophic)
Woolston STW improvement (planned for 2014/15) was delayed until 2018

Figure 3 shows that most of the Solent is a designated NVZ, especially those areas that drain to eutrophic waters. The NVZ designations occurred in 2008 so for many years subsequently, landowners in NVZs have had to reduce N inputs to water. A 2015 study by ADAS[1] suggests that as a result of NVZ designations in the Solent area, N inputs from agriculture to Solent estuaries have decreased by 8% on average. Voluntary measures such as Catchment Sensitive Farming and Environmental Stewardship schemes have resulted in additional, smaller reductions.

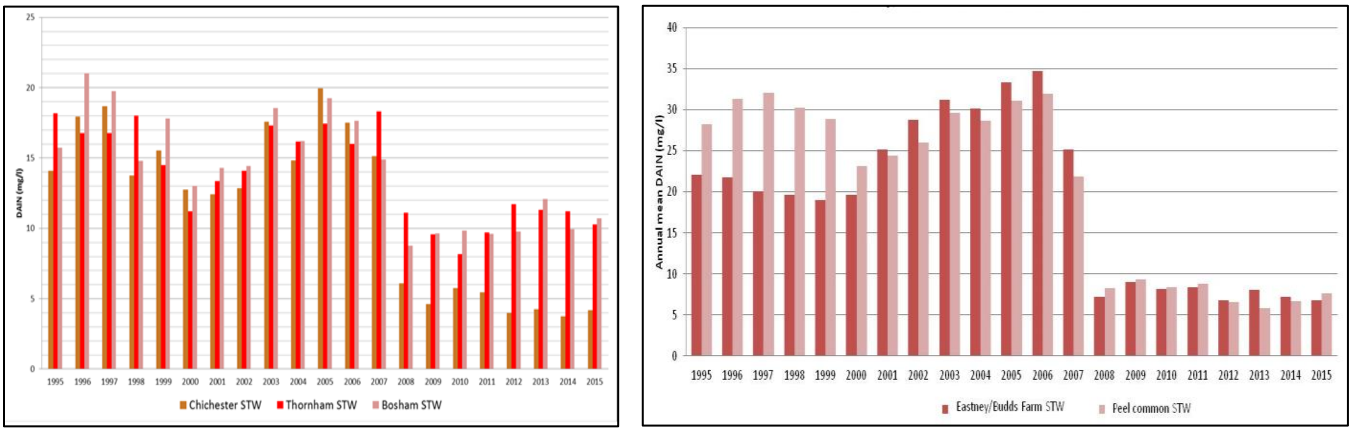
Figure 3 also shows the 11 sewage treatment works discharges to marine/estuarine waters that have had N reductions via changes to their permits, and the 3 sewage discharges that have been moved out of estuaries (brown lines). These improvements have been delivered between 2001 and 2018, so some have had time to contribute to environmental improvement while others are too recent.

2.2 Nutrient changes from STWs

EA data confirms that where N permits have been put in place, N concentration in the discharge has generally decreased by over half, although this varies with individual STW discharges. Figure 4 shows an example of the decrease in N from some of these discharges. Significant reductions in N loads from STW discharges have occurred throughout the Solent area, despite population growth in the catchments. N permit reductions were based on each STW's 'fair-share' contribution to eutrophication and the permits included a small allowance for development growth up to 'headroom'.

Figure 4 Nitrogen reductions at example sewage discharges that were improved in 2008

(i) Discharges into Chichester Harbour (ii) Discharges into the Solent

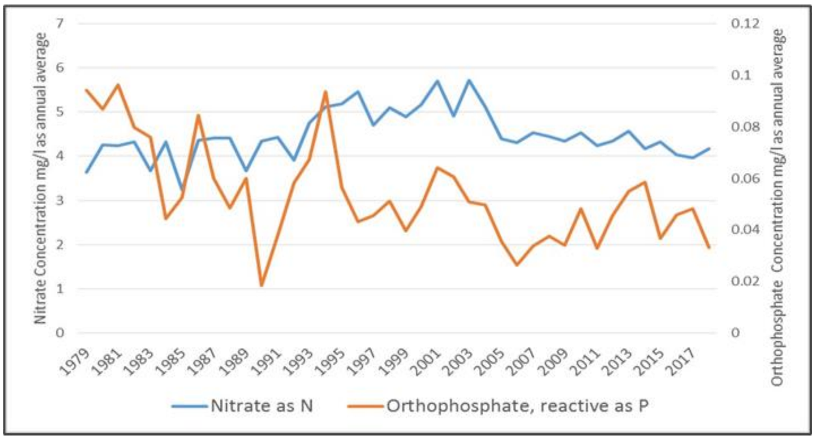


Note: N is expresses as DAIN (Dissolved Available Inorganic Nitrogen) in µg/l

2.3 Nutrient changes in rivers and groundwaters

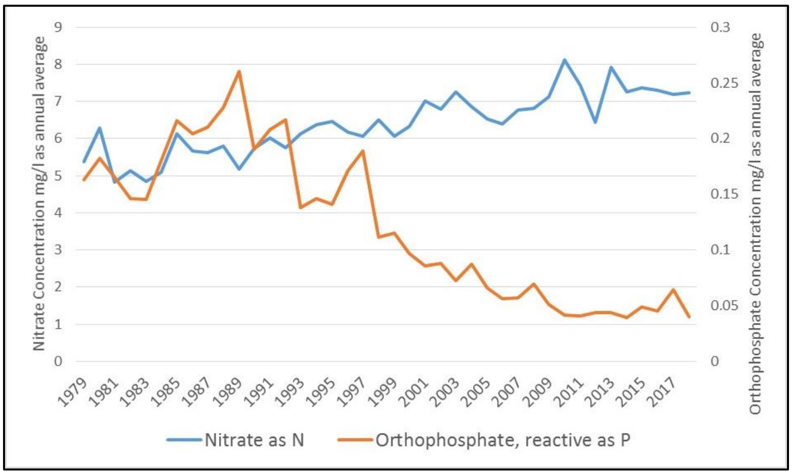
Many Solent rivers are now decreasing in N. In addition, most Solent rivers are decreasing in phosphorus (P), mostly as phosphate, due to improvements at STWs (due to tighter permits) and reductions in P from detergents over many years. (P is also a plant nutrient and is needed for growth; P tends to be the limiting nutrient for plant growth in freshwaters whereas in saline waters N is usually the limiting nutrient). Figure 5 shows slowly reducing concentrations of N in the River Medina since its peak in 2001, along with a general trend of reduced P over a longer period.

Figure 5 Trends in concentrations of N and P in the River Medina (at Shide Weir)



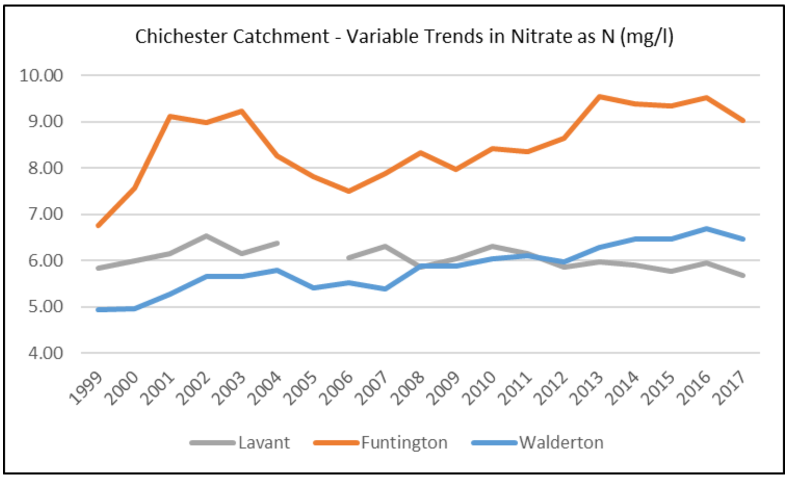
However, some rivers like the Test & Itchen have chalk geology so are strongly fed by groundwater which can 'hold up' historic N for many years, and so N in these rivers is still increasing. Current N concentrations in such rivers reflect historic farming practices. Figure 6 shows N and P concentrations in the River Test where N continues to rise due to the influence of groundwater, but P (which is naturally low in groundwater and not 'held up') is reducing due to improvement actions in the catchment.

Figure 6 Trends in concentrations of N and P in the River Test (at Testwood)



In other groundwater within Solent catchments, N has already started to reduce. For example, in the Chichester catchment, in the relatively young groundwater at Lavant, peak nitrate levels have already occurred and groundwater N levels are now reducing (Figure 7). In the same catchment at Funtington, N is predicted to peak soon (around 2023) then reduce slowly, whereas at Walderton, where much of the groundwater is older, nitrate peaks are still about a decade away.

Figure 7 Different trends in concentrations of N in Groundwater within the Chichester Catchment



In summary, river and groundwater N trends vary throughout the Solent catchments, depending on factors including geology and when improvements came on-line. However, recent evidence from EA studies confirms that overall N loads to Solent estuaries have significantly decreased over the last 20 years, as detailed in the following section.

2.4 Overall decreases in nutrient loads to estuaries

In 2020 the EA undertook modelling work[2] in Solent estuaries to review eutrophication issues. As part of this work, actual monitored nutrient loads were assessed from two different time periods approximately 20 years apart:

- Baseline (circa 1997-2000, prior to any significant improvement work)
- Present Day (circa 2015-2019)
  Note that the precise dates varied between estuaries, as they were chosen to reflect both the timing of improvement works and the available data sets.

This assessment confirmed that there have been significant overall reductions in both N and P loads to Solent estuaries, as summarised in Figures 8 and 9. For example, in Langstone Harbour the N load has decreased by 49% and the P load by 75 %. (Langstone Harbour was the earliest site to benefit from nutrient reductions because a direct discharge from STW was transferred outside the estuary and into the Solent in 2001, in addition to tightening the N permit). These load reductions are a result of all the measures that have occurred over a long period in the Solent catchments.

In general P loads to estuaries have decreased more than N because STW are a main source of P and these have been highly regulated, so P (mostly as phosphate) is decreasing in most of the Solent area rivers, as previously explained. The biggest P decreases are in the estuaries where sewage discharges were diverted out of the estuaries in Langstone Harbour (75% P load decrease), Medina estuary (77%) and Hamble estuary (66%).

In contrast, much of the N load to Solent estuaries comes from diffuse inputs from agriculture which are harder to reduce. In addition, in areas of the Solent that are strongly influenced by N-rich groundwater, rivers may still be rising in N due to historical agricultural inputs; eventually, when younger water starts to come through, N in these rivers will reduce and contribute further to the N load reductions in the estuaries. Nevertheless, overall, over a 20 year period, it is evident that N loads have significantly reduced to all Solent estuaries, despite the influence of groundwater and other factors like development growth in the catchments.

Figure 8 N load reductions to Solent estuaries over approximately 20 years

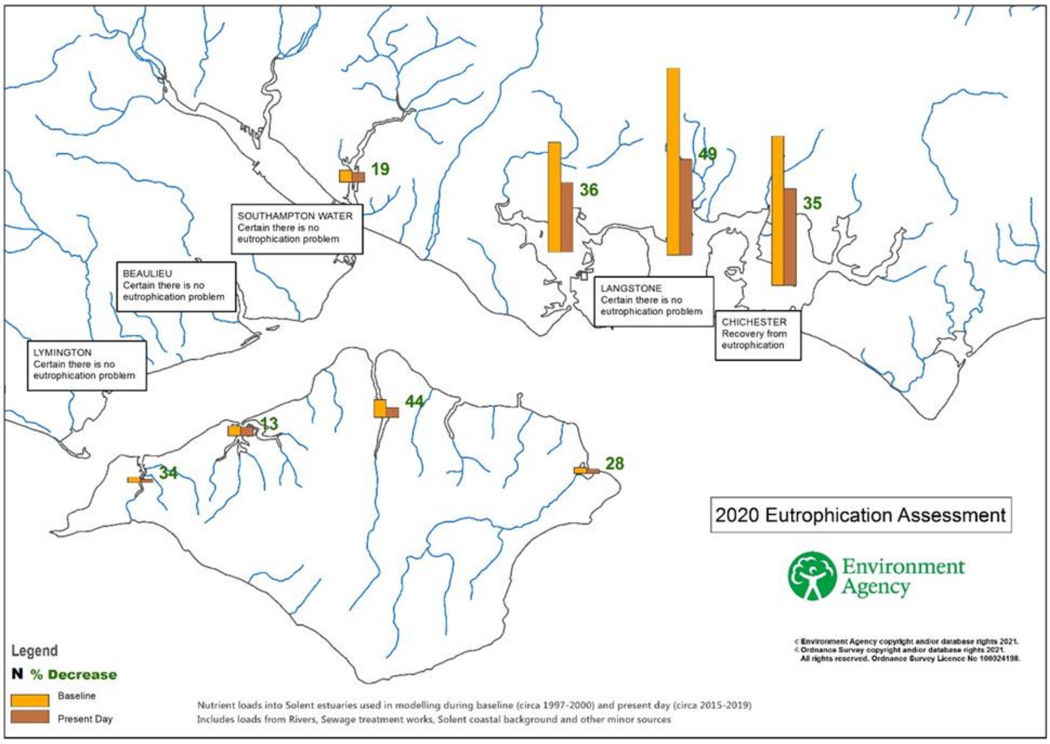
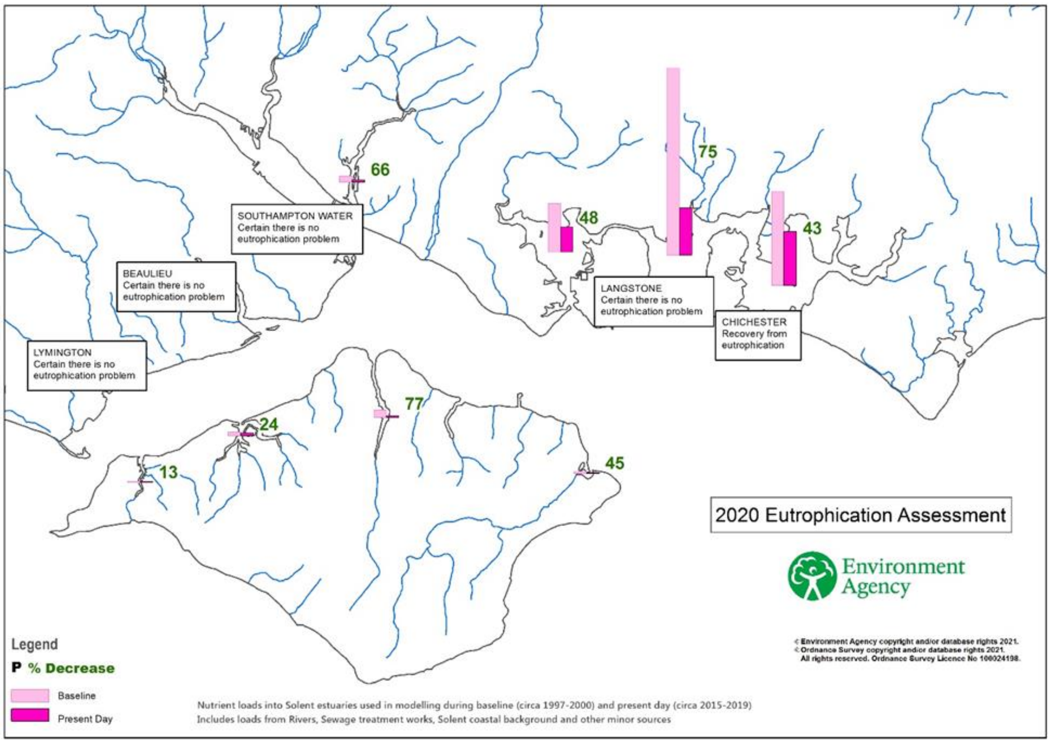


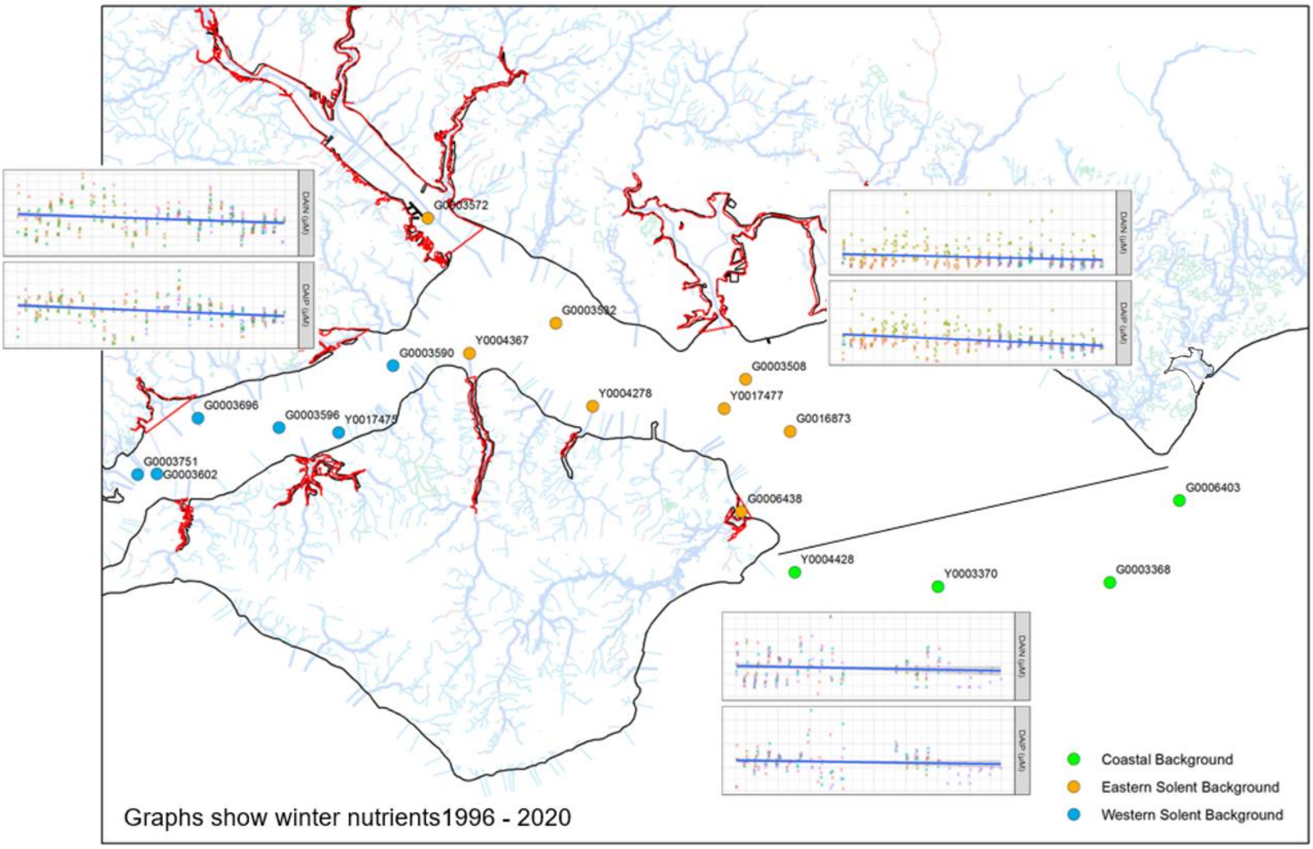
Figure 9 P load reductions to Solent estuaries over approximately 20 years



Notes on Figs 8 & 9: Boxes show estuaries with no eutrophication impacts, based on the 2020 EA Weight of Evidence Eutrophication Assessment Where stated 'no eutrophication problem', this is assessed at waterbody scale

There has also been a trend of decreasing nutrients in the Solent itself, as well as in the coastal background water, due to nutrient reductions from many sources. Figure 10 shows the decreasing nutrient trends in these waters over a 15 year period. Note that coastal background nutrients (green dots) are mostly from the English Channel – see Appendix 3 for further explanation.

Figure 10 Reducing nutrient concentrations in the Western Solent, Eastern Solent and Coastal Background water



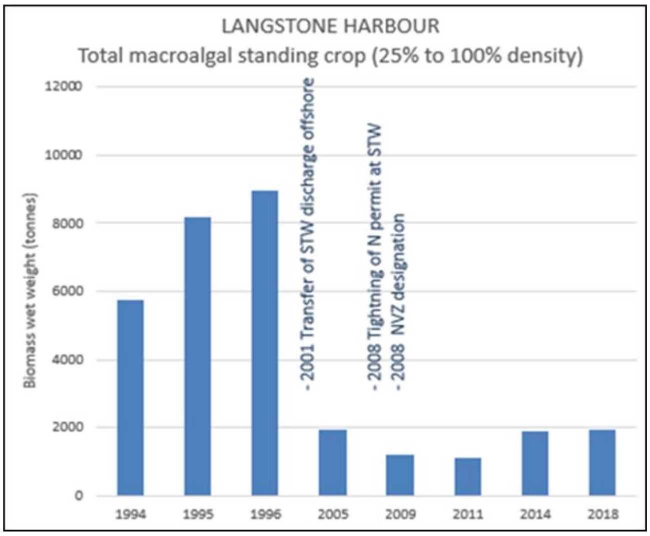
Notes: *N is expressed as DAIN (Dissolved Available Inorganic Nitrogen) in µM*
P is expressed as DAIP (Dissolved Available Inorganic Phosphorus) in µM

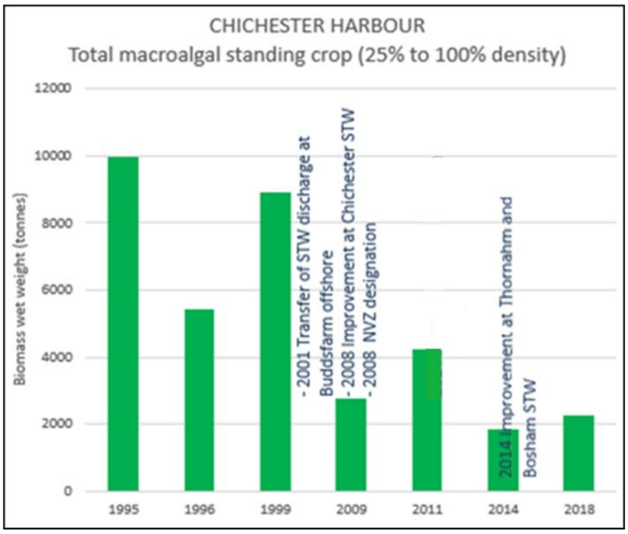
3. Environmental Recovery

As a result of all the reductions in nutrients that have occurred over the last 20 years, we are now seeing reduced amounts of green macroalgae in several Solent estuaries, plus other encouraging signs of recovery. Recovery has taken time due to the influence of groundwater and ecological time lag: the latter is the time it takes a natural system to rebalance and respond following a change.

Figure 11 shows monitoring data illustrating the reduction in macroalgal standing stock in Langstone and Chichester Harbours from 1994/5 to 2018; it also shows the timings of some of the key N reduction measures. Figure 12 shows photographic comparisons illustrating the reduction in macroalgae at fixed monitoring sites in Chichester and Portsmouth Harbours from 2004/2011 to 2019. Note that the amount of macroalgae does vary annually due to environmental factors (eg wet winters increase river flow and flush more nutrients into estuaries which fuel spring growth), but overall the data confirms that these harbours demonstrate sustained reductions in macroalgae compared to historic levels of growth. Indeed, Langstone and Chichester Harbours now meet their target classifications of GOOD status for macroalgae under the Water Framework Directive (WFD) which achieves their Natura 2000 objective set in 2015 (to '*Improve water quality to a level that biological indicators of eutrophication [opportunistic macroalgal and phytoplankton blooms] achieve GOOD WFD overall status').* Natura 2000 objectives that were agreed in 2015 are shown in Appendix 4. Further WFD information and data can be found in the Environment Agency Catchment Data Explorer.

Figure 11 Monitoring data showing reducing macroalgal standing stock in Langstone and Chichester Harbours over time (showing dates of some of the key N reduction measures)



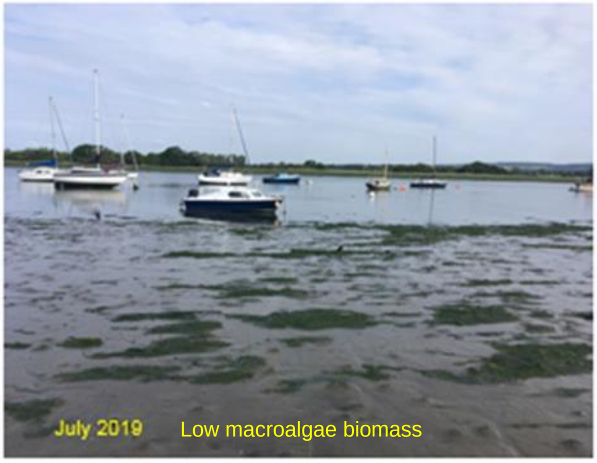


Overall, the Environment Agency uses a 'weight of evidence approach' to assess eutrophication in the estuaries at WFD water body scale and following the most recent (2020) assessment we can say that in Langstone Harbour we are certain there is no longer a eutrophication problem and that Chichester Harbour is recovering from eutrophication. Note that macroalgae is still present in these harbours, but, at water body scale, not at problematic levels.

Figure 12 shows photographic illustrations of the improvements in Chichester and Portsmouth Harbours at the same sites over time.

Figure 12 Photos showing reducing macroalgal cover in Chichester and Portsmouth Harbours at fixed monitoring sites

Chichester Harbour at Dell Quay in July 2011 and July 2019



Portsmouth Harbour at Grove Avenue July 2004 and July 2019

Other significant signs of recovery from eutrophication in Solent estuaries, and signs of improved water quality, include the following:

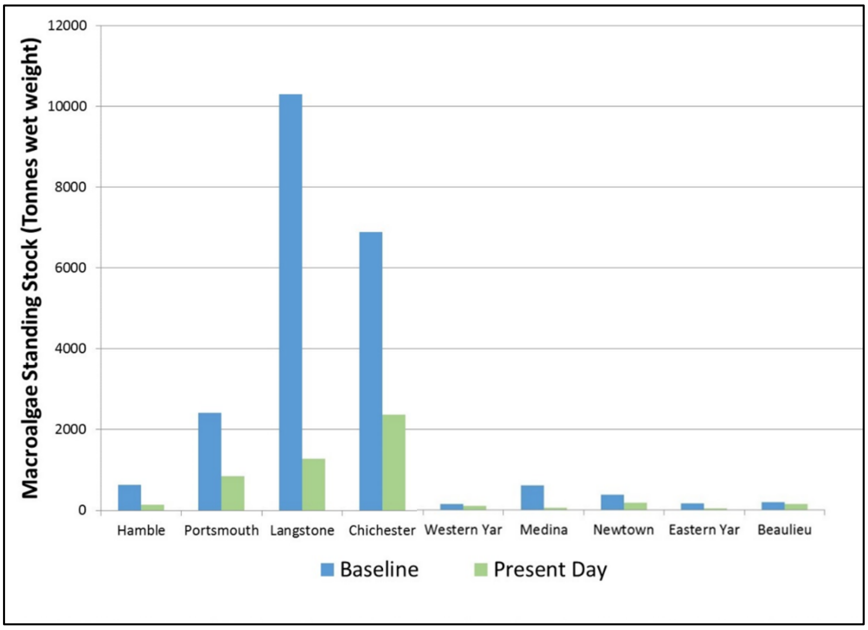
1. Portsmouth Harbour's WFD macroalgae classification has improved and is now on the Good/Moderate boundary. (As already described, Langstone Harbour and Chichester Harbour already meet their target WFD classification of GOOD).
2. In estuaries where buried* macroalgae was recorded frequently (eg Chichester and Portsmouth Harbours) it is no longer found during EA surveys.
3. In estuaries where macroalgae used to persist throughout the winter* months it is now significantly reduced or no longer persists at EA long term survey sites.
4. In Portsmouth Harbour seagrass beds are extending - one of the original macroalgae survey sites is now within a seagrass bed!
5. In Chichester harbour, we recorded seagrass during the 2018 macroalgae survey in locations we have never seen it before.
6. Seahorses are now frequently observed in surveys in Southampton Water and Chichester Harbour.

**See Appendix 5 for notes on the relevance of buried and over wintering macroalgae to environmental recovery.*

4. Modelling work increases confidence

The modelling work[2] referred to above by the EA in 2020 was undertaken to quantify the nutrient contributions from different sources and assess the effect of these nutrients on the trophic status of the estuarine systems. The dynamic Combined Phytoplankton Macroalgal (CPM) models were applied over a baseline period and a present day period, approximately 20 years apart. The results predict significant decreases in overall nutrient loads and macroalgal standing stock in all the estuaries studied. Figure 13 shows the predicted reductions in macroalgal standing stock (tonnes of macroalgae, baseline and present day) from the modelling.

Figure 13 Comparison of predicted baseline and predicted present day macroalgal standing stock



One of the reasons for undertaking the CPM modelling was to evaluate the expected effects of improvements already completed, once historic nutrients have left the system – in other words, because the modelling is not subject to ecological time lag it can predict the full extent of macroalgal reductions. The modelling results conclude that in most of the Solent estuaries there will be further reductions in macroalgae even if no additional nutrient reduction measures are undertaken, particularly in those estuaries where measures occurred more recently. This is because of the ecological time lag before the full extent of reductions will be seen. In addition, in some Solent catchments with chalk geology we'll see further reductions in macroalgae in future, as groundwater N reduces over time.

Finally, the modelling assessed the factors which can limit primary production, (light, space, N, P) and predicted the fraction of the year that each factor limits algal growth. It concludes that some estuaries have experienced significant changes in N:P ratio due to all the improvement measures undertaken and warns that further reductions in P are likely to move the local environment further away from a natural balance. It suggests that the best opportunities to continue controlling algal growth while protecting the wider marine ecosystem are to continue measures to reduce N, to catch up with the improvements which have been made in P and restore a more natural N:P ratio.

Overall, the CPM modelling results support the changes we are seeing in the environment and increase our confidence that the existing nutrient reduction measures are, and will continue to, reduce eutrophication impacts in the Solent.

5. Conclusions

1. A wide range of nutrient reduction measures have been undertaken over the last 20 years in the Solent wide area.

2. As a direct result of these measures, there have been very large reductions in N & P loads into affected estuaries. For example, in Langstone Harbour there has been a 49% reduction in N load and a 75% reduction in P load since the1990s.

3. Consequently, there have been significant reductions in macroalgae (the primary biological indicator of eutrophication) in many Solent estuaries. For example, macroalgae has reduced in Langstone and Chichester Harbours by more than half and both harbours now achieve their WFD target status of GOOD for macroalgae. (However, at a smaller, feature scale, NE condition assessments indicate that in some localised areas macroalgae levels remain higher than required for Habitats Directive purposes). Further WFD information and data can be found in the Environment Agency Catchment Data Explorer.

4. In estuaries where measures started early eg Langstone and Chichester Harbours, there are good signs of recovery; elsewhere it will take longer.

5. Recent modelling supports the improvement we are seeing in the environment – we are now even more confident that existing measures do/will make a measurable difference to eutrophication impacts in the Solent.

6. Modelling confirms that in some harbours there will be further reductions in macroalgae even if no additional nutrient reduction measures are undertaken. This is because there is an ecological time lag before we will see the full extent of reductions. There may still remain pockets where there are more dominant localised influences affecting macroalgal growth.

7. There will be additional future reductions in nitrogen in some areas of the Solent as groundwater N reduces over time.

8. We need to continue catchment measures to tackle the large diffuse agricultural sources of N that affect rivers and groundwater as these are the dominant N sources.

9. Recovery from eutrophication in the Solent area is well underway, with further improvement to come.

6. References

1. ADAS UK Ltd, 'Solent Harbours Nitrogen Management Investigation'. Report for Natural England by Gooday R., Hockridge B. and Lee, D. (March 2015).

2. Environment Agency, OCS Water Quality & SSD Analysis and Reporting Team (Marine) 'Summary of 2020 dynamic CPM modelling in Solent Wide Area, Final Version' (April 2021).

Please send any enquiries about this Overview to the Environment Agency at SSDEnquiries@environment-agency.gov.uk

For data retrieval please use the following links:

Open data, Water Quality archive: http://environment.data.gov.uk/water-quality/view/landing
Open data, Biosys archive: https://data.gov.uk/data/search?q=biosys

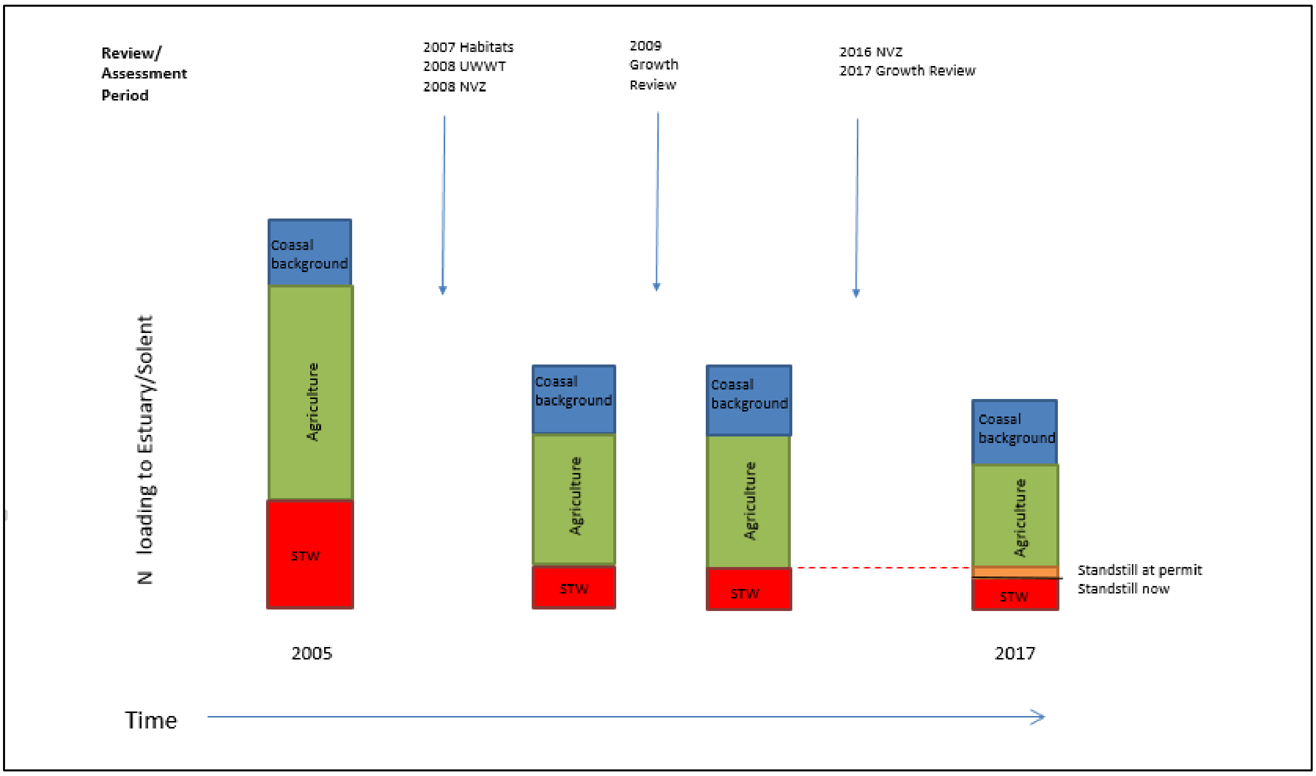
Appendix 1 Timeline of eutrophication reviews/designations and implementation of regulatory measures in the Solent area. (Additional voluntary measures are not shown for clarity).

The Environment Agency frequently reviews what measures are required to protect the Solent marine sites from eutrophication as shown below, most recently including NVZ reviews in 2016 and water industry Periodic Reviews in 2019.

Designations and Reviews	Year	Environmental Status	Regulatory Measures tackling N
	1994	1994 – 2002 Baseline macroalgae and nutrient status	
	1995		
	1996		
	1997		
UWWTD Sensitive Area designations (1998)	1998		
	1999		
Natura 2000 designations (Birds Directive & Habitats Directive)	2000		
	2001		2001 – Eastney/Budds Farm STW improvement and transfer (from Langstone) under UWWTD
UWWTD Sensitive Area designations (2002)	2002		
	2003		
Periodic Review assessments (2004)	2004		
	2005		
	2006		
Habitats Directive Review of Consents (2007)	2007		
UWWTD SA & Nitrates Dir NVZ designations (2008)	2008		2008 – various STW improvements under UWWTD
Population growth assessments (2009) Periodic Review assessments (2009)	2009	2009 - 2014 Interim macroalgae and nutrient status. Too early to see improvements	2009 – NVZ measures tackling diffuse inputs
Diffuse Water Pollution Plans (2010)	2010		2010 – Fairlee STW transfer (Medina)
	2011		
	2012		
	2013		
WFD nutrient Investigations (2014/15)	2014		2014/2015 – Habitats Directive improvements to STWs in Southampton Water and Solent
Periodic Review assessments (2014)	2015		
NVZ Reviews (2016)	2016		
Population growth assessments (2017)	2017	Beginning to see signs of environmental recovery	
	2018		2018 Woolston STW improvement
Periodic Review assessments (2019)	2019		
Solent DWPP Judicial Review (2019/2020)	2020		
	2021		
	2022		
	2023		
	2024		
	2025		
	2026		
	2027		
	2028	Predicted reduction in macroalgae following time lag in groundwater N, uptake of N in sediments etc	
	2029		
	2030		
	2031		
	2032		
	2033		
	2034		
	2035		
	2036		

Note: Different types of designation/review are colour coded for clarity

Appendix 2 Schematic diagram of N reduction and key reviews in the Solent area



Note: arrows are EA reviews, the orange bar represents development growth

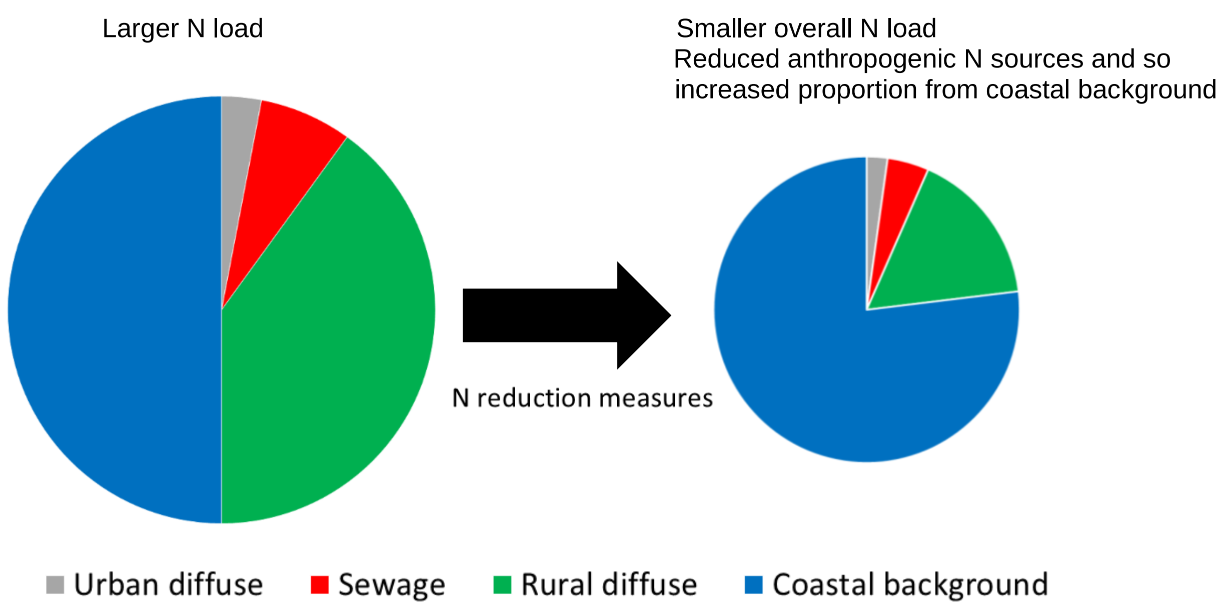
Appendix 3 Note about Coastal Background Nitrogen

Coastal background nitrogen (N) is the 'background' concentration of nitrogen in the sea that enters the Solent on each tide. (This is not the same as the water that enters the estuaries on each tide). The source apportionment for most Solent estuaries shows a large proportion of N from coastal background sources due to the large volume of seawater exchange with each estuary, not because nitrogen concentrations in the sea are high (they are not).

In the Solent source apportionment modelling 'coastal background' N is mostly N from the English Channel, which could be described as 'natural' N (largely non-anthropogenic). However, it does also include other small contributions of N from sources that the models cannot enumerate: these include direct inputs to estuaries and the coast (ie not via rivers) such as direct run-off (urban and rural), direct minor streams and ditches and direct private package sewage plants. Although the latter sources are included in coastal background N they will be very small compared to 'real' coastal background N coming from the English Channel. (Note that the Solent modelling does enumerate all other N sources from rivers and STWs, including direct and indirect sources). Coastal background N is likely to reduce very slowly over time, reflecting measures to reduce N that enters the English Channel.

As N reduction measures in estuaries progress, the N contributions from sources like rural diffuse, sewage and urban diffuse will reduce, and so the coastal background element will increase proportionally. However, the overall N load to the estuary will have decreased – see the schematic diagram, Figure 15, below. In an idealised pristine estuary, most of the N source apportionment would be from coastal background N!

Figure 15 Schematic diagram of change in N source apportionment in a Solent estuary over time



Appendix 4 Objectives for marine Natura 2000 sites agreed by NE and EA in 2015

Maintain *water quality (mean winter dissolved inorganic nitrogen) at existing levels where biological indicators of eutrophication (opportunistic macroalgal and phytoplankton blooms) achieve GOOD WFD overall status.*

Improve *water quality (mean winter dissolved inorganic nitrogen) to a level that biological indicators of eutrophication (opportunistic macroalgal and phytoplankton blooms) achieve GOOD WFD overall status.*

Appendix 5 Notes on the relevance of buried and over wintering macroalgae

The presence of **buried** macroalgae increases the impact on designated intertidal habitats and birds, by increasing the risk that changes in sediment conditions will occur, resulting in a change in the benthic community. It can also provide a nutrient source in the sediment which fuels macroalgae growth in the spring/summer and potentially delays the recovery time of intertidal habitats.

The presence of **over wintering** macroalgae increases the impact on designated wintering birds by affecting their access to prey species and increasing the risk of altering the benthic community. It can also enable a greater and more rapid growth spurt of macroalgae in the spring.