BLUE MARINE FOUNDATION

SEAGRASS VS WATER QUALITY:

HOW THE CURRENT CRISIS IS DAMAGING OUR ABILITY TO FIGHT CLIMATE CHANGE

PROJECT SEAGRASS

SURFERS AGAINST SEWAGE

EXECUTIVE SUMMARY

Seagrass is one of our greatest assets in the fight against climate change, but poor water quality is turning it into a source of carbon emissions. This shocking fact, revealed by this report, should be reason enough for regulators and industry to wake up to the water quality crisis in our seas.

Blue Marine Foundation, Project Seagrass and Surfers Against Sewage (supported by Flotilla Foundation) have come together on this critically important topic. Seagrass beds in good conditions are extraordinary nursery habitats for juvenile fish. Poor water quality (primarily from livestock waste, sewage discharges and excess fertiliser use) damages these services that seagrass provides. This is therefore an urgent fisheries and food security issue that our government should not ignore.

This report sets out the scientific evidence for how seagrass is being affected by water quality issues. As you will see, nutrient enrichment threatens to release carbon stored beneath seagrass. We are calling on regulators to rapidly develop better regulation and enforce current policies to tackle water quality issues at source, helping to allow seagrass to fulfil its role as a powerful solution to climate change.

Dan Crockett, Director, Ocean and Climate, Blue Marine Foundation

PROBLEM:

Seagrasses across the British Isles are in a perilous state due to poor water quality, primarily excess nutrients from sewage and livestock, reducing their ability to sequester carbon and mitigate climate change.

RECOMMENDATION 1:

The UK and the devolved governments should adequately enforce existing regulations to urgently reduce nutrient pollution, particularly in our estuaries and coastal zones, to prevent the deterioration of key habitats in the fight against climate change.

RECOMMENDATION 2:

The Department for Environment, Food and Rural Affairs, alongside the devolved governments should commission research to understand the consequences of elevated nutrients in habitats such as seagrass and their impact on Greenhouse Gas Emissions and on the UK's Nationally Determined Contributions..

RECOMMENDATION 3:

The UK and the devolved governments should update the UK Marine Strategy and define targets for seagrass meadow health using evidence-based Good Environmental Status indicators.

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Photo: **Lewis Jefferies**

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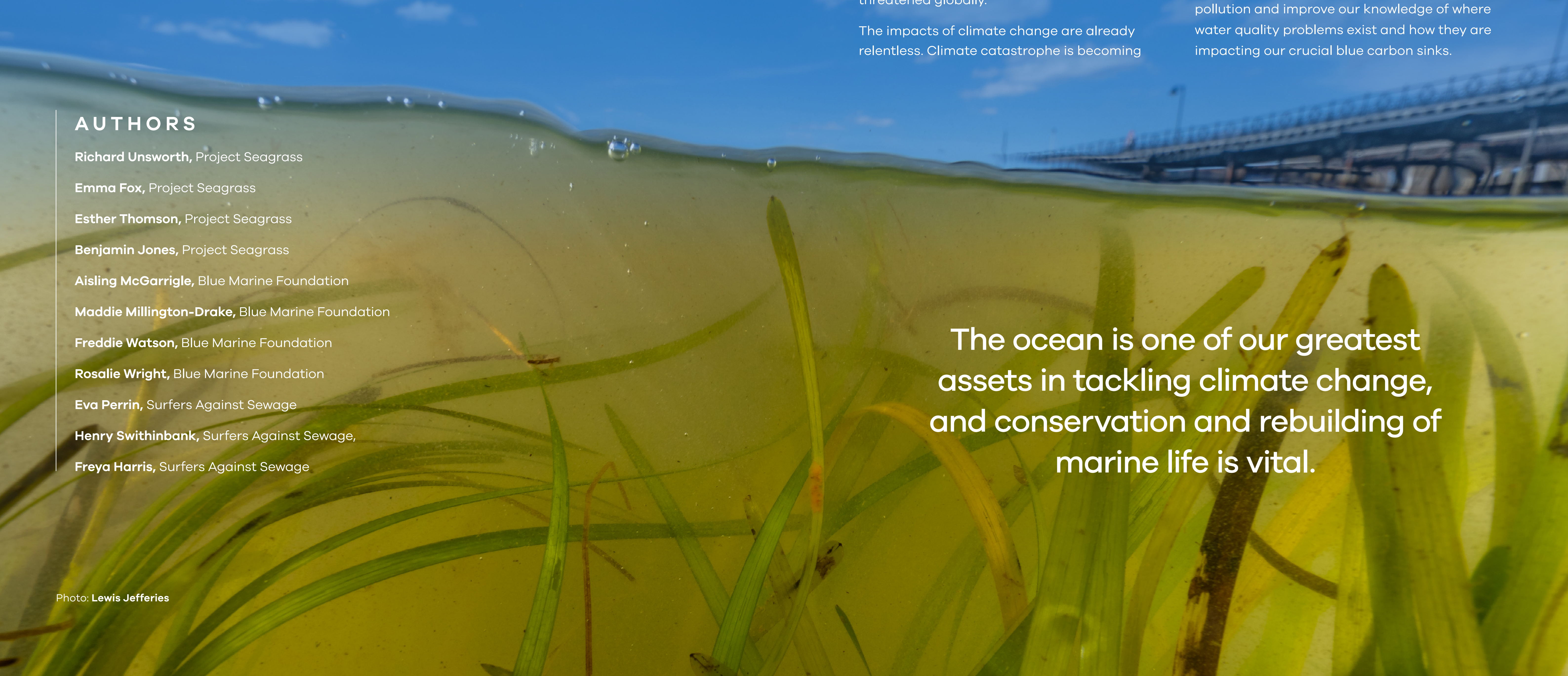

Photo: **Lewis Jefferies**

INTRODUCTION

Seagrass meadows play a critical role for the coastal environment, supporting people and the planet. Recent estimates suggest that seagrass meadows support the productivity of a fifth of the world's biggest fisheries (Unsworth et al., 2018) and store and sequester carbon rapidly, creating a potential 'Nature-based Solution' to climate change (Macreadie et al., 2021). However, these incredible underwater meadows are threatened globally.

The impacts of climate change are already relentless. Climate catastrophe is becoming more common across many parts of the world and we must take urgent action. The ocean is one of our greatest assets in tackling climate change, and the conservation and rebuilding of marine life is vital. However, as this study highlights, **water quality is one of the biggest threats to our oceans and limitations to conservation and restoration efforts.** Action is urgently needed to reduce the threats posed by pollution and improve our knowledge of where water quality problems exist and how they are impacting our crucial blue carbon sinks.

The ocean is one of our greatest assets in tackling climate change, and conservation and rebuilding of marine life is vital.

SEAGRASS IN THE UK: OVERVIEW

Seagrasses are powerhouses of the ocean that provide a range of ecosystem services, such as coastal protection through the stabilisation of marine sediments. The seagrass meadows in the British Isles on average store 114 ± 73 MG of carbon per hectare, support at least nine commercial stocks of fish and hundreds of species of animals (Unsworth et al., 2021). They also provide a key means of reducing coastal erosion.

Seagrass distribution spans our coasts, estuaries, lagoons and offshore islands creating incredibly diverse habitats. In the UK we have two species of seagrass, *Zostera marina* extends across all our marine environments, and *Zostera noltii*, that has a narrower niche, living largely within estuarine and lagoon environments. However, seagrasses like many other habitats and species have been degraded and destroyed, **in the UK the loss of seagrass might be as high as 92 per cent** (Green et al., 2021). It is thought seagrasses no longer exist in 50 per cent of UK estuaries (Green et al., 2021). Causes for these losses are many; coastal land reclamation, water quality problems, historic metal mining and early industrialisation of the UK are likely causes of the decline (Green et al., 2021).

As seagrass habitats are located near-shore, they are especially sensitive to anthropogenic pressures such as eutrophication, habitat fragmentation and destruction, overfishing and forestry and commercial developments (Turschwell et al., 2021). Coastlines have been reclaimed to build ports, cities and harbours, whilst centuries of metal mining polluted our estuaries as catchments were degraded by increasingly intensive agriculture. The loss of seagrass has led to feedback mechanisms in many locations, hindering the potential recovery of these ecosystems (Maxwell et al., 2017). Many subtidal seagrass meadows remain in a stressed state (Jones & Unsworth, 2016; Jones et al., 2018) and are subject to a range of cumulative stressors that are often poorly understood.

Optimism does exist in some locations with examples of intertidal meadows increasing in area and health, possibly due to reduced disturbances and improved water quality (Bertelli et al., 2017). As plants, they are susceptible to low light and algal overgrowth. Therefore, changes in seagrass distribution, abundance and condition can be related to environmental conditions (McMahon et al., 2013; Bertelli et al., 2021).

IN THE UK THE LOSS OF SEAGRASS MIGHT BE AS HIGH AS

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Photo: **Lewis Jefferies**

ABOUT THE STUDY

In this study we have aimed to understand how nutrients are impacting areas of abundant seagrass across a range of environments throughout the British Isles. These range from coastal sites such as those famed for seahorses at Studland Bay, to lagoons and harbours such as Portsmouth Harbour, and muddy estuary sites such as the Thames and the Firth of Forth that can sustain seagrass meadows. We were also able to examine seagrasses at island and offshore sites in the Isles of Scilly, Orkney and the Channel Islands.

We assessed the elemental tissue nutrients of the Eelgrass (*Z. marina*) within 33 different water bodies at 46 different sites. We also assessed the tissue nutrients of the Dwarf Eelgrass (*Z. noltii*) within eight different water bodies across 16 different sites. This created 41 water bodies overall that are spread across Ireland, England, Scotland, Wales, Northern Ireland, the Channel Islands and the Isle of Man[1].

Outputs from the research found three main problems and associated impacts on seagrass meadows stemming from poor coastal water quality. Full and detailed analysis which underpin the below findings can be found in Annex 1.

Outputs from the research found three main problems and associated impacts on seagrass meadows.

[1]The method used has previously been utilised in the UK (Jones & Unsworth, 2016) but is more widely known for its role in helping marine park authorities understand the impacts of catchment degradation on the Great Barrier Reef in Queensland, Australia.

THE PROBLEM

ELEVATED NITROGEN AND PHOSPHORUS

The average percentage of nitrogen in seagrass found in the British Isles is 2.8 per cent, above the global average of 2.7 per cent. The highest concentration of nitrogen (3.5 per cent) and phosphorus (0.3 per cent) are in estuarine seagrasses that are most vulnerable to catchment water pollution. Most of the water bodies around the British Isles contain seagrasses that are enriched by nitrogen isotopes indicative of organic nitrogen from urban sewage or livestock.

POOR LIGHT AVAILABILITY

Seagrasses are photosynthetic plants and need high levels of light to grow, requiring clear water. Seagrasses in the British Isles have an average carbon:nitrogen (C:N) ratio of 18, much lower than the global average of 21 suggesting our seagrass meadows are subject to reduced light availability. Four of the sites we surveyed had a C:N ratio of less than 12 which suggests severe light limitation.

POOR ENVIRONMENTAL CONDITIONS

We created a metric to assess seagrass environmental condition for the 41 water bodies selected (Chart 1). 43 per cent of these water bodies we categorised as being in a good seagrass environmental condition. However, 34 per cent were in a poor condition, primarily brought about by these elevated nutrient conditions.

Our data finds evidence that marine protection of seagrass is not working. 57 per cent of the sites defined as being in poor condition were located within Special Areas of Conservation. We also found that the regulatory assessments also are not effectively quantifying condition. We compared our condition assessments to the government regulatory assessments (based on what used to be the Water Framework Directive (WFD[2])). This revealed that seagrass condition across the sites surveyed did not align with its site WFD status. Four of the worst performing sites in our study (The Wash, the Solway Firth, Skomer and Humber) are categorised by government as being of either moderate or good WFD status. All the seagrasses in these water bodies are subject to poor light availability, alongside highly elevated nitrogen and phosphorus concentrations.

57% OF THE SITES DEFINED AS BEING IN POOR CONDITION WERE LOCATED WITHIN SPECIAL AREAS OF CONSERVATION.

[2]The Water Environment (Water Framework Directive) (England and Wales) Regulations 2017 (legislation.gov.uk)

CAUSES OF THIS PROBLEM

We found clear evidence that seagrass meadows throughout the British Isles are being subject to poor water quality, namely in terms of excess nutrients, particularly nitrogen. We also found evidence of seagrasses suffering poor light availability caused by high turbidity in the water column due to poor water quality (e.g. suspended sediments, plankton blooms). The values of nitrogen recorded in the British Isles are globally amongst the highest ever recorded for seagrass tissue, highlighting the challenges that these seagrasses face.

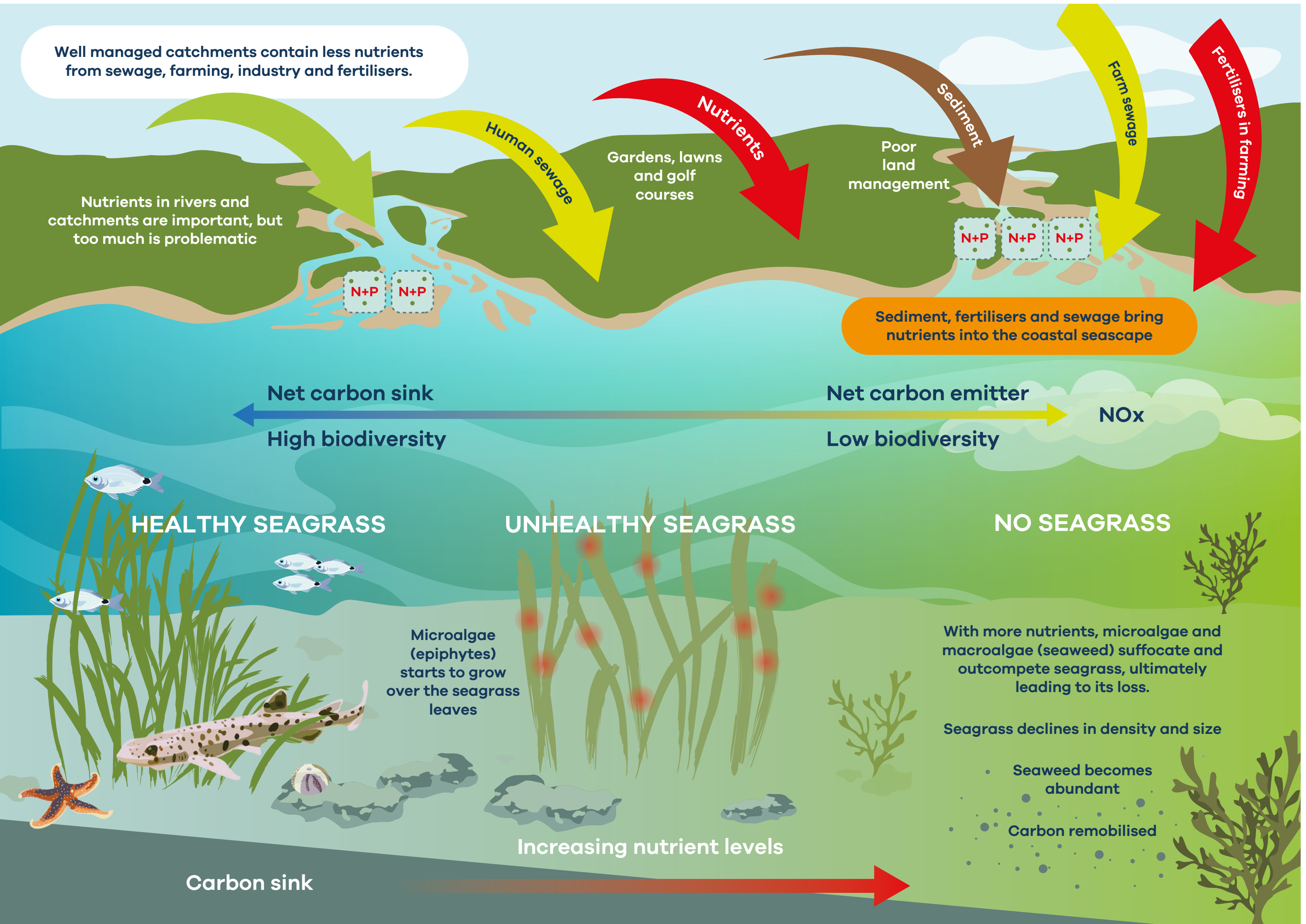
An earlier study (Jones et al., 2018) of a subset of the sites assessed in this study examined the different types of nitrogen present in the seagrass (their isotopes). Jones et al (2018) found compelling evidence that they all contained contamination that was likely by nutrients of an organic (human and livestock waste) origin.

Nitrogen in the marine environment largely comes down riverine catchments which run into the sea containing pollution from agriculture, chemical and organic fertilisers (manures and urine) and human sewage. It also comes from fertiliser use on golf courses, sports fields and gardens. The main sources of phosphorus in coastal waters are sewage effluent (primarily from water industry sewage treatment works), and losses from agricultural land (Environment Agency, 2024). Food waste, food and drink additives and phosphorus dosing of drinking waters all contribute to sewage phosphorus loadings.

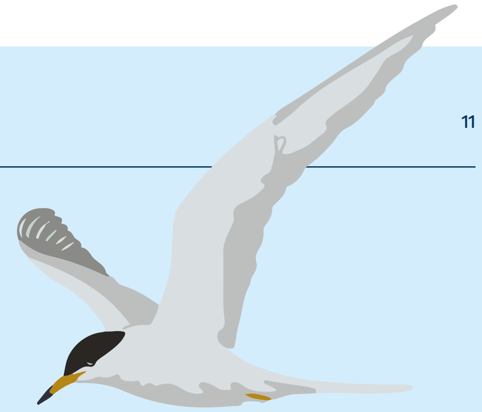
Photo: **Richard Unsworth**

Nutrients often leach rapidly into rivers and streams due to land and river ecosystem degradation. Dense vegetation on riverbanks, good land management and slower catchment release of water reduces the flow of nutrients and other particulates into the coast. Throughout the British Isles riverbanks are devoid of vegetation due to poor land management. This results in rapid surface run off of water and nutrients (including agricultural waste and sewage) into our rivers and coasts.

The most recent assessments under the WFD found that sewage pollution from wastewater was one of the most common reasons that waterways in England failed to achieve Good Ecological Status. Out of 84 per cent of rivers which failed to meet Good Ecological Status, 36 per cent were prevented from doing so due to the impact of wastewater from sewage treatment works and/or untreated sewage. Point-source pollutions such as sewage discharges are known to represent a major challenge to water quality due to their high nutrient concentrations, which includes nitrates (Albini et al., 2023; Howden et al., 2009). Sewage effluent is known to be one of the largest contributors to nitrate pollution after agriculture, accounting for 25-30 per cent of nitrates in the UK's waters (Environment Agency, 2019).



SOLENT CASE STUDY

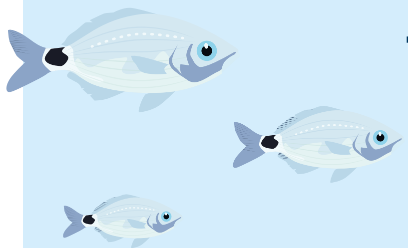


The Solent Seascape Project[3] is a collaborative five-year initiative working to restore multiple habitats across the Solent strait, a diverse estuarine system between the Isle of Wight and mainland England. The project is the first of its kind in the UK: Blue Marine Foundation and nine partners, including Project Seagrass, are pioneering UK seascape-scale restoration of seagrass, saltmarsh, oyster reef and seabird nesting habitats. The key aim is to reconnect 522 km^2 of the Solent's estuarine and coastal area into a functioning seascape by improving the condition, extent and connectivity of key marine and coastal habitats, using protection and restoration initiatives.

At present, the Solent continues to face severe threats from development, erosion, poor water quality and sea level rise. In particular, intensive agricultural activity and high levels of coastal development in the area result in nitrate run-off to the Solent. Given this land-based run-off is likely contributing to the significant loss and degradation of local seagrass meadows, successful habitat restoration necessitates changes to land management and stronger action from regulators.

The Solent received a 'Moderate' Ecological Status classification in most recent water quality assessments and is subject to multiple water quality pressures. In addition to land-based runoff, sewage discharges from rivers and estuaries entering this water body introduce elevated nutrient concentrations and negatively impact water quality. For example, the river Itchen and the Itchen estuary, both of which feed into the Solent, received a total of 177 untreated sewage discharges lasting 1,595 hours in 2022. Water quality sampling undertaken by Surfers Against Sewage in 2023 found a number of samples containing elevated levels of sewage-derived bacteria (Surfers Against Sewage, 2023). For example, results found two sites in the Itchen estuary to have received a 'Poor' water quality classification for bacterial pollution. Not only are these bacteria directly harmful to humans, they provide an indication of the overall pressures the Solent faces from sewage discharges, which are known to result in elevated nutrient concentrations.

The project's active restoration efforts have great potential to enhance existing seagrass extent and result in more resilient, thriving marine systems. For these benefits to be realised, sources of elevated nitrate concentrations must be controlled to mitigate further negative impact.



The project is the first of its kind in the UK.

3 https://issuu.com/bluemarinefoundation/docs/solent_seascape_two_pager_edited_pdf_1_

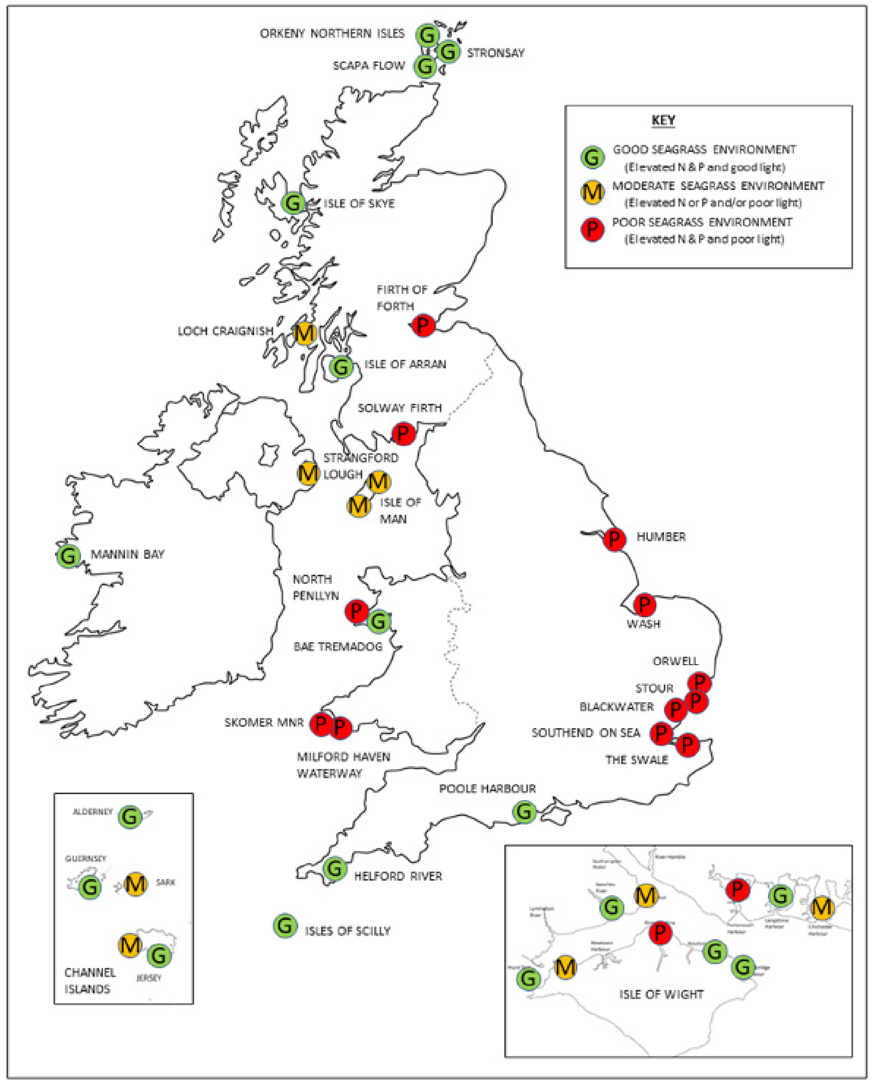


Chart 1. Seagrass environmental condition for 41 water bodies around the British Isles as determined by their elemental nitrogen, phosphorus and carbon:nitrogen ratio. Sites are categorised into three levels of condition (good, moderate and poor) based on levels of these indicators in global studies, together with an understanding of the percentile distribution within the current dataset.

EFFECTS AND IMPACT OF WATER QUALITY ON SEAGRASS: STUDY IMPLICATIONS

It is evident that seagrass meadows across the British Isles are under increasing pressure. This study has identified three key impacts of water quality on seagrass meadow health:

1. **High risk, fragile ecosystems**
2. **Increased Greenhouse Gas emissions**
3. **Poor environmental standards**

Beyond the three key problems outlined, the **resilience of these seagrass meadows** is likely to also be weakened due to changes of the trophic structure of the marine environment caused by overfishing and large-scale ecosystem degradation. This makes the seagrasses in this region highly vulnerable to future loss (Yan et al., 2020).

Photo: **Lewis Jefferies**

HIGH RISK, FRAGILE ECOSYSTEMS

Low level nutrient enrichment can have initial beneficial effects on seagrass productivity (Vieira et al., 2022) and likely their associated communities due to stimulation of the food web. However, evidence exists that as the seagrass system experiences increased eutrophication the associated animal communities begin to reduce in diversity and productivity (Deegan et al., 2002; Gil et al., 2006; Jaschinski et al., 2010; Daudi et al., 2012). Recent information from the south coast of England also finds preliminary evidence that with increasing eutrophication, seagrasses may store less carbon (Lima et al., 2020). Furthermore, nutrient enrichment decreases seagrass meadow density leading to fragmentation. The continued eutrophication from excess nitrogen and phosphorus together with high turbidity is likely to impact the ecosystem services seagrass meadows can provide. Meadows are less likely to be able to act as crucial nursey habitat and mitigate coastal erosion (McCloskey & Unsworth, 2015, Ondiviela et al., 2014). Estimates of seagrass coverage in the UK alone indicate at least 8493 hectares are still present but given that 34 per cent of the seagrass meadows sampled were in a poor state, the expectation that these 8493 hectares all provide extensive ecosystem services would be naïve.

INCREASED GREENHOUSE GAS EMISSIONS

Coastal wetlands have been found to have extensive emissions of the Greenhouse Gas (GHG) Nitrous Oxide (SØvik et al., 2006; Roughan et al., 2018) particularly linked to increasing enrichment. Eutrophic estuaries have also been found to release significant emissions (Murray et al., 2015). With limited data available on the nitrogen fluxes of seagrass (Eyre et al., 2023), there remains much speculation about their full emissions. However, due to the highly elevated nitrogen levels recorded in seagrasses throughout the British Isles, it is likely that some of these meadows are producing Nitrous Oxides.

Degradation, decreasing density and fragmentation of seagrass due to poor water quality will also begin to destabilise carbon stores and make them more prone to disturbance by hydrodynamic impacts, ultimately leading to greater levels of carbon remobilisation and oxygenation. Seagrass meadows have increasingly been held up as an example of how nature can be revitalised to fight climate change. Reducing the impacts of water quality to prevent seagrass meadows becoming net emitters of GHGs is critical to this fight.

The continued eutrophication from excess nitrogen and phosphorus together with high turbidity is likely to impact the ecosystem services seagrass meadows can provide.

POOR ENVIRONMENTAL STANDARDS

Communities and organisations across the British Isles appreciate the value of seagrass and wish to bring it back through restoration. The results of this study not only suggest seagrasses are under threat but highlight the difficulty of restoring these ecosystems. Effective seagrass restoration requires conditions that are well within their environmental window and the conditions currently observed in many locations do not meet this standard. This highlights the potential futility of planting seagrass in many localities, principally due to water quality that remains in a poor state. To achieve the collective aims of the Government, regulators, funders and NGOs involved with seagrass restoration, we need to think about both the process of planting and how we can improve water quality.

REDUCED ECOSYSTEM RESILIENCE

Seagrasses in these substandard conditions can survive as a functional habitat, but by being subject to high nutrient levels, their resilience and productivity is increasingly compromised (Unsworth et al. 2015). Sustained uptake of water-column nitrates along with poor light availability, are both thought to reduce the build-up of carbon stores in seagrasses. These stores are critical for survival during periods of stress. In addition, there is evidence that seagrasses have reduced growth rates under ammonia enrichment (Burkholder et al., 2007). The build-up of a series of cumulative pressures (many of which are not considered here) further compromises seagrass resilience to deal with future stressors (see Chart 2).

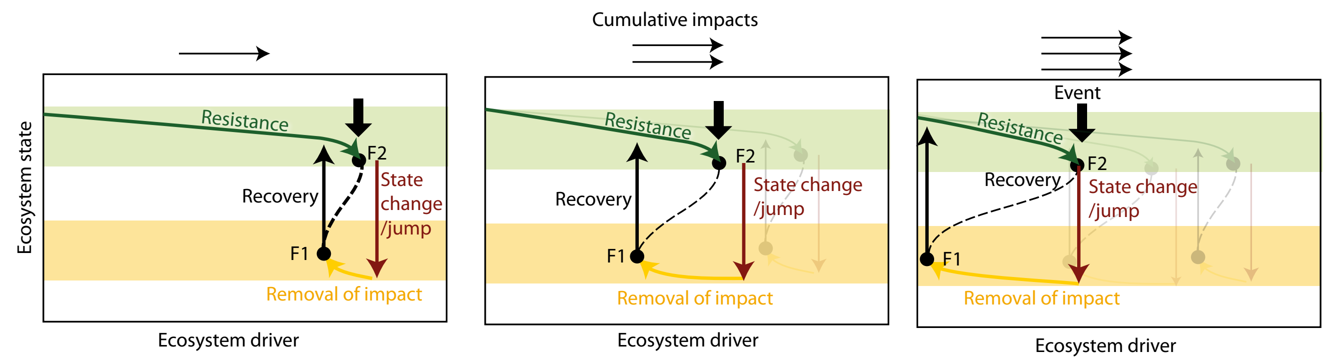


Chart 2. (From Unsworth et al. 2015) Worsening environmental conditions (often of a cumulative nature) or a large disturbance event can force seagrass ecosystems to undergo a regime shift. This shift could be analogous to a change in community from one that is a **climax community** (flora and fauna) existing in a state of meadow maintenance, to one that is a community in a colonizing state dominated by disturbance and species exhibiting colonizing traits. Once the **physical disturbance** has passed, a resilient meadow (left panel) will return on a trajectory of recovery without significant intervention. A meadow with increasing numbers of cumulative impacts (becoming non-resilient) will more easily undergo a regime shift at lower environmental pressure as it doesn't have the capacity to resist. Furthermore, a non-resilient meadow requires a much greater push back to enable recovery to original community status.

SOLUTIONS: POLICY RECOMMENDATIONS

RECOMMENDATION 1:

The UK and the devolved governments should adequately enforce existing regulations to urgently reduce nutrient pollution, particularly in our estuaries and coastal zones, to prevent the deterioration of key habitats in the fight against climate change.

Our data shows urban sewage and agricultural runoff are enriching our coastal seas, damaging our key carbon sequestering habitats such as seagrass. In inland waters, agricultural pollution contributes to approximately 70 per cent of total inputs of nitrates, and sewage effluent contributes between 25-30 per cent. 55 per cent of England is designated a Nitrate Vulnerable Zone, primarily due to elevated nitrate concentrations in rivers and groundwaters. Much of this water ultimately feeds into estuaries and coastal regions; in the most recent WFD assessment, 93 per cent of monitored estuarine water bodies and 47 per cent of monitored coastal water bodies in England exceeded nitrate standards (Environment Agency, 2019). Many of these habitats that are in poor condition are located within existing Special Areas of Conservation.

Current legislation requires water companies to treat water 'effectively' and only permits storm overflows to discharge in 'exceptional circumstances'. However, in 2022 UK water companies discharged sewage over 300,000 times (EAC 2022). Similarly, environmental regulators have failed to enforce the legislation that should protect water courses from agricultural pollution, with the Environment Agency admitting they only have the resources to regulate farms in Britain less than once every 200 years. Unless regulators properly enforce existing regulation and manage nutrient run off, they will continue to negatively impact blue carbon habitats, reducing our resilience to climate change.

The UK Government **must direct regulators to enforce existing law** and provide them with the necessary resources to properly prevent nutrient pollution at source.

Photo: **Lewis Jefferies**

Photo: **Lewis Jefferies**

RECOMMENDATION 2:

The Department for Environment Food and Rural Affairs, alongside the devolved governments should commission research to understand the consequences of elevated nutrients in habitats such as seagrass and their impact on GHG Emissions and on the UK's Nationally Determined Contributions.

Information from saltmarshes and other aquatic vegetated systems indicates that under conditions of elevated nitrogen and increasing disturbance these habitats become emitters of high levels of nitrous oxides, key GHGs that need to be urgently controlled.

The UK Government formed the UK Blue Carbon Evidence Partnership; a body that aims to facilitate, coordinate and progress the evidence base for blue carbon habitats across the UK. This group and its network should be used to corroborate robust data to better understand real-life impacts of poor water quality on our fragile marine ecosystems and the additional emissions they produce.

This data must be used to monitor and inform effective management of marine protected areas for blue carbon habitats.

55%

OF ENGLAND IS DESIGNATED A NITRATE VULNERABLE ZONE

RECOMMENDATION 3:

The UK Government and devolved governments should update the UK Marine Strategy and define specific targets for seagrass meadow health using Good Environmental Status indicators.

Given the increasing understanding of poor water quality around our coasts and the detrimental impact it has on seagrass, mechanisms are needed to monitor ecosystem health alongside sewage spill frequency. Cefas data notes the UK has achieved its target of Good Environmental Status for eutrophication within the UK Exclusive Economic Zone (EEZ)[4]; however it notes that eutrophication problems remain in **coastal and estuarine waters.** These coastal areas, prone to poor conditions due to eutrophication, often overlap with significant portions of UK seagrass resulting in inaccuracies in reporting for specific habitats and condoning the need for more specific indicators for seagrass.

The same data set shows that we have not yet achieved Good Environmental Status for benthic habitats in the UK.

Good Environmental Status is measured across a broad range of habitats and conditions. If we are to properly monitor the mosaic of seagrass meadows and other important habitats across our waters more distinct parameters and measurements are needed.

[4]Eutrophication - Marine online assessment tool (cefas.co.uk)

CONCLUSION

There is a real need to recognise the multiple pressures our ocean faces; from overfishing to climate change. Every metric of the health of the ocean tells a story of vast degradation. The ocean has the potential to deliver environmental benefits, a sustainable food supply and effectively remove carbon from our atmosphere. However, if we do not urgently act to remove the significant pressures it faces our ecosystems will continue to deteriorate and potentially contribute to climate change.

The report clearly shows that the declining state of water quality in the UK is impacting the ability of our seagrass meadows to mitigate the threat of climate change. We know that the components of poor water quality can be attributed to sewage discharges and agricultural run-off. Until the UK Government begins to adequately enforce its own regulations our poor water quality will continue to affect not only human health, but that of our delicate marine ecosystems.

Optimal seagrass growing conditions are in coastal, shallow areas; an area where many NGO-led restoration projects have been established and we frequently see overlapping sewage discharges. The impact of these sewage discharges on restoration initiatives has the potential to be environmentally regressive; damaging the precious habitat we are trying to recover.

We need to begin effectively protecting the large seagrass meadows around our coastline. Genuine effort is required from the UK and devolved governments to not only uphold the commitments they've already established, but to increase ambition and properly deliver effective management of UK coasts.

Photo: **Lewis Jefferies**

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ANNEX ONE

METHODOLOGY

This study sort to understand how nutrients are impacting areas of abundant seagrass across a range of environments throughout the British Isles. The following methodology was used to better understand the nutrient content and conditions of marine and coastal waters in seagrass leaves.

Assessment of the nutrient content of seagrass leaves provides a better cumulative assessment of the nutrient content. This creates a time-integrated measure of water quality and differs from 'in-water samples' that aren't always collected at times of storm overflow and tend to hide the true nature of the conditions. This data also differs from loggers that record all events but are not placed in shallow water environments and are not extensive in number due to their high capital and maintenance costs.

By measuring seagrass plant tissue nutrients, we see an indication of what the actual biota is being subjected to. This is because any concentration of nutrient recorded in the water column will have a different impact on the ecosystem dependent upon many other factors such as tidal flushing and may or may not be available to the biota present. By examining different ratios of particular elements in the seagrass tissue we're also able to estimate the amount of light available to the seagrass, this is particularly important as seagrasses require light to photosynthesise. Disturbance and excessive pollution can increase the turbidity of the water reducing the amount of light available.

RESULTS

Elevated Nitrogen and Phosphorus

The average percentage of elemental nitrogen in seagrass within the British Isles is 2.8 ± 0.38 (s.d) %. This is above the global average of 2.7%. Our study recorded 30 of a total of 41 water bodies in the British Isles to contain seagrass that had greater than the global average concentration of Nitrogen (Chart 1a). 15 water bodies had seagrass with 1.5 times the global average of elemental nitrogen. Six of these water bodies had approximately double the global average. Phosphorus is also a problem for seagrass in the British Isles (Chart 1b) with an average percentage of 0.26 ± 0.05%. Although this mean value is below the global average of 0.27%, 16 of a total of 41 water bodies in the British Isles contained seagrass that had concentrations of elemental Phosphorus greater than the global average. Three of these water bodies have levels at least double that of the global value. Two of these water bodies had three times the global average.

The highest concentrations of nitrogen and phosphorus are in estuarine seagrasses that are most vulnerable to catchment water pollution. Coastal and lagoon seagrasses also had elevated values of nitrogen above global means but the corresponding values of phosphorus were more indicative of global concentrations. Lowest concentrations were in island and then offshore environments, which had values far lower than the global average. Seagrass at some sites shows nitrogen isotope signatures that indicate enrichment is from inorganic fertilisers, but most of the water bodies contain seagrasses that are enriched by nitrogen isotopes indicative of organic nitrogen from urban sewage or livestock.

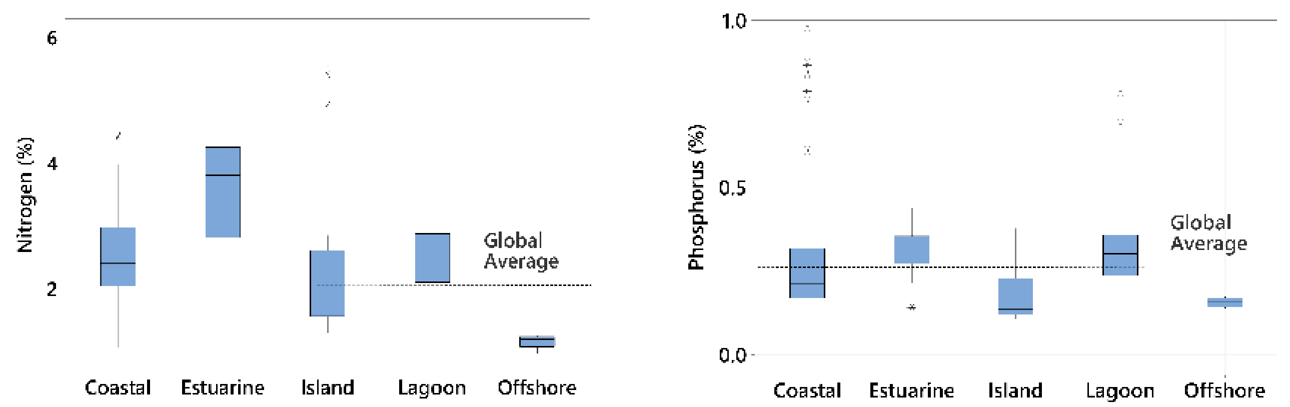

Chart 3: Concentration of % Nitrogen and % Phosphorus in seagrass (*Zostera marina*) tissue across 42 sites around the British Isles, see chart 1.

Poor light availability for marine plants

Seagrasses as photosynthetic plants and need high levels of light to grow, in the ocean this is facilitated by clear water. Assessment of the carbon:nitrogen (C:N) ratio in seagrass provides an indicator of the availability of this light. This is because higher investment in carbon is brought about by more photosynthesis. Seagrass in the British Isles had an average C:N ratio of 18, this is much lower than the global average of 21, suggesting our seagrass is subject to reduced light availability. We recorded 13 sites to have sub-optimal light availability, with a C:N ratio of less than 15. Four of these sites had values less than 12 suggesting severe light limitation. Seagrasses in the Wash, the Humber, the Solway Firth, the Thames and the Orwell were amongst the most light-limited.

Poor environmental condition

We used the data presented here (%N, %P and C:N) to create a metric of seagrass environmental condition for all the water bodies selected (see chart 3). 18 (43%) of these water bodies we categorise as being in a good seagrass environmental condition. 9 (23%) of the water bodies were in a moderate condition and 14 (34%) were in a poor condition. Examining our environmental condition assessments relative to the government regulatory assessments (based around what used to be the Water Framework Directive (WFD)), reveals seagrass conditions that are largely not in agreement with the WFD status of the waterbody. Four of the worst performing sites in our study (The Wash, the Solway Firth, St Brides Bay and Humber) are water bodies categorised as being of either moderate or good WFD status. All the seagrasses in these water bodies are subject to poor light availability and highly elevated nitrogen and phosphorus concentrations. The regulatory assessments do categorise 13 of the seagrass localities as being subject to excess dissolved inorganic nitrogen (DIN) as a reason for them not recording a status of good, but in none of the cases is the DIN found to result in the status being recorded by government as poor.

Certain geographies were of note for repeated poor water seagrass environmental condition. The Essex and Suffolk coastline from the Thames to the Orwell all contained seagrasses of a poor environmental condition. In our study, an abundance of sampling occurred in the Solent and Isle of Wight region, although the area is well known for problems of excess nitrogen in coastal waters as defined by their WFD assessments, not all of the water bodies were recorded by our study to be of poor condition, with half of the ten water bodies in good condition. Problematic water bodies of poor environmental conditions in the Solent and IoW region were found at Portsmouth Harbour and at the mouth of the Medina River at Cowes (IoW).

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