DATASHEET:

Nitrate vulnerable zone (NVZ) designation 2017 – Eutrophic Waters (Estuaries and Coastal Waters)

Publication Date: June 2016
Introduction

This document provides a summary of the evidence used in proposing an area of land as one which should be, or should continue to be, designated as a Nitrate Vulnerable Zone (NVZ) for the purposes of the Nitrate Pollution Prevention Regulations 2015.

A full description of the methods used in developing the NVZ proposals is set out in the detailed methodology for eutrophication-related NVZs, available via http://apps.environment-agency.gov.uk/wiyby/141443.aspx. These methods were developed under the guidance of a review group convened by the Defra for the last NVZ review (2011-2013), which included representatives from the farming and water industries as well as independent academic experts. Minor refinements to the methods have been made for the current review.

NVZs are areas of land that drain to polluted waters and which contribute to the pollution of those waters. Polluted waters include those which are eutrophic or may in the near future become so if the Regulations were not to apply there.

Eutrophication is defined as “the enrichment of water by nitrogen compounds, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned”.

For both freshwaters and saline waters, a weight-of-evidence based approach to assessing the risks and impacts of eutrophication was employed. The evidence for individual water bodies was assessed against a national suite of criteria for eutrophication in the different categories/types of water for review. The criteria are both quantitative and qualitative and reflect scientific understanding of the process and effects of eutrophication. They are broken down in the same way for each water category as follows:-

- Nutrients
- Plants/algae
- Secondary and other effects

For each designated or candidate water body which might meet the criteria for eutrophication, a datasheet such as this one was completed, bringing together information about the water body, its catchment, its uses, evidence of eutrophication and the sources of nitrogen input.

This document is a record of the evidence used in the designation process, including results from national monitoring and assessment programmes, and further information supplied by Area staff. The proposals for NVZ designation are made as a result of close working between Area and national Environment Agency teams, with further quality assurance for the eutrophication designations through the use of a national expert panel.

Some features of the maps within this report are based on digital spatial data licensed from the Centre for Ecology and Hydrology, ©.

Please note that any maps shown here have not used detailed field boundaries and therefore represent the indicative 'soft' boundary only. The definitive NVZ area can be seen on the “What’s in Your Backyard” (WIYBY) website (http://apps.environment-agency.gov.uk/wiyby/141443.aspx).
FORM A COVER SHEET
Candidate Sensitive Area (Eutrophic) and/or (Nitrate)/Polluted Waters (Eutrophic)

<table>
<thead>
<tr>
<th>Sensitive Area coverage (highlight appropriate coverage):</th>
<th>England</th>
<th>England &amp; Wales</th>
<th>Wales</th>
<th>England &amp; Scotland</th>
</tr>
</thead>
</table>

1) Name of regulator

Environment Agency, Integrated Environment Planning, Devon & Cornwall Area

2) Candidate name

Kingsbridge Estuary

3) Main river catchment

No significant river – a number of small watercourses

4) Location & extent of candidate
(Map should be included)

The boundaries of the candidate Polluted Water [Eutrophic] (PW(E)) are shown in Figure 1 below and in Figure 3 on Form D. The Kingsbridge Estuary has been divided into two management units for the purposes of the Water Framework Directive: the Kingsbridge transitional water; and the Harbour coastal water. This candidate PW(E) comprises the Kingsbridge transitional waterbody. The total catchment area is about 90 km², while the area of this part of the estuary is 5.2 km².

The catchment which drains to the Kingsbridge transitional water is predominantly agricultural with scattered villages, hamlets, and farmsteads. The farming is generally mixed, with arable and livestock.

The town of Kingsbridge (resident population about 6,000) is at the head of the estuary, and Salcombe (resident population about 2,000) is near the mouth. Tourism is a major industry in the catchment area, so that the population in the summer months increases significantly.

There are no major rivers draining to the Kingsbridge Estuary, but a large number of streams. Most of the streams have relatively small flows, with annual mean daily flows < 0.1 m³/s, and only one stream has an annual mean daily flow greater than 0.1 m³/s (Small Brook with an annual daily mean flow of 0.34 m³/s). The total freshwater flow entering the estuary, as an annual daily mean flow, is just
greater than 1 m$^3$/s. For comparison, the annual daily mean flows in the two main rivers adjacent to Kingsbridge Estuary are 3.6 m$^3$/s for the River Avon, and 10.9 m$^3$/s for the River Dart.

The Kingsbridge Estuary catchment is bounded to the north by the River Wash which is part of the catchment draining to the Dart Estuary.

The Kingsbridge catchment is bounded to the east by coastal streams and the streams draining to Slapton Ley; one of these streams draining to Slapton Ley, the Start stream, is a designated Nitrate Vulnerable Zone (NVZ).

The Kingsbridge catchment is bounded to the west by coastal streams and the River Avon catchment; the Buckland stream and the southern bank of the Avon Estuary is a designated NVZ.

5) Type(s) of candidate (Using WFD Classification) (Tick all boxes that apply)

- Running freshwater
- Still freshwater
- Estuarine water
- Coastal water

6) Is the candidate proposed as a: (Tick all that apply)

- Sensitive Area (Eutrophic)
- Polluted Water (Eutrophic)
- Sensitive Area (Nitrate)

7) Is the candidate:

- Drinking water source which does or could contain >50 mg/l nitrate set in Directive 75/440?
- Eutrophic now?
- At risk of becoming eutrophic if protective action is not taken?*
Figure 1  Kingsbridge Estuary catchment

Legend
- Salcombe Kingsbridge Estuary Catchment
- Salcombe Kingsbridge Estuary Candidate PW(e)
8) In previous reviews was the candidate designated as a: 

(Tick all that apply)

Not previously designated

9) Summary of comments from stakeholders on candidate area:

Comments from Russ Money, Natural England, 15th January 2016

Key nature conservation designations:

- SALCOMBE TO KINGSBRIDGE ESTUARY Site of Special Scientific Interest (Wildlife and Countryside Act 1981, as amended)

This Estuary possesses a very rich and diverse intertidal and sub-tidal flora and invertebrate fauna, with certain communities being outstanding examples of their type in the North-east Atlantic. Small areas of salt marsh occur at the heads of the tributary creeks. The estuary is used as an overwintering ground by large numbers of wildfowl such as wigeon, teal and shelduck and the intertidal mudflats are important feeding grounds for passage waders.

Natural England advises that eutrophication, due to elevated nitrogen, is a recognised cause of unfavourable conservation status of the estuary, particularly through excessive growth of macroalgae.

10) Is the proposal consistent with Eutrophication Strategy, LEAPs, other activities?

Yes

11) Executive summary of evidence/justification for designation(s).

The Kingsbridge transitional water body is being proposed for PW(E) designation as data collected have shown significant opportunistic macroalgal blooms in the summer along with over-wintering macroalgae. The water body is moderate status under the Water Framework Directive for both DIN and opportunistic macroalgae. Summer surveys have shown the extent of opportunistic macroalgae to exceed 65% of the available intertidal area. Seasonal surveys have shown that some opportunistic macroalgae persists through the winter months. The estuary is an SSSI. The Kingsbridge Estuary unit of the SSSI is not considered to be in favourable condition due to concern that the macroalgae may be impacting on Zostera beds and the feeding grounds of estuarine birds.

12) Summary of qualifying sewage treatment work discharges (i.e. greater than p.e. 10,000) which contribute to the pollution of the candidate sensitive area.

None, but this is a candidate PW(E) therefore the designation does not depend on a qualifying sewage treatment works.

Note: The largest STW is at Kingsbridge but does not serve a sufficiently large population to be a qualifying works. The total resident and peak tourist population equivalent given by South West Water in 2010 was just over 8,000. Kingsbridge STW had N reduction (15 mg/N) implemented in March 2015, to reduce its impact on the SSSI. The reduction is required for the period April to October. Assuming the UWWTD concentration of 15mg/l total nitrogen is achieved, we estimate this would result in an overall reduction in the TIN loadings to the upper estuary of about 10 to 15% in summer.
13) Nutrient contributions from Agricultural and other sources:

a). Does nitrate pollution from agricultural land contribute to the eutrophication problem?

Yes (Provide supporting evidence in either case)

Summaries of the annual loadings in kg/day for Dissolved Available Inorganic Nitrogen (DAIN, taken to be the sum of Total Oxidised Nitrogen and Ammonia, both as N) from consented Water Company continuous discharges (Wastewater Treatment Works, STWs) and the streams entering the Kingsbridge Estuary are given in Table 1. There is one small, indirect STW (East Allington STW) discharging into the Kingsbridge Estuary through Small Brook which accounts for approximately 1% of the river load. The remaining river loading is due to diffuse, agricultural sources.

The annual loads have been assessed using average flows and average concentrations. The flows for STWs are either consented average flows (1.25 times the consented Dry Weather Flow), or the average of measured flows over the period 2006 to 2009, where these are available. Table 1 includes a summary of the loads before N reduction at Kingsbridge STW (referred to as “historic” loads in the table) and also the estimated load after N reduction. The “new Kingsbridge limit” loads have been assessed assuming a concentration of 15mg/l DAIN from Kingsbridge STW. The data indicates that the main source of DAIN is not direct or indirect STWs, and is therefore most probably agriculture.

The estuary is fed by a number of small streams (Figure 2). Although the streams are small there is a clear relationship between DAIN and salinity suggesting that freshwater sources are significant (Figures 8.1a-c in Form D). The relative contribution from each of the main streams and direct STWs are shown in Figure 2. This shows that the highest annual load is from Small Brook, followed by the Sherford Stream, Marlborough STW and Kingsbridge STW.

<table>
<thead>
<tr>
<th></th>
<th>DAIN Load (kg/day)</th>
<th>Percentage of Total Measured Load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Historic</td>
<td>New Kingsbridge Limits</td>
</tr>
<tr>
<td>Total STWs Direct to the Estuary</td>
<td>53.39</td>
<td>34.84</td>
</tr>
<tr>
<td>Total Streams*</td>
<td>408.14</td>
<td>88.4</td>
</tr>
<tr>
<td>Total STWs and Streams</td>
<td>461.5</td>
<td>446.00</td>
</tr>
<tr>
<td></td>
<td>Historic</td>
<td>New Kingsbridge Limits</td>
</tr>
<tr>
<td></td>
<td>11.6</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>91.5</td>
<td></td>
</tr>
</tbody>
</table>

*As mentioned above, 1% of this figure includes upstream STWs (data from the SIMCAT-SAGIS model).
Table 2 below shows the DAIN loadings for the summer months (June-August). This data indicates that the DAIN loading from STWs remains relatively constant throughout the year, but the loading from streams is lower during the summer months. Therefore STWs are a more significant source of N at the height of the growing season than during winter months.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Summary of summer direct point source loads and stream loads to Kingsbridge Estuary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DAIN Load (kg/day)</strong></td>
<td><strong>Percentage of Total Measured Load</strong></td>
</tr>
<tr>
<td><strong>Historic</strong></td>
<td><strong>New Kingsbridge Limits</strong></td>
</tr>
<tr>
<td>Total STWs Direct to the Estuary</td>
<td>44.705</td>
</tr>
<tr>
<td>Total Streams*</td>
<td>209.33</td>
</tr>
<tr>
<td>Total STWs and Streams</td>
<td>257.05</td>
</tr>
</tbody>
</table>

*As mentioned above, 1% of this figure includes upstream STWs (data from the SIMCAT-SAGIS model).
b). Is the candidate within the catchment of an EXISTING Nitrate Vulnerable Zone?
   No
   Remarks if appropriate (e.g. when and why the NVZ designated).

c). If (a)=Yes & (b)=No, is the designation of a new Nitrate Vulnerable Zone recommended?
   Yes – as per Figure 1.

d). Does phosphate pollution from agricultural land contribute to the eutrophication problem as well or instead?
   No

The data indicates that a greater percentage of the total DAIP loading to the estuary comes from STW discharges rather than diffuse inputs to the streams. Modelling indicates that the macroalgae in the Kingsbridge estuary is limited by DAIN for 62% of the year, light 19% of the year and DAIP for the remaining 18% of the year.

e). If (a) &/or (d) = Yes, is there any evidence to suggest that certain types of agricultural practice in the catchment are contributing most to the problem?
   No

   (Provide supporting evidence in either case)

f). Is there any evidence to suggest other land uses or activities in the catchment are contributing to the problem (i.e. other than agriculture or STWs)?
   No

   (Provide supporting evidence in either case and if applicable, what is proposed to tackle the problem).

Environment Agency Recommendation for the candidate water body designation

(to be completed by National Panel)

14) Is the candidate water body now recommended for designation as *(Tick all that apply)*

- Sensitive Area (Eutrophic)
- Polluted Water (Eutrophic)
- Sensitive Area (Nitrate)

Environment Agency’s remarks on its decision and recommendation:

On the basis of the evidence summarised in this document, we recommend that this waterbody be designated as a Polluted Water (Eutrophic) with the catchment designated as an NVZ.
Candidate Sensitive Area (Eutrophic) / Polluted Waters (Eutrophic)

1) Candidate name: (take name from Form A)

Kingsbridge Estuary

2) Define approximate area of estuarine water using grid references:

The boundaries of the candidate Polluted Water match the boundaries of the Kingsbridge WFD transitional water body. The area starts at the normal tidal limit of each stream. The end point is the boundary between the Kingsbridge transitional water body and the Salcombe Harbour coastal water body.

Surface area (ha): 520 (area of Kingsbridge WFD transitional water body)

<table>
<thead>
<tr>
<th>Start point</th>
<th>SX coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bowcombe Creek NTL</td>
<td>SX 74830 44110</td>
</tr>
<tr>
<td>Collapit Creek NTL</td>
<td>SX 72840 42120</td>
</tr>
<tr>
<td>Blanksmill Creek NTL</td>
<td>SX 72695 40990</td>
</tr>
<tr>
<td>Batson Creek NTL</td>
<td>SX 73520 39710</td>
</tr>
<tr>
<td>Frogmore Creek NTL</td>
<td>SX 77530 42605</td>
</tr>
<tr>
<td>Southpool Creek NTL</td>
<td>SX 77460 40110</td>
</tr>
<tr>
<td>Watermead Creek NTL</td>
<td>SX 77000 38860</td>
</tr>
<tr>
<td>End line between</td>
<td>SX 74150 38870 and SX 74295 38705</td>
</tr>
</tbody>
</table>
3) Attach map showing PW(E) and locations of chemical sample points, biological sample points, any direct or indirect sewage treatment work discharges, direct or indirect discharges of nitrogen compounds from agricultural sources, and other significant discharges of nitrogen or phosphorus e.g. industrial.

Chemistry data was collected from the sample points shown on Figure 3. A separate map showing the locations of macroalgae sample points is provided in section 9 of this report.
4) **Approximate retention/flushing time (days):**

The average flushing time for the inner estuary is in the order of about 5 days. Tidal flushing is the significant mechanism for the Estuary, due to the small freshwater input, and the tidal flushing is determined mainly by the exchange at the mouth of the Estuary.

5) **Brief description of geo-morphological nature of estuary** *(e.g. broad and flat, deep and fjord-like, salinity regime, stratification etc)*

The Kingsbridge Estuary is a classic example of a “Dendritic Ria”, a series of river estuaries “drowned” by rising sea levels as ice melted following the end of the last Ice Age, from around 10,000 years ago. The ‘estuary’ system which developed in the ria includes mudflats, sandbanks, beaches, saltmarsh and other dynamic geomorphological systems. Each of these systems interact with others, providing a diversity of substrates for the rich diversity of marine life which inhabits the area. Only a small quantity of freshwater flow (just greater than 1 m$^3$/s in total as annual daily mean flow) enters the estuary so tidal flows and marine conditions dominate.

6) **Summary of main uses and designations:** *(Tick all boxes that apply)*

| ✓ Amenity | ✓ Boating |
| ✓ Water sports | OSPAR problem area |
| ✓ EC Bathing Water | ✓ Angling |
| Commercial fishery | Designated EC Shellfish Water |
| ✓ Designated EC Shellfish Harvesting Area | Non - designated shellfish harvesting area |

Other uses or designations:
- SSSI
- South Devon AONB
- South Devon Heritage Coast

7) **If waterbody has conservation status provide details**

**Salcombe to Kingsbridge Estuary is a SSSI** – it possesses a very rich and diverse intertidal and sub-tidal flora and invertebrate fauna, with certain communities being outstanding examples of their type in the North-east Atlantic.

Below is an extract from the SSSI condition assessment for unit 8 Salcombe to Kingsbridge Estuary. This unit was last assessed in 2010. Further details are available on the Natural England website and maps are available on the magic website (http://www.magic.gov.uk):

"Littoral sediment - mostly muddy gravels in this unit. Between Saltstone and Wareham Point, the muddy sands in this tide-swept channel are notable for the infaunal richness, the abundance of Sabella pavonina and Lanice conchilega as well as epifauna attached to the polychaete tubes. East of the Saltstone the biotope also contains the burrowing anemone Cereus pedunculatus and numerous epibenthic red algae harbouring numerous amphipod species. The infauna is dominated by small polychaete species. Intertidal Zostera noltii is confined to this unit within the SSSI and measures some 500,000 m$^2$ as a main or secondary biotope, located in Collapit Creek, Blank's Mill Creek and the mudflats of Park Bay, adjacent to Park Farm Sewage Works. The infaunal analysis from sediment cores taken adjacent to the Park Farm..."
area and the Collapit Creek Zostera bed showed the sediments at these sites to be species poor and no scarce species were found. In the Park Farm area the green algae Ulva pseudocurvata and U. prolifera dominated the mudflats. The highest figure for organic carbon sediment content, 6.95%, of all coring sites was that adjacent to Park Farm. The main reason for unfavourability of this unit is the seasonal algal blooms which cover large parts of this unit.”

Note that Park Farm sewage treatment works, referred to in the above extract, is the same STW that is called Kingsbridge STW elsewhere in this report.

8) What data are available? (Tick boxes if evidence is supplied)

- Dissolved available inorganic phosphorus (DAIP)
- Dissolved available inorganic nitrogen (DAIN)
- Chlorophyll-a
- Cell counts

* Cell count data are available from the adjacent coastal water body

9) What biological / observational data are available?

- Planktonic algal blooms
- Macroalgae
- Presence of foam / scum
- Shellfish / invertebrate / fish mortality
- Photographs

Chemical data: summary statistics of samples

<table>
<thead>
<tr>
<th>Winter DAIN μM/l (Nov-Feb surface samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicative Conditions</td>
</tr>
<tr>
<td>1. Significantly enhanced (&gt;50%) relative to background concentrations for a defined geographical area based on salinity between Dec – Mar period;</td>
</tr>
<tr>
<td>2. Changing Winter nutrient ratios where elevations occur above: N:P &gt;25, and N:Si &gt;2;</td>
</tr>
<tr>
<td>3. Winter values of nutrient concentrations significantly exceed 12μM/l DAIN in the presence of at least 0.2μM/l DAIP (CSTT* standards).</td>
</tr>
<tr>
<td>Sampling Site</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Churston Stream</td>
</tr>
<tr>
<td>Geese Quarry</td>
</tr>
<tr>
<td>Southpool Creek</td>
</tr>
<tr>
<td>Salcombe SFW</td>
</tr>
<tr>
<td>Mid Estuary</td>
</tr>
</tbody>
</table>

Sampling sites within the estuary but seaward of candidate boundary:

<table>
<thead>
<tr>
<th></th>
<th>Data Included</th>
<th>n</th>
<th>Mean Salinity</th>
<th>Mean DAIN</th>
<th>StDev DAIN</th>
<th>Min DAIN</th>
<th>Max DAIN</th>
<th>n Exceeding Condition 1</th>
<th>% Exceeding Condition 1</th>
<th>n Exceeding Condition 2</th>
<th>% Exceeding Condition 2</th>
<th>n Exceeding Condition 3</th>
<th>% Exceeding Condition 3</th>
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</thead>
<tbody>
<tr>
<td>Millbay</td>
<td>2007 - 2015</td>
<td>18</td>
<td>34.1</td>
<td>22</td>
<td>26</td>
<td>4</td>
<td>102</td>
<td>6</td>
<td>33</td>
<td>4</td>
<td>22</td>
<td>9</td>
<td>50</td>
</tr>
<tr>
<td>Estuary Bar</td>
<td>2007 - 2015</td>
<td>17</td>
<td>34.4</td>
<td>18</td>
<td>24</td>
<td>4</td>
<td>103</td>
<td>3</td>
<td>18</td>
<td>2</td>
<td>12</td>
<td>4</td>
<td>24</td>
</tr>
</tbody>
</table>

**Interpretation and discussion**

DAIN data for the 7 sampling sites in the estuary are summarised above and presented in Figures 8.1a, b, and c. Sample points at Millbay and Estuary Bar are outside of the candidate area, but data from these high salinity sample points are presented to show DAIN levels in the estuary as a whole. DAIN data was not collected in the Kingsbridge Estuary in 2014.

Water Framework Directive (WFD) classifications show that DAIN is moderate status in the Kingsbridge transitional water body and the adjacent Salcombe Harbour coastal water body, indicating that the estuary is hyper-nutrified throughout.

There is a clear relationship between DAIN levels and salinity suggesting that freshwater sources are significant.

No clear temporal trend is apparent from the 2007 to 2015 dataset. The introduction of nutrient reduction at Kingsbridge STW in 2015 is estimated to have reduced the TIN load to the upper part of the estuary by up to 15% in the summer but, despite this improvement, **DAIN in the estuary is expected to remain at WFD Moderate status.**
Figure 8.1a Winter DAIN Data (2007 to 2015, samples were not collected in 2014)

![Graph showing DAIN vs Salinity (Nov to Feb data)](image)

- DAIN umol
- Linear (DAIN umol)
- \( y = -14.918x + 532.532 \)
- \( R^2 = 0.769 \)

Figure 8.1b Winter DAIN Means

![Graph showing Mean Winter DAIN (Nov to Feb data)](image)

- Churston Stream
- Geese Quarry
- Southpool Creek
- Salcombe SFW
- Mid Estuary
- Millbay
- Estuary Bar

Figure 8.1c  Seasonal DAIN and Salinity Means (2007 to 2015, samples were not collected in 2014)
Winter DAIP µM/l (Nov-Feb surface samples)

Indicative Conditions

1. Significantly enhanced (>50%) relative to background concentrations for a defined geographical area based on salinity between Dec – Mar period;

<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Data Included</th>
<th>n</th>
<th>Mean Salinity</th>
<th>Mean DAIP</th>
<th>StDev DAIP</th>
<th>Min DAIP</th>
<th>Max DAIP</th>
<th>n Exceeding Condition 1</th>
<th>% Exceeding Condition 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Churstow Stream</td>
<td>2007 - 2015</td>
<td>20</td>
<td>30.0</td>
<td>0.97</td>
<td>0.32</td>
<td>0.58</td>
<td>1.87</td>
<td>9</td>
<td>45</td>
</tr>
<tr>
<td>Geese Quarry</td>
<td>2007 - 2011</td>
<td>18</td>
<td>30.9</td>
<td>0.86</td>
<td>0.21</td>
<td>0.61</td>
<td>1.39</td>
<td>6</td>
<td>33</td>
</tr>
<tr>
<td>Southpool Creek</td>
<td>2007 - 2015</td>
<td>16</td>
<td>32.3</td>
<td>0.70</td>
<td>0.20</td>
<td>0.16</td>
<td>0.97</td>
<td>3</td>
<td>19</td>
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<tr>
<td>Salcombe SFW</td>
<td>2007 - 2015</td>
<td>19</td>
<td>33.0</td>
<td>0.80</td>
<td>0.21</td>
<td>0.42</td>
<td>1.10</td>
<td>8</td>
<td>40</td>
</tr>
<tr>
<td>Mid Estuary</td>
<td>2007 - 2015</td>
<td>20</td>
<td>33.2</td>
<td>0.74</td>
<td>0.18</td>
<td>0.39</td>
<td>1.07</td>
<td>5</td>
<td>25</td>
</tr>
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</table>

Sampling sites within the estuary but seaward of candidate boundary:

<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Data Included</th>
<th>n</th>
<th>Mean Salinity</th>
<th>Mean DAIP</th>
<th>StDev DAIP</th>
<th>Min DAIP</th>
<th>Max DAIP</th>
<th>n Exceeding Condition 1</th>
<th>% Exceeding Condition 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millbay</td>
<td>2007 - 2015</td>
<td>18</td>
<td>34.1</td>
<td>0.77</td>
<td>0.25</td>
<td>0.48</td>
<td>1.55</td>
<td>14</td>
<td>78</td>
</tr>
<tr>
<td>Estuary Bar</td>
<td>2007 - 2015</td>
<td>17</td>
<td>34.4</td>
<td>0.78</td>
<td>0.34</td>
<td>0.16</td>
<td>1.74</td>
<td>13</td>
<td>76</td>
</tr>
</tbody>
</table>

Interpretation and discussion:

DAIP levels in the Estuary are elevated relative to background waters in the western English Channel. Long term data from Station E1 near the Eddystone Rocks shows peak winter values for DAIP of about 0.6 µM/l.

It is likely that the DAIP levels in the Estuary waters are buffered with phosphorus bound to the estuarine sediments, as there is no clear relationship between the DAIP levels and salinity, as shown in Figure 8.2a below.

Modelling shows that the macroalgae in the Kingsbridge estuary is limited by DAIN for 62% of the year, light 19% of the year and DAIP for the remaining 18% of the year.
Figure 8.2a  Winter DAIP Data (2007 to 2015, samples were not collected in 2014)

\[ y = -0.030x + 1.779 \]
\[ R^2 = 0.155 \]

Figure 8.2b  Winter DAIP Means

Mean Winter DAIP (Nov to Feb data)

- Churston Stream
- Geese Quarry
- Southpool Creek
- Salcombe SFW
- Mid Estuary
- Millbay
- Estuary Bar
**Chlorophyll a (µg/l) during growing season (Mar-October) including surface and depth samples**

<table>
<thead>
<tr>
<th>Sampling Site</th>
<th>Data Included</th>
<th>n</th>
<th>Mean Salinity</th>
<th>Mean Chla</th>
<th>StdDev Chla</th>
<th>Min Chla</th>
<th>Max Chla</th>
<th>n Exceeding Condition 1</th>
<th>n Exceeding Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Churstow Stream</td>
<td>2007 - 2011</td>
<td>36</td>
<td>33.4</td>
<td>12.2</td>
<td>18.9</td>
<td>0.6</td>
<td>70.3</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td>Geese Quarry</td>
<td>2007 - 2011</td>
<td>39</td>
<td>34.2</td>
<td>4.6</td>
<td>6.2</td>
<td>0.3</td>
<td>34.5</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>Southpool Creek</td>
<td>2007 - 2009</td>
<td>30</td>
<td>34.5</td>
<td>3.3</td>
<td>2.4</td>
<td>0.6</td>
<td>8.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Salcombe SFW</td>
<td>2007 - 2010</td>
<td>34</td>
<td>34.3</td>
<td>3.8</td>
<td>3.1</td>
<td>0.5</td>
<td>9.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mid Estuary</td>
<td>2007 - 2011</td>
<td>36</td>
<td>34.6</td>
<td>3.2</td>
<td>2.8</td>
<td>0.5</td>
<td>9.4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Sampling sites within the estuary but seaward of candidate boundary:**

<table>
<thead>
<tr>
<th>Site</th>
<th>Data Included</th>
<th>n</th>
<th>Mean Salinity</th>
<th>Mean Chla</th>
<th>StdDev Chla</th>
<th>Min Chla</th>
<th>Max Chla</th>
<th>n Exceeding Condition 1</th>
<th>n Exceeding Condition 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millbay</td>
<td>2007 - 2013</td>
<td>55</td>
<td>34.7</td>
<td>2.1</td>
<td>1.7</td>
<td>0.3</td>
<td>7.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Estuary Bar</td>
<td>2007 - 2013</td>
<td>55</td>
<td>34.7</td>
<td>2.3</td>
<td>2.1</td>
<td>0.3</td>
<td>9.4</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Interpretation and discussion of chlorophyll and phytoplankton blooms:**

The Kingsbridge Estuary is proposed as a candidate PW(E) primarily because of concerns about the level of opportunistic macroalgae in the estuary, rather than concern about phytoplankton blooms. Summary information about chlorophyll levels in the estuary is still presented in this report, but the estuary does not frequently experience high levels of chlorophyll.

Both the Kingsbridge transitional water body and the adjacent Salcombe Harbour coastal water body are at High status for phytoplankton under the WFD.

A plot of Chlorophyll against salinity is given in Figure 8.3a, and this shows the generally low levels of chlorophyll, and the occurrence of some phytoplankton blooms.

Phytoplankton blooms do occur, mostly in the upper part of the system, and red tides occur most years. The Estuary Officer for the Kingsbridge Estuary reported sightings of visible algal blooms in the Kingsbridge, Frogmore and Bowcombe Creeks to the Environment Agency between 2001 and 2010. These records are included in Appendix 1.

Phytoplankton cell count data is not routinely collected in the Kingsbridge Estuary transitional water body. Cell count data was collected as part of a WFD operational monitoring programme in the adjacent Salcombe Harbour coastal water body from 2010 to 2013. Cell counts exceeded WFD single and total taxa thresholds on 2 occasions (Figure 9.1). On both occasions the high cell counts were identified to be diatom blooms of *Chaetoceros (Hyalochaetia)*.
Figure 8.3a  Summer Chlorophyll Data

Chlorophyll a vs Salinity (Mar to Oct data)

Figure 8.3b  Summer Chlorophyll Means

Mean Summer Chlorophyll a (Mar to Oct data)
Figure 8.3c  Seasonal Chlorophyll and Salinity Means

![Seasonal Means graph]

9) a) Phytoplankton blooms

Figure 9.1 Total phytoplankton cell counts in samples from Salcombe Harbour
The locations of the sampling stations are shown in Figure 9.2

![Total taxa cell counts graph]
Figure 9.2. Locations of phytoplankton sampling stations in Salcombe Harbour coastal water body
b) Opportunistic macroalgae

Extent of macroalgae in the summer

Opportunistic macroalgae in the Kingsbridge Estuary has been assessed under the WFD. Aerial images collected during flight monitoring in September 2008 and September 2009 were used to estimate and map the extent of opportunistic macroalgae. An example of the 2009 images are shown in Appendix 2. From these aerial surveys the opportunistic macroalgae was estimated to cover between 22% (2009 survey) and 29% (2008 survey) of the available intertidal habitat (Figure 9.4). The estimated 2008 extent exceeds UWWTD criteria ‘cover greater than 25% of the intertidal area’.

Field surveys were carried out by hovercraft in August 2010, 2011 and 2012. The surveyors drove the hovercraft around the macroalgae patches to map the extents of patches. Quadrat surveys were carried out to assess percent cover, biomass and the presence of entrained macroalgae within each patch. The quadrat locations from each survey are shown on maps in Appendix 3.

Opportunistic macroalgae (25 to 100% cover) covered 65% to 74% of the available intertidal area, exceeding UWWTD criteria in all three years (Figure 9.7b). The areas with the highest percent cover tend to be in the upper estuary near Gerston (Figure 9.8). The South Pool area in the lower estuary had the lowest average percent cover, but still exceeded the UWWTD criteria. The difference in cover between the upper and lower parts of the estuary is considered to reflect the general increase in the tidal flushing towards the mouth of the estuary.

The biomass averaged 0.6 to 0.8 kg/m² over the available intertidal area; and 0.8 to 1.1 kg/m² over the area affected by macroalgae patches. A biomass of one kg/m² has been identified as a level of biomass above which significant harmful effects on biota have been, or may be observed. This level was exceeded around Gerston, Collapit and Blanksmill, and Charleton. The lower biomass levels in Bowcombe Creek compared with elsewhere in the upper estuary is considered to be related to the larger freshwater flow in the Small Brook compared with other freshwater inputs, which results in lower salinities locally in the creek. The growth of green macroalgae is known to be suppressed when salinities are reduced (Kamer and Fong, 2001).

Entrained macroalgae were only present in less than three percent of quadrats surveyed.

The WFD classification method for opportunistic macroalgae uses summer survey data from the previous six years. The WFD classification for Kingsbridge Estuary was reported as moderate status in 2015, based on the survey results from 2009 to 2012.

Seasonal macroalgal biomass surveys

Three sites in the Kingsbridge Estuary have been monitored every three months, since November 2011, to assess how macroalgae varies throughout the year and whether it persists through the winter. The locations of the three sites, at Gerston, Blanksmill and Frogmore, are shown in Figure 9.10. The results show that macroalgae regularly survives the winter months of January to March although at relatively low biomass. A photo of the macroalgal cover at Frogmore from the August 2015 survey is shown in Figure 9.9.
Trends in macroalgae

There is concern that the extent of macroalgae has been increasing in the Kingsbridge Estuary since the 1990s. The earliest photo of the upper estuary is from mid October 1992 (See Figure A4.1 in Appendix 4). This shows some green macroalgae in the area of Gerston, and locally elsewhere in the creeks. An aerial photograph of the Gerston area of the estuary taken in summer 1999 is shown in Figure A4.2 in Appendix 4. From this photograph it appears that macroalgae covered only a very low percentage of the AIH around Gerston in 1999. The extent of the green macroalgae round Gerston STW had increased by the summer of 2005, as shown in Figures A4.3. In 2008 and 2009, the extent of the macroalgae was estimated to cover over 20% of the AIH, based on the aerial imagery surveys during the summer of those years (see Figures in Appendix 2). The extent of macroalgae was estimated to cover over 60% of the AIH each summer from 2010 to 2012 (see Figure A4.4 and A4.5 in Appendix 4 for the extents in 2010 and 2012). Some of the difference in estimated extent may be attributable to the change in survey method, from aerial imagery to hovercraft surveys, and to natural inter-annual variation. However, the recent observations in 2011 and 2012 indicate that the green macroalgae cover is extensive over most of the Kingsbridge Estuary.

Nutrient reduction was introduced to Kingsbridge STW in 2015. The site at Gerston, used as one of the three seasonal monitoring sites, is located close to the Kingsbridge STW discharge point, but the data from this site does not yet indicate a change in macroalgal cover or biomass since nutrient reduction was introduced at the STW (Figures 9.11 and 9.12).

Figure 9.3 Map showing names of creeks and areas of intertidal within the Kingsbridge Estuary referred to in the Figures below
Figure 9.4  Opportunistic macroalgae (25 to 100% cover) in the Kingsbridge Estuary in September 2009 (mapped using aerial imagery)

Opp Mac = 90.87ha
AIH = 407.5
Opp Mac/AlH = 22.3%

Mapped by Geomatics using aerial imagery

Legend
- AIH
- Opp Mac 2009
Figure 9.5  Opportunistic macroalgae (25 to 100% cover) in the Kingsbridge Estuary in summer 2011 (mapped using a hovercraft)

Opp Mac = 281.60ha
AIH = 407.5
Opp Mac/AIH = 69.11%

Mapped by Area A&R using Hovercraft

Legend
- AIH
- Opp Mac 2011
Figure 9.6  Opportunistic macroalgae (25 to 100% cover) in the Kingsbridge Estuary in summer 2012 (mapped using a hovercraft)

Opp Mac = 267.43ha
AIH = 407.5
Opp Mac/ AIH = 65.63%

Mapped by Area A&R using Hovercraft
Figure 9.7  Summer extent of opportunistic macroalgae in the Kingsbridge Estuary

a) Area estimated from aerial images taken in 2008 and 2009
Percent cover within the algal patches was not estimated.

b) Area estimated from hovercraft surveys in 2010, 2011 and 2012
Percent cover within the algal patches was assessed using quadrat surveys
Figure 9.8  Average percentage cover in sub areas of the Kingsbridge estuary in summer 2010, 2011 and 2012

The locations of these areas are shown on Figure 9.3 above

Figure 9.9  Average macroalgal biomass (g/m²) in the Kingsbridge Estuary from the 2010, 2011 and 2012 hovercraft surveys
Figure 9.10  Locations of seasonal monitoring sites

Figure 9.11  Average percent cover from seasonal surveys since November 2011 at Gerston, Blanksmill and Frogmore
Figure 9.12 Average biomass (g/m²) from seasonal surveys since November 2011 at Gerston, Blanksmill and Frogmore.

![Average biomass (g/m²) from seasonal surveys since November 2011 at Gerston, Blanksmill and Frogmore.](image)

Figure 9.13 Photo of opportunistic macroalgal cover in the upper estuary near Gerston from the 2005 survey

(NGR SX 7401 4222 looking ENE on 8th Sept 2005)

![Photo of opportunistic macroalgal cover in the upper estuary near Gerston from the 2005 survey](image)
Figure 9.14 Photo showing macroalgal cover taken at the Frogmore macroalgal survey site on 18/08/2015
10) Which of the methodology indicators are exceeded?

- Y Nitrate concentrations (February nitrate/nitrogen concentrations significantly enhanced)
- WFD phytoplankton classification of moderate ecological status or worse
- Occurrence of unusual algal blooms
- Oxygen deficiency (based on WFD and/or UWWT/Nitrate directive methods)
- Y Macroalgae exceeds thresholds (UWWT and WFD)

11) Other evidence of adverse effects on uses and designations:

- The SSSI is not considered to be in favourable condition due to excessive growth of opportunistic macroalgae. An intertidal biotope survey carried out in 2009 informed this assessment (Bunker et al., 2010). With regard to the opportunistic macroalgal cover in the upper estuary, this report concluded: “Of concern was the low abundance of *Z. nolti* and dense mats of green algae over an extensive area by the mudflats of Gerston Point sewerage works. This area was not considered to be in favourable condition.”

- L K Barcroft, from the University of Plymouth, investigated the effects of macroalgal mats on the distribution and foraging behaviour of wading birds at Kingsbridge Estuary between October 2007 to January 2008 (Barcroft, 2008). Barcroft observed that there were significantly higher numbers of wading birds (oystercatchers, redshank and curlew) present on a clear intertidal site compared with a site covered in macroalgae. Barcroft also observed greater feeding success for birds on the clear site, indicated by higher rates of pecks and swallows per minute. More information on the survey methods and results is provided in Appendix 5.

12) Executive summary of the chemical, biological and other evidence illustrating eutrophication in the SA(E)/PW(E)

The Kingsbridge Estuary is hyper-nutritured with respect to Inorganic Nitrogen. The biological expression of this nutrient enrichment is primarily through the development of extensive opportunistic macroalgal mats in the middle and upper estuary. Some macroalgae has been found to persist over winter. There is concern that the opportunistic macroalgal mats have become more extensive and denser over time, and that they are, or are beginning to, impact unfavourably on the ecology of the Estuary.

Macroalgae in the estuary is at WFD moderate status, and is the main reason the Kingsbridge Estuary unit of the SSSI is not considered to be in favourable condition.

13) Summary of eutrophication control measures (already in progress and/or already planned) if any, for the candidate area.

Kingsbridge STW had N reduction implemented by March 2015, to reduce its impact on the SSSI.

The catchments draining to the Kingsbridge Estuary are part of a priority catchment under the Catchment Sensitive Farming initiative. Further information on catchment sensitive farming is available on the Natural England website.
References


Appendix 1

Recorded sightings of phytoplankton blooms from Nigel Mortimer (Kingsbridge/Salcombe Estuary Officer):

Red tides were noticed by Nigel Mortimer, in Kingsbridge, Bowcombe & Frogmore Creeks, for several years prior to these shown below but no samples were taken or dates recorded.

2001
no dates recorded – *Prorocentrum micans* – (ID’d by Environment Agency)
evident in Kingsbridge, Bowcombe & Frogmore Creeks.

2002
7th August to 24th September – *Prorocentrum spp.* & *Protoperdinium spp.* – (ID’d by Environment Agency)
evident in Kingsbridge & Bowcombe Creeks.

2003
5 days only within the ‘summer’.

2004
9th August to ~30th August – *Glenodinium foliaceum* – (ID’d by Environment Agency)
evident in Kingsbridge & Bowcombe Creeks.

2005
31st May to 3rd July – *Alexandrium tamarenisis* - (ID’d by Dr Gerald Boalch – MBA)
evident in Kingsbridge & Bowcombe Creeks.

9th August to mid September * - *Prorocentrum micans* - (ID’d by Dr Gerald Boalch – MBA)
evident in Kingsbridge, Bowcombe & Frogmore Creeks.
* end-date is uncertain as autumn rains and resultant soil runoff discolouration obscured the red tide colouration

2006
26th August – taxa not identified
Bloom evident in Kingsbridge Creek, confirmed in Frogmore Creek 30 August and Bowcombe Creek 31 August

2007
10th June – patches seen in Kingsbridge and Tacket Wood Creeks on windward side however, didn’t seem to bloom further and no trace a few days later – lots of freshwater runoff from very heavy rains meanwhile. No testing believed to have taken place.
19th July – *Prorocentrum micans* – (ID’d by Dr Gerald Boalch 14 August 2007) – bloom reported in Kingsbridge Creek.

20th July – bloom confirmed in Kingsbridge and Bowcombe Creeks.

21st July – bloom confirmed in Frogmore Creek

9th August – have received an unprecedented number of reports of the red tide bloom from members of the public, incl. a confirmed report that the bloom has spread down as far as Ox Point.

10th September – faint traces just seen in Kingsbridge Creek

2008

23rd July – bloom first reported from Bowcombe Creek

26th July – bloom confirmed in Kingsbridge and Bowcombe Creeks

28th September – bloom seen at mid tide (1500hrs) off Ox Point, ‘solid’ from there north

6th October – still evident in Kingsbridge Creek

* end-date is uncertain as autumn rains and resultant soil runoff discolouration obscured the red tide colouration

2009

3rd June – bloom first reported in Kingsbridge Creek

c.a. 17th June – bloom appeared to have dissipated

12th July – bloom reappeared in Kingsbridge Creek; Kingsbridge and Bowcombe Creeks most affected.

* end-date is again uncertain as autumn rains and resultant soil runoff discolouration obscured the red tide colouration but certainly into October again

2010

25th June – bloom seen at top of Frogmore Creek – (ca. 1hr before high water, reasonably opaque 5cm below surface - 2hrs after high water, no longer evident)

12th July – bloom reported in Kingsbridge Creek (reported on 19th as being there all week)

19th July – bloom reported in Bowcombe Creek

12th September – very dense red tides seen in Kingsbridge and Bowcombe Creeks during high spring tides

3rd October – as 12th September

1st November – Report of blooms in Singing Paddles in Bowcombe, Kingsbridge and Collapit Creeks

* end-date is uncertain
Appendix 2. Examples of the aerial images of the Kingsbridge Estuary taken in 2009
2009 Imagery mapped by Geomatics

Legend
- Opp Mac Extent
Appendix 3. Quadrat sites from the 2010, 2011 and 2012 opportunistic macroalgal surveys

Quadrat sites in 2010

Quadrat sites in 2011

Quadrat sites in 2012
Appendix 4  A sequence of aerial photographs of the macroalgal mats in the vicinity of Gerston STW between 1992 and 2012

Figure A4.1. Upper Kingsbridge Estuary 15/10/1992 (Aerial Photography by DCC and the NRA)
Figure A4.2. Gerston – Summer 1999

Figure A4.3. Gerston – August 2005 (Geomatics Aerial Photography)

Figure A4.4. Gerston – June 2010
Figure A4.5. Gerston – 2012 (Imagery from Channel Coastal Observatory)
Appendix 5 Extracts from the report by Laura Barcroft, “Investigating the effects of macroalgal mats on the distribution and foraging behaviour of wading birds (Charadrii) at Kingsbridge Estuary”
The aim of this study was to determine the effect of macroalgal mats on wading birds distribution and foraging behaviour, the objectives were to assess feeding efficiency and success of several bird species at two study sites, and also to determine differences in distribution in regards to algal mats.

The study incorporated bird counts at a clear site and a site with algal mats to determine if birds occurred less at the algal site. The study also conducted focal studies of individual waders to determine the effects of the algal mats on foraging behaviour.

For the study two similar sized sections of the estuary were chosen. One of which was a site where algal mats were present (see Image.I -W on map), and the other which was clear (see Image. IE on map) (See Photo 1: for photographic image of the two study sites).
Image 1. Map of study sites showing the position of the two study sites: W: West Bank = Algae Site, E: East Bank = Clear Site (Map adapted from Waterhouse, 2007 Pers.comm). The two study sites shall be referred to as the Clear Site and the Algae Site for the duration of this report.
Data was collected from October 2007 to January 2008; with most data being collected during December and January, a total of 16 days of data were obtained for the focal and scan samples.

A total of 2948 birds were counted during the study (1447 at the Algae Site and 1501 at the Clear Site). Results for the 48 scans/counts, 23 at the Algae Site and 25 at the Clear Site, showed a significant difference for mean number of Curlew ($U=89.00, P<0.001$), Oystercatchers ($U=45.00, P<0.001$), Redshank ($U=94.00, P<0.001$), Shelduck ($U=46.00, P<0.001$) and Little Egret ($U=192.50, P=0.014$), (see table below for the total number of individuals seen at each site). Waders never occupied those areas of the study site with the densest algal mats, and of those that did feed in the algal site, most were seen to be feeding in the clear patches between the algae, or in some cases like that of the redshank were seen to toss algae away before pecking at the mud's surface.

### The total number individuals seen for each species during the study at each site

<table>
<thead>
<tr>
<th>Species</th>
<th>Algal site</th>
<th>Clear site</th>
<th>Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curlew</td>
<td>206</td>
<td>397</td>
<td>***</td>
</tr>
<tr>
<td>Oystercatcher</td>
<td>136</td>
<td>621</td>
<td>***</td>
</tr>
<tr>
<td>Redshank</td>
<td>54</td>
<td>328</td>
<td>***</td>
</tr>
<tr>
<td>Greenshank</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Shelduck</td>
<td>922</td>
<td>102</td>
<td>***</td>
</tr>
<tr>
<td>Little Egret</td>
<td>3</td>
<td>22</td>
<td>*</td>
</tr>
<tr>
<td>Heron</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Brent Geese</td>
<td>115</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Cormorant</td>
<td>9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1447</strong></td>
<td><strong>1501</strong></td>
<td></td>
</tr>
</tbody>
</table>

Overall bird numbers were similar at the two sites, however, when considering only the wader species there is a significant difference, with the clear site having considerably more birds present overall. *(P=0.05-0.01), ***(P<0.005) indicates those species with a significant difference in numbers at the two sites.

The study also looked at differences in foraging behaviour and feeding success of curlew, oystercatchers and redshank between the algae and clear sites and found that all three species pecked and probed more per minute at the clear site and had more mean swallows per minute at the clear site; this could be because the algae not only causes a barrier to feeding and thus
reduce pecking rate but may also form an obstacle to movement and thus reduces pacing rates, or it could be that birds feed at more rapid rates in order to utilise the available food resources at the clear site due to the higher feeding success. All three species pecked more at the clear site this could be due to similar reasons as for the feeding efficiency, and predominantly because there is no physical barrier to pecking at the clear site.

![Graph](image_url)

**Fig 1.** Mean number of pecks and probes per minute performed by the three species at both sites. * (P=0.05-0.01) indicates significance between species.
Fig. 4. Mean number of swallows per minute by each species at the two sites studied, giving an indication of feeding success. * (p=0.05-0.01) indicates the significant difference between species.
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