Seagrass in the Stour, Orwell and Blackwater 2020/21

First published April 2024

Natural England Commissioned Report NECR481

www.gov.uk/natural-england

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Tim Gardiner, Jim Pullen, Tom Cameron

Published April 2024

Project details

This report should be cited as:

Gardiner, T., Pullen, J., and Cameron, T.C. 2023. Seagrass in the Stour, Orwell and Blackwater 2020/21. Natural England Commissioned Report, NECR481.

Natural England Project manager

Gina Wright, Alan Kavanagh and Jenny Baker

Contractor

University of Essex, Wivenhoe Park, Colchester, CO4 3SQ

Authors

Tim Gardiner, Jim Pullen, Tom Cameron

Keywords

Zostera marina, Zostera noltei, seagrass, Stour, Orwell, Blackwater, restoration

Further information

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Acknowledgements

The lead author's interest in seagrass was inspired by the Environment Agency (EA) ecologists James Clemence, Dan Hayter, Kirk Markham, Hannah Westoby and Adrian Wood and Rebecca Bromley from Anglian Water, who provided information on existing meadows on the Essex and Suffolk coast. Thanks are also due to Harwich Haven Authority (HHA) for funding this project and to the University of Essex for administering it. It should be acknowledged that the 2020 data was collected by the lead author on a voluntary basis during daily walks. He also collected the 2021 as a private individual and not during EA duties. The survey design was undertaken by Tim Gardiner, Tom Cameron and the clients (HHA and Natural England), the survey was implemented by Tim Gardiner

and Jim Pullen, the initial draft of reports by Tim Gardiner and all authors contributed to revisions.

Executive Summary

Eelgrass (*Zostera* spp.) declined in the 20th century throughout the UK. To provide a baseline for *Zostera* eelgrass in the Stour, Orwell and Blackwater estuaries in north Essex and Suffolk, a survey was undertaken in summer 2021 to follow a shore-walking survey from autumn 2020. The summer 2021 survey involved shore-walking for recording *Zostera noltei* patches and drone surveys to search for *Zostera marina* and map all seagrasses in the survey area where possible. It is the aim of this report to present the results and discuss restoration ideas based on all available information. For the shoreline walked surveys in the Stour and Orwell Estuaries, 38 out of 40 locations were recorded as having *Zostera* seagrasses present, with *Z. marina* seen at four of these (Lower Holbrook, Orwell Observatory, Nacton Foreshore and Strandlands in Copperas Bay). The patch estimation from shore walking indicated 3.9 ha of *Zostera* in the Stour Estuary compared to 6.2 ha in the Orwell. Of the 10.1 ha of *Zostera*, the majority (99%) was formed of *Z. noltei* with only 0.1 ha of *Z. marina*. There were new locations for *Z. noltei* where it was not recorded in the 1970s including the Bridge Wood group cluster, Freston Tower and Piper's Vale along the Orwell Estuary and Nether Hall (Harkstead) and Stutton Mill in the Stour Estuary.

In 2021, the *Zostera* area was divided into 1238 patches (Orwell: 837, Stour: 401) of greatly varying size. Approximately 67% of patches were less than 10 m^2 reflecting the small size (median patch area: 4 m^2) and high fragmentation of meadows. Only 18 patches of either *Zostera* species were ≥ 1000 m^2 (0.1 ha) representing continuous meadows covering substantial areas of intertidal mudflat and sand. The largest areas of *Zostera* were located at Nether Hall (2.13 ha), Nacton Foreshore (1.32 ha), Deer Park Lodge (Woolverstone (1.32 ha) and Orwell Park House (1.05 ha).

Considering *Z. noltei* alone, it was ≥ 0.1 ha at only 15 out of 40 sites (38%) indicating that most locations on the Stour and Orwell estuaries had only a small extent of eelgrass (Table 1). Median *Zostera* cover for summer 2021 (70%) was much higher than in the autumn 2020 surveys (48%). The coverage of mudflat and sand by *Zostera* was highly variable from site to site (0- 98%) and dense overall (median cover 70% for Orwell and 78% for Stour) in south Essex (Canvey Point 81%, Old Leigh 88%). This indicates good coverage across sites, despite the presence of macroalgae (median percentage cover 14% for both estuaries).

Of the two sites visited for shore-walking surveys in the Blackwater Estuary, and the two further sites visited for less formal opportunistic shore-walking surveys in 2021, *Zostera* seagrasses (only *Z.noltei*) were only present in St. Lawrence bay.

Drone surveys were carried out at fewer sites than what was possible by shore-walking surveys. The objective of these surveys was to obtain a visual assessment and estimation of seagrass aerial extent at some key sites and to do this beyond the field of view of shore-based surveyors. Secondly, to seek out seagrass aggregations that may not be higher intertidal *Zostera noltei*, but *Zostera marina*. *Z. marina* was observed by drone at four sites at distances further than 20m from the shore: Lower Holbrook, Nacton Foreshore, Orwell Observatory (Nacton) and Strandlands (Copperas Bay).

Large and dense widgeon grass *Ruppia maritima* aggregations were discovered at Goldhanger bay in the Blackwater. The same species was not observed in the Stour and Orwell. At Goldhanger it was predominately seen behind a sandbank in the upper intertidal.

Eutrophication of coastal mudflats by agricultural and sewage treatment inputs can result in the smothering of eelgrass by opportunistic macroalgae such as Sea Lettuce *Ulva lactuca*. Common Cordgrass *Sporobolus anglicus* has encroached on *Z. noltei* meadows, although in some cases, it may shelter eelgrass from wave action. Where *Z. noltei* has disappeared it may be worthwhile reintroducing it by reseeding or transplanting shoots. The co-ordinated conservation efforts of global seagrass organisations could be crucial in securing a future for *Z. noltei* in a changing environment.

Contents

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

This report was commissioned to inform Natural England of the location, extent and density of intertidal seagrass (*Zostera* spp.) in Essex and Suffolk, providing a baseline after major declines throughout the 20th century. The findings will fill key evidence gaps for this geographical area and will be used to inform condition assessments of designated sites. The results will also contribute to the EU LIFE Recreation ReMEDIES project for Reducing and Mitigating Erosion and Disturbance Impacts affecting the Seabed, of which Natural England is the lead partner (www.saveourseabed.co.uk).

1. Introduction

The Stour and Orwell estuaries were historically characterised by large eelgrass (*Zostera* spp.) meadows (c. 345 ha, Gardiner 2021a), detailed data for the Stour Estuary suggesting around 150 ha of *Zostera* spp. in the 1960s (Burton 1961). The bays along the Stour were well-known to fishermen for their eelgrass meadows including Copperas, Erwarton, Holbrook and Jacques Bays. *Zostera noltei* was a key component of the historic meadows along with Z. *marina*. Wasting disease led to large-scale dieback in the 1930s but it appeared that widespread eelgrass coverage remained in both estuaries (Burton 1961) and estimates of up to 380 ha have been noted (Green et al. 2021). However, by autumn 2020 only 5.4 ha remained, representing a 98% decline since the 1970s (Gardiner 2021a), although this was higher than the 1 ha thought to be extant (Green et al. 2021).

Similar historical status followed by declines in the 1930s, declines or stationary dynamics between the 30s and 70s and significant further declines between the 70s and a contemporary period of sporadic surveys including in 1996 and 2014 have been documented in the outer Thames Estuary including the Blackwater (see review by Jackson et al., 2016). Environment Agency led surveys in the late summers of 2016 and 2018 captured seagrass aggregations still existing in St. Lawrence bay, and some small patches at Stone Point (Analysis and Reporting Team, EA East Anglia 2016, 2018). No seagrasses were observed in either of these surveys at Osea Island in 2016 or 2018, but Jackson et al. notes they found widgeon grass (*Ruppia maritima*) there in 2014 and seagrasses were present there in the 1990s (Jackson et al., 2016). Other areas locally known for seagrasses in the past such as between Cudmore Grove and Colne Point have suffered significant sediment loss due to erosion and seagrasses are thought not likely to recover there, but formal surveys of these sites have not occurred for some time and new surveys to examine historical areas of Essex and Suffolk are overdue.

To provide a modern baseline for *Zostera* eelgrass in the Stour, Orwell and Blackwater estuaries in north Essex and Suffolk, a survey was undertaken in summer 2021 to follow the shore-walking survey from autumn 2020. The summer 2021 survey involved shore-walking for recording *Zostera noltei* patches and drone surveys to search for *Zostera marina* and map all seagrasses in the survey area where possible. It is the aim of this paper to report the results and present a discussion of restoration ideas based on all available information.

2. Study areas

The Stour and Orwell in south-east England (Essex and Suffolk counties) are two relatively short (length: c. 17 km and 12 km, respectively) and narrow (maximum width: c. 2 km and 1.2 km, respectively) estuaries. The estuaries straddle the Shotley Peninsula, Stour Estuary to the south, Orwell Estuary to the north. The valley hills rise to 46 m above mean sea level (AMSL) and are gently sloping to the shore (median slope gradient -4%), often with fairly steep sand and clay cliffs (median cliff slope -23%). Valley slopes of the undulating landscape are characterised by intensively managed arable farmland, occasional grazing pasture, hedgerows and woodland often ancient in origin (wooded for over 400 years). There are several urban areas along the Stour (Brantham, Manningtree, Mistley, Harwich and Shotley) and Orwell (Felixstowe and Ipswich) estuaries and two ports: Harwich International Port (Stour) and Felixstowe (Orwell). Two significant marinas exist along the Orwell Estuary (Levington and Woolverstone).

The Blackwater Estuary in mid-Essex is an area known for seagrass, bordered by arable farmland and coastal grazing marsh. Maldon is the major town in the catchment to the west where most recent and continuing seagrass observations have been made. The estuary flows easterly where it meets the Colne Estuary near Mersea Island at its eastern extent. The Colne is the major treated wastewater receiving inshore waters for Colchester and Brightlingsea, and there are up to 14 wastewater infrastructure sites in and surrounding the Maldon district as well as at Tollesbury and West Mersea all flowing into the Blackwater. Across both the Colne and Blackwater there are many household and agricultural single point source storm drains and run-offs from Septic tank systems. Both estuaries are highly modified but remain important ecologically for several marine features and wintering and breeding shorebirds. Recreational boat, commercial fishing and shellfishery activities are extensive across the Essex and Suffolk sites.

3. Recording methods

Shore-walking

The current state of *Zostera* meadows in the Stour and Orwell estuaries was first investigated using shore-walking surveys in autumn 2020 (Gardiner, 2021a), recording 5.4 ha of eelgrass (Stour: 3.1 ha, Orwell: 2.3 ha) with *Z. noltei* still extant at several sites such as Copperas Wood, Holbrook Bay and Nacton Foreshore. A shore-walking patch estimation method was again used to resurvey the 35 sites found in autumn 2020, in June and July 2021 when *Zostera* cover should be at its most extensive.

A widespread low-tide shore-walk method ensured all existing eelgrass sites were surveyed along with potential sites of (re)colonisation. The main aim was to survey all current sites for *Z. noltei* and produce an accurate estimate of eelgrass area and percentage cover at each site that is repeatable in future. The apparent patchiness of *Z. noltei* as determined from previous surveys by the EA (Kirk Markham pers.comm.) had resulted in difficulties estimating patch extent using a Global Positioning System (GPS) device to plot patch boundaries as too many patches were small (e.g. 1 x 1 m) and within the error of most equipment (c. 3-5 horizontal m). Therefore, a simpler estimation of *Zostera* area and ground cover at each site was developed.

At sites (except Nether Hall) where *Zostera* was found, a 1 ha area was searched (either 250 x 40 m or 1000 x 10 m) and the number of patches and their area (in m^2) were recorded. The area of *Z. noltei* was so extensive at Nether Hall on the Stour Estuary that a 3ha area had to be surveyed to cover the patch. For patches of *Zostera* under 10 m^2 their size was determined using a measuring tape or pacing technique. For those patches 10-999 m^2 in area, a GPS running watch (Garmin Forerunner) was used to estimate distances (accurate to 3 m) and plot the edge of patches. Extensive and continuous meadows were measured using the GPS watch and verified by measurement from aerial photographs. To accompany the area estimate for each site, four 1 x 1 m quadrats were sampled to record percentage cover of *Zostera* and opportunistic macroalgae (from Ulvaceae family) which could smother eelgrass meadows. The method developed was quick enough to allow good coastline coverage, while maintaining accuracy of *Zostera* extent and cover estimates for an assessment of the status in the two estuaries.

Two previously surveyed *Zostera* meadows were visited in the Blackwater, St. Lawrence and Goldhanger bay, while opportunistic visits were also taken to Cudmore Grove and Colne Point. Visits to Osea, Northey Island and Stone Point were not possible, but both were sampled at least twice in 2014-2018 (Jackson et al., 2014; Environment Agency, 2016, 2018).

Drone surveys

The limitation of the shore-walking technique is that observations are limited to less than 40 m from the shore due to health and safety considerations (e.g. sinking in mud) and potential damage to the beds themselves. Remotely operated drones surveyed the extensive mudflats beyond the reach of the shore walker. The main aims of these drone surveys were to find *Z. marina* meadows and any *Z. noltei* patches beyond the limit of walking, and where possible to digitally map the beds for future reference. Four sites were surveyed by drone in summer 2021 in the Stour and Orwell: Copperas Bay, Harkstead, Holbrook Bay and Nacton Foreshore; and two sites in the Blackwater: St. Lawrence and Goldhanger bay.

Two drones were used: 1) DJI Phantom 4 Pro V2 with 20 megapixel camera for seagrass mapping and still shots and 2) VJI Air 2S with a 20 megapixel camera for video footage. All drone surveys were subject to permission of access and all legal notices.

4. Results

Shore-walking: Stour and Orwell estuaries

For the shoreline walked surveys, 38 out of 40 locations were recorded as having *Zostera* seagrasses present (Table 1), with *Z. marina* seen at four of these (Lower Holbrook, Orwell Observatory, Nacton Foreshore and Strandlands in Copperas Bay). The patch estimation from shore-walking indicated 3.9 hectares (ha) of *Zostera* in the Stour Estuary compared to 6.2 ha in the Orwell. Of the 10.1 ha of *Zostera*, the majority (99%) was formed of *Z. noltei* with only 0.1 ha of *Z. marina*.

There were new locations for *Z. noltei* where it was not recorded in the 1970s including Bridge Wood group cluster, Freston Tower and Piper's Vale along the Orwell Estuary and Nether Hall (Harkstead) and Stutton Mill and Ness in the Stour Estuary.

In 2021, the *Zostera* area was divided into 1238 patches (Orwell: 837, Stour: 401) of greatly varying size (Table 2). Approximately 67% of patches were less than 10 m^2 reflecting the small size (median patch area: 4 m^2) and high fragmentation of meadows. Only 18 patches of either *Zostera* species were ≥ 1000 m^2 (0.1 ha) representing continuous meadows covering substantial areas of intertidal mudflat and sand. The largest areas of *Zostera* were located at Nether Hall (2.13 ha), Nacton Foreshore (1.32 ha), Deer Park Lodge (Woolverstone (1.32 ha) and Orwell Park House (1.05 ha).

Considering *Z. noltei* alone, it was ≥ 0.1 ha at only 15 out of 40 sites (38%) indicating that most locations on the Stour and Orwell estuaries had only a small extent of eelgrass (Table 1). Three sites had over 100 patches (Lower Holbrook, Nacton Foreshore and Strandlands). Median *Zostera* cover for summer 2021 (70%) was much higher than in the autumn 2020 surveys (48%). The coverage of mudflat and sand by *Zostera* was highly variable from site to site (0- 98%; Table 1) and dense overall (median cover 70% for Orwell and 78% for Stour) comparable in many instances to the much larger meadows (Canvey Point 7 ha, Old Leigh >100 ha; estimated from GoogleEarth 2020) in south Essex (Canvey Point 81%, Old Leigh 88%; estimated from GoogleEarth 2020). This indicates good coverage across sites, despite the presence of macroalgae (median percentage cover 14% for both estuaries).

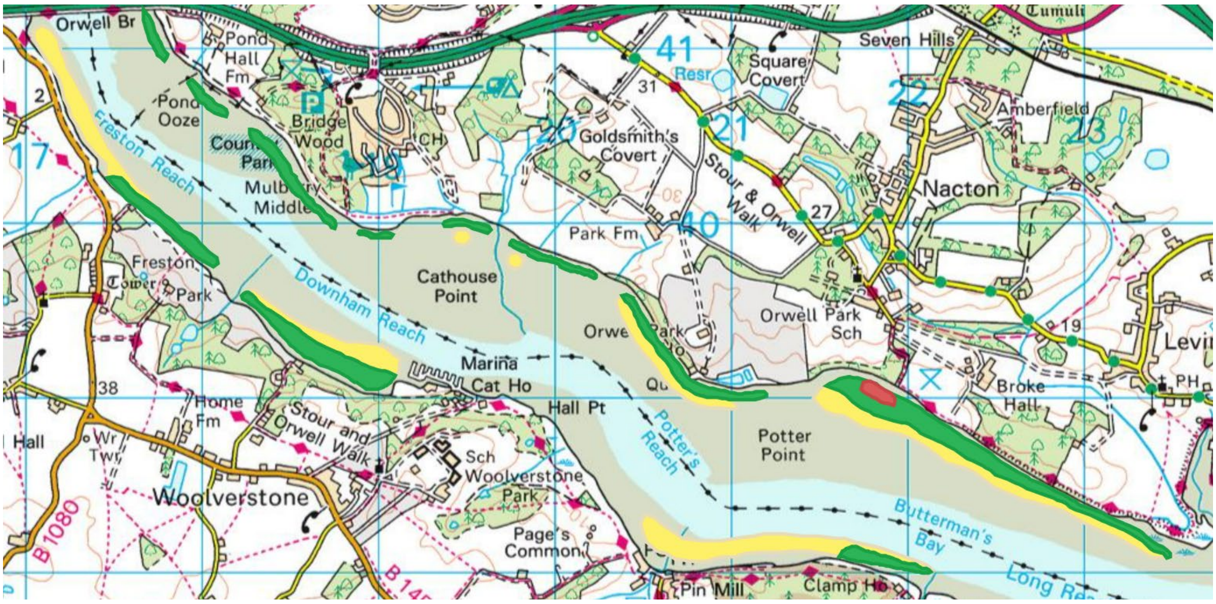

Figure 1. Current (2021) and historic (1973) extent of Zostera species in the Orwell Estuary. Key: yellow = Zostera (all species) 1973, green = Zostera noltei 2021, red = Zostera marina 2021. Contains OS data © Crown Copyright and database right 2021.

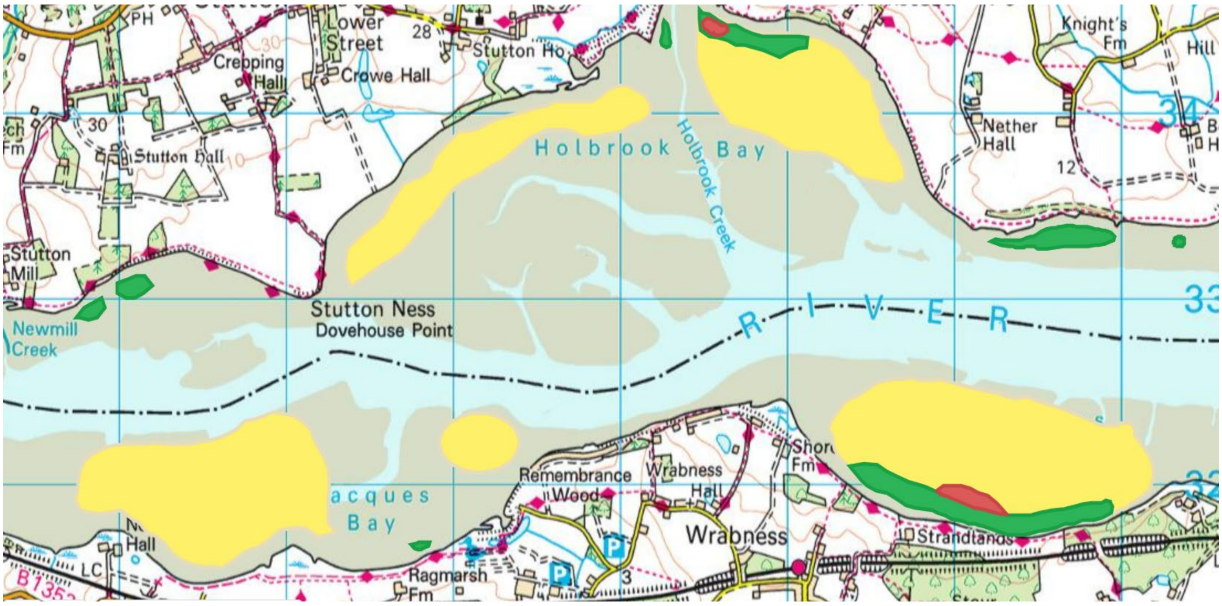

Figure 2. Current (2021) and historic (1973) extent of *Zostera* species in the Stour estuary . Key: yellow = *Zostera* (all species) 1973, green = *Zostera noltei* 2021, red = *Zostera marina* 2021. Contains OS data © Crown Copyright and database right 2021.

Blackwater estuaries

Of the two sites visited for shore-walking surveys, and the two further sites visited for less formal opportunistic shore-walking surveys in 2021, *Zostera* seagrasses (only *Z.noltei* during this survey, but *Z. marina* was found in 2023 by Emma Fox of Project Seagrass) were only present in St. Lawrence bay. While isolated blades of *Z. noltei* have been identified at Cudmore Grove, Colne Point and even West Mersea foreshores, there was no evidence of aggregations of intertidal seagrasses there in 2021 or in other recent summers. Environment Agency surveys in 2018 confirm *Z.noltei* presence on Stone Point, but not Osea Island. Walkover survey at Goldhanger bay found no seagrass aggregations, but see below for observations of other species. Including the sites at Stone Point, the total area of *Zostera* is less than a hectare making it much sparser than either the Stour or Orwell Estuaries (c. 10 ha) or the Old Leigh and Canvey area (>100 ha).

Table 1. Characteristics of the 40 survey locations on Stour and Orwell estuaries from 2021 shore-walking surveys. *Total area (ha) and patches presented and median % cover for Zostera and macroalgae. Symbol code: ++ is ≥70% Zostera cover, + is ≥10% macroalgae cover.

Estuary / Site name	Site group	*Zostera* area (ha)	Number of patches	*Zostera* % cover	Macroalgae % cover
Stour Estuary					
Nether Hall	Holbrook	2.13	24	81^{++}	23^{+}
Strandlands	Copperas	0.52	104	77^{++}	14^{+}
Lower Holbrook	Holbrook	0.45	119	87^{++}	2
Carrington Creek	Copperas	0.38	39	79^{++}	14^{+}
Long Twill	Copperas	0.33	49	84^{++}	4
Copperas Wood	Copperas	0.03	11	82^{++}	18^{+}
Harkstead	Holbrook	0.01	16	85^{++}	3
Palace Quay Bank	Holbrook	0.01	21	93^{++}	13^{+}
Stutton Ness	Stutton	<0.01	2	69	27^{+}
Stutton Mill	Stutton	<0.01	6	71^{++}	28^{+}
Palace Quay Shore	Holbrook	<0.01	2	93^{++}	5
Jacques Bay	-	<0.01	1	65	5

Estuary / Site name	Site group	*Zostera* area (ha)	Number of patches	*Zostera* % cover	Macroalgae % cover
Julie’s House	Copperas	<0.01	2	3	10^{+}
Wharf Farm Seawall	Holbrook	<0.01	0	0	99^{+}
Copperas Wood Farm	Copperas	<0.01	2	3	53^{+}
Johnny All Alone	-	<0.01	0	0	73^{+}
Stour overall*		**3.87**	**401**	**78**	**14**
Orwell Estuary					
Nacton Foreshore	Nacton	1.32	244	89^{++}	7
Deer Park Lodge	Woolverstone	1.32	63	50	55^{+}
Orwell Park House	Nacton	1.05	62	92^{++}	4
Bridge Wood	Orwell CP	0.57	57	98^{++}	2
Woolverstone Cliff	Woolverstone	0.40	30	55	28^{+}
Orwell Deer Park	Nacton	0.39	66	60	19^{+}
Orwell Observatory	Nacton	0.37	13	28	60^{+}
Orwell Oyster Beds	Nacton	0.27	21	75^{++}	5
Woolverstone Marina	Woolverstone	0.11	36	74^{++}	23^{+}
Pond Ooze	Orwell CP	0.10	56	87^{++}	8
Polly’s Cottage	Nacton	0.07	42	93^{++}	8
Nacton Quay	Nacton	0.05	13	43	24^{+}

Estuary / Site name	Site group	*Zostera* area (ha)	Number of patches	*Zostera* % cover	Macroalgae % cover
Freston Park	Freston	0.05	37	73^{++}	25^{+}
Priory Park	Orwell CP	0.05	26	93^{++}	4
Stoke Sailing Club	Freston	0.03	9	25	55^{+}
Piper’s Vale	Orwell CP	0.02	13	85^{++}	8
Monkey Lodge	Freston	0.01	8	58	5
Gun Towers	Orwell CP	0.01	3	46	15^{+}
Freston Tower	Freston	0.01	13	69	20^{+}
Butterman’s Bay	Pin Mill	<0.01	3	70^{++}	12^{+}
Pin Mill	Pin Mill	<0.01	6	70^{++}	20^{+}
Home Wood	Nacton	<0.01	8	63	13^{+}
Mansbrook Grove	Orwell CP	<0.01	6	24	19^{+}
Mulberry Middle	Orwell CP	<0.01	2	55	8
Orwell overall*		**6.21**	**837**	**70**	**14**

Table 2. Size distribution of Zostera patches (%) in the Stour and Orwell estuaries in 2021.

Patch size (m^2)	Stour	Orwell	Total	%
<10	264	567	831	(67.1)
10-99	110	218	328	(26.5)
100-999	20	41	61	(4.9)
1000+	7	11	18	(1.5)
Total	401	837	1238	(100)

Table 3. Characteristics of the 2018 Environment Agency survey on Blackwater Estuary. *Total area (ha) and patches presented and median % cover for Zostera and macroalgae. See text for 2021 survey results at St. Lawrence.

Site name	*Zostera* area (ha)	Number of patches	*Zostera* % cover	Macroalgae % cover
St. Lawrence	0.63	2	50	0
Stone Point	<0.01	18	30	30
Blackwater overall*	**0.64**	**20**	**40**	**15**

Drone survey

Drone surveys were carried out at fewer sites than what was possible by shore-walking surveys. The objective of these surveys was to obtain a visual assessment and estimation of seagrass aerial extent at some key sites (see Appendix I) and to do this beyond the field of view of shore-based surveyors. Secondly to seek out seagrass aggregations that may not be higher intertidal *Zostera noltei*, but *Zostera marina*. *Z. marina* was observed by drone at four sites at distances further than 20m from the shore: Lower Holbrook (Fig.3), Nacton Foreshore, Orwell Observatory (Nacton) and Strandlands (Copperas Bay; Fig. 4). At Lower Holbrook, Nacton Foreshore and Orwell Observatory, *Z. marina* was also seen during the shore-walking surveys but the addition of patches recorded further from the accessible shore in soft wet mud with pools at all three sites indicates the preferred poorly-drained mudflat habitat for this species. At greater distances from the shore (>100 m) no *Z. marina* was found but macroalgae was extensive in places particularly at Nacton Foreshore and Orwell Observatory (>70% cover). Confirmation of *Zostera marina* at all sites was undertaken by looking at blade length (it must be at least 30 + cm) and width (1.5-2 mm) at the nearest shore samples. Site maps with inset photographs of seagrasses observed and GPS/GIS estimated aerial extent from the 2021 surveys are provided in the Appendix I for Copperas Bay, Harkstead (Stour & Orwell), St. Lawrence bay (*Z. noltei*, Blackwater) and Goldhanger bay (*Ruppia* spp., Blackwater). Comparing them to area estimates from the shore-walking method can help place the two methods in context to each other. Drone estimated aerial extent tends to be lower compared to shore walked estimates.

Figure 3. A drone photograph at Lower Holbrook of Zostera marina. Credit: Jim Pullen.

Figure 4. A drone photograph at Strandlands of Zostera marina. Credit: Jim Pullen.

Widgeon grass (*Ruppia maritima*) sites

Large and dense widgeon grass *R. maritima* aggregations were discovered at Goldhanger bay in the Blackwater. The same species was not observed in the Stour and Orwell. To tell *Ruppia* apart from *Zostera*, the former has distinctly branched leaves while the latter does not (Fig. 5. Widgeon grass is more of a tidal lagoon species than eelgrass (Gardiner and Gardiner 2021) but was found on wetted mud and in pool areas of the intertidal in the Blackwater. At Goldhanger it was predominately seen behind a sandbank in the upper intertidal (see Appendix I). Other local sites visited opportunistically have also been found to have this species growing in the intertidal and shore-based estimates of their area are provided (Table 4).

Table 4. Widgeon grass (Ruppia maritima) locations in Essex with estimated area. Some cells are left intentionally blank.

Site name	SAC	Area (ha)
Goldhanger	Essex Estuaries	0.6
Mersea	Essex Estuaries	<0.1
The Naze	Hamford Water	0.7
Overall area		**1.3**

Figure 5. Comparison between the branched leaves of Ruppia maritima (right) and unbranched Zostera marina (left). Credits: Tim Gardiner.

5. Discussion

In the 1960s, 150 ha of *Z. noltei* was present in the Stour Estuary (unknown quantity in Orwell), which had decreased to 25 ha in 1997/8 and 3.9 ha in 2020. The reduction between the 1960s and 2021 represents a 97.3% decline. If the overall area of *Z. marina* and *Z. noltei* is considered for both estuaries combined, meadow area has declined from 345 ha in 1973 to just 10.1 ha in 2021 (97.1% decline). This catastrophic reduction relates to a loss of *Zostera* from Erwarton Bay and large parts of Copperas Bay, Holbrook Bay, Jacques Bay and Wrabness in the Stour Estuary (Fig. 2). It has disappeared from Levington, Pin Mill and Wherstead in the Orwell Estuary (Fig. 1). Similar declines are documented in the Blackwater Estuary with 37 ha present in 1976 reduced to under one hectare at present (Worley and Simpson., 1977).

It is worth noting that all the declines and estimates of current status of intertidal seagrasses in Essex and Suffolk struggle to identify an appropriate baseline with which to assess change in maximum seagrass extent, but recent attempts to reconstruct historical seagrass extent has suggested that the losses since the 1930s were preceded by much greater losses (Green et al., 2021). Such ambiguities also exist in documenting timelines of seagrass dynamics from historical literature. Jackson et al., (2016) discuss historical change in seagrass coverage at Osea Island in the Blackwater from 1960s to 2014, but on closer inspection it was found that all the reports cited for seagrasses on Osea Island referred back to surveys taken in the 1970s, i.e. no new primary survey sources were cited beyond the 1970s and their Table 1 could be misleading (Jackson et al., 2016 and references therein). This concern arises again in Gouldsmith et al. (2023) who reprints the same Table of information citing Jackson (Jackson et al. 2016). This same issue applies in aforementioned assumptions about seagrasses at Tollesbury, Mersea Island and Point Clear – where no new primary survey sources can document seagrass aggregations in any contemporary survey beyond the 1970s (Wyer et al., 1971; Jermyn 1974; Boorman and Ranwell 1977). In this scenario where we don't know when seagrasses disappeared from known sites, local ecological knowledge (LEK) is vitally important. We have been able to confirm that seagrasses were present not just on the south west shore of Osea Island in 1996 but along the northern shore as has been described in some older texts (Mark Dixon pers. comm.). The *Zostera* beds were considered to be so extensive and robust on the northern Osea Island shore that an Environment Agency funded turf translocation project was permitted in 1996, taking seagrass turf from that site to others in the area. The turfs did not take to their new sites, but reports for this work were not digitised and have since been lost. At what point after 1996 these *Zostera* beds on Osea on either the north or south-west shores became extinct is not clear. Zostera seagrassesare stated as still being present at Osea and Tollesbury/Goldhanger by Jackson et al., (2016) in 2006, but being absent by 2011 byreferencingthe Essex Biodiversity Partnership (1999) in 1999 and Chesman et al.,(2006) in 2006 respectively. Similarly LEK interviews confirmed that seagrass aggregations have been absent from Mersea, Point Clear and the Colne for many decades, certainly the late 1970s.

Despite these many unknowns, taking either the historical estimated baselines (e.g. Green et al., 2021) or the contemporary baselines of the 1930s-60s, the seagrass beds of the Stour, Orwell and Blackwater can be considered to be in *unfavourable condition*. Much of the seagrass losses can be estimated to have occurred between the1930s to at least the 1990s, with declines as strong between 1970 and 1990s/00s as they were prior to 1970s in the Blackwater. That being said there are sites in the Stour and Orwell where intertidal seagrasses were not recorded in the 1970s but are present now (e.g. Bridge Wood group cluster). Likewise where information is available, some intertidal seagrass and similar plant communities have increased in area and density over contemporary periods. However, changes in the condition and apparent presence of intertidal *Zostera* seagrasses is an often forgotten feature of their ecology. Interannual variation is a feature of these seagrass habitats and snapshot surveys of any one year can give misleading impressions of recovery or loss on different timescales. For example, while it's clear that there has been extensive loss of seagrasses in the Blackwater Estuary, the beds at St. Lawrence were estimated at 0.43, 0.67 and 0.19 hectares in 2016, 2018 and 2021 respectively. This same local dynamism has been well documented in the beds at Leigh-on-Sea (Wyer et al., 1971). Loss and re-appearance of beds may well be a common feature of seagrasses caused by environmental variation, and where suitable estuarine landscapes exist we may expect them to behave as metapopulations over longer timescales. This also applies to other intertidal plant communities that can have similar beneficial properties to seagrasses such as sediment stabilisation and carbon storage. Widgeon grass (*Ruppia maritima*) is a brackish water grass-like plant that can take annual or perennial strategies in coastal intertidal habitats. Attributing records to Gibson, Jermyn (1974) describes both *R. maritima* and *R. cirrhaso* as present in Essex and the Essex/Suffolk Stour, with *R. maritima* being present across the Blackwater, Colne, Hamford Water and the Stour. While it was not documented by Environment Agency surveys of Osea Island in 2016 & 2018, it was documented by others in 2014 at that site (Jackson et al., 2016). Jackson et al., (2016) did not document it at Goldhanger Bay but the authors found it there in 2021 (0.45 ha, see Appendix I). In shore-walking surveys that were not part of this work in 2021 we also found widgeon grass on Mersea Island and at the Naze on Hamford Water. *R. maritima* was also recorded in St. Lawrence Bay among *Z. noltei* and *Z. marina* in 2023. Understanding the role of widgeon grass in seagrass establishment, whether it is a competitor or facilitator and whether it is another nature-based solution to sediment loss and carbon sequestration warrants further investigation.

All things considered, at present the vast majority of the sites we have examined could be described as *Unfavourable maintaining*, with some sites in the Stour and Orwell as *Unfavourable recovering*. But it must be noted that the survey site may not be the appropriate scale to examine highly dynamic beds. The vulnerability of these remaining beds must also be taken into account, with bait digging activities causing major damage to the *Z. noltei* bed at Nacton on the Stour in winter 2021/22. A follow up survey to this site must occur in 2022 to examine what effects that disturbance has had relative to nearby beds that were not disturbed by bait digging. Using the larger data set from the Stour and Orwell, we find that macroalgae cover is negatively related to seagrass cover. It has often been assumed that macroalgae encroachment will damage seagrasses, but there are some indications that this is only when it is extensive and very thick layers of algae.

Macroalgae relationships with seagrass is not a new phenomenon, with potential negative effects of excessive macroalgae growth on seagrass beds identified in the 1970s (e.g. Boorman & Ranwell, 1977). There is no clear conclusion on the role of nutrient pollution of affecting seagrasses directly, but it is generally assumed that by providing subsidy to opportunistic microalgae, eutrophication encourages algal growth which creates a stressful environment for seagrasses when they are trying to gain resources and set seed.

When considering seagrass restoration, in the short-term it may be prudent to attempt reintroduction at sites from which seagrass is known to have been lost (Table 5, Fig. 6 and Fig. 7). The key is to ensure that the reason for extirpation is not still acting on the intertidal areas (e.g., bait digging, boat damage, opportunistic macroalgae blooms, pollution, erosion and sedimentation). However, for reasons discussed above we might not know why seagrasses have been lost in part because we don't know when they have been lost. In this survey, *Z. noltei* was the most abundant and widespread of the two eelgrass species and despite disappearing from two sites due to macroalgae it appears to spread quite quickly at existing locations in the Stour and Orwell. At several sites where it is precariously existing in small patches, e.g. Stone Point in the Blackwater, restoration should be considered. There is also an argument that intervention for *Zostera noltei* restoration is not needed, as it will recover when and where conditions allow due to local seed banks, and it may already be in all places where conditions allow (Ranwell et al., 1974).

Z. marina which now forms just 1% of eelgrass cover in the two Suffolk estuaries and despite historical records had not been seen in the Blackwater for some time until that one single shoot was found on a subtidal survey at Tollesbury in 2018 by TC/JP, is a major priority for further investigation. The drone surveys have shown that *Zostera marina* has largely disappeared from the mudflats further from the shore so research should focus on whether the conditions at these sites would be suitable for this species in the lower intertidal and subtidal, should a seedbank be provided. If that is the case then restoration should focus on re-establishing meadows at Lower Holbrook, Nacton Foreshore, Orwell Observatory and Strandlands in Copperas Bay, and in the upper Blackwater near Osea.

Transplantation of seagrass shoots can be used as a restoration method (Ward et al. 2020), although this method may be susceptible to failure due to genetic bottlenecks in small establishing meadows (Jahnke et al. 2015). In the UK the presence of the burrowing worm *Nereis diversicolor* led to poor establishment of transplants, perhaps due to the plant fragments being grasped and dragged into their holes by the ragworms (Hughes et al. 2000). While areas with *N. diversicolor* could be avoided when choosing transplantation sites, this may be challenging in these southern North Sea estuaries as it is a ubiquitous species. In an open coast Marine Park in Portugal, *Z. noltei* transplants from the Sado Estuary did not survive 100 days after planting, with winter storms probably the cause of failure (Paulo et al. 2019). This is not a new approach or finding as similar transplant attempts in Norfolk, Suffolk and in Essex in the 1970s and 1990s also had mixed results (Ranwell et al., 1974; M.Dixon pers comm.). Storm damage or wave energy may not be a problem in the narrow Orwell Estuary where fetch is low (mean 1.3 km), but the Blackwater is renowned for significant storm turbulence (mean fetch 2 km), particularly with strong easterlies while the Stour Estuary is exposed too (mean fetch 2.1 km) (Cousins et al. 2017, Gardiner 2021b). While others have described Essex sites as low wave energy (Jackson et al., 2016), the difference between the predicted energy of seagrass present and absent sites was relatively small and further work to parametrise this modelling approach may prove useful in selecting sites for shoot or turf transplants.

In the Wadden Sea some success has been achieved with shoot transplants; *Z. noltei* persisting at 4 out of 7 transplant sites for at least 2 years (van Katwijk et al. 2009). One site lasted for over 10 years, while *Z. noltei* merged with a nearby meadow at two more. This evidence of success indicates that shoot transplants may be an effective method of re-establishing meadows. However, caution must be exercised when using shoots from small meadows so that the donor populations are not endangered.

The alternative to transplantation of shoots is reseeding after collection of seeds from existing meadows. Seeds, contained within a green capsule with membranous walls, are negatively buoyant and may sink into holes created by shellfish and establish new plants. Therefore, reseeding may mimic this process by planting seeds into shallow holes. It may be possible to incorporate *Z. noltei* establishment into schemes such as salt marsh terraces to aid flood defence and reduce wave erosion (Naylor et al. 2018). Project Seagrass is currently undertaking a largescale programme of *Z. marina* reseeding in the UK using weighted hessian sacks with seeds dropped onto the seabed in subtidal areas (Unsworth et al. 2019), and trials using *Z. noltei* in the Essex and Suffolk estuaries are imminent. Trial seagrass restoration is afoot in the UK with the EU LIFE program funding for the ReMEDIES project resulting in seeding in Plymouth and the Solent using seed ‘pillows’ and direct injection into the seabed (project website www.saveourseabed.co.uk.)

There are now opportunities to combine dredged materials with re-seeding of *Zostera* spp. seagrasses, a beneficial use of dredged materials, where historical sediment loss is a driver of previous seagrass loss or to utilise seagrasses to better stabilise any sediment recharge. Pumped dredge material could be trialled on the Stour and Orwell, with a possible location at Levington Marina having been discussed with HHA partners.

In conclusion, the restoration options for the Stour, Orwell and Blackwater estuaries are:

1. Recovery by nature for *Z. noltei* at most sites with monitoring (Table 5)
2. Re-establishment of *Z. marina* at four sites to extend meadow patches (Table 5)
3. Understand mechanisms of and barrier to natural recovery of *Zostera* sp.
4. Monitoring of all existing sites at 5-yearly intervals
5. Trial alternative seed bank based restoration methods
6. Monitoring of re-establishment sites where restoration has taken place

Further work to understand the limits to natural recovery of seagrass meadows in the Blackwater is necessary to make similar decisions as for the Stour & Orwell (e.g. Table 5). This includes surveys of other historical sites including re-visiting Osea and Northey islands, Mersea Island, Tollesbury, St Oysth/Point Clear and the Dengie peninsula. In August 2023, the first small-scale *Z. noltei* restoration trial (240 core transplants) was undertaken in St. Lawrence Bay, led by Emma Fox of Project Seagrass in conjunction with the Environment Agency, Essex Wildlife Trust and Natural England. It is hoped trials can be completed on the Stour and Orwell in future depending on the success at St. Lawrence.

Table 5. Restoration options and priority for Stour and Orwell eelgrass sites with habitat characteristics. Analysis by TG based on Z. marina given higher priority, then sites where apparent recovery is slow or beds are currently small and fragmented.

Site Number	Estuary / Site name	*Sporobolus* within 10m	Substrate	Restoration options	Priority
Stour Estuary					
1	Nether Hall	Yes	Mud/sand	Recovery by nature	None
2	Strandlands	Yes	Mud/sand	Restore *marina*	High
3	Lower Holbrook	Yes	Mud/sand	Restore *marina*	High
4	Carrington Creek	Yes	Mud/sand	Recovery by nature	None
5	Long Twill	Yes	Mud/sand	Recovery by nature	None
6	Copperas Wood	Yes	Mud/sand	Recovery by nature	None
7	Harkstead	Yes	Mud	Recovery by nature	None
8	Palace Quay Bank	No	Sand	Recovery by nature	None
9	Stutton Ness	No	Mud/sand	Restore *noltei*	Medium

Site Number	Estuary / Site name	*Sporobolus* within 10m	Substrate	Restoration options	Priority
10	Stutton Mill	No	Mud	Restore *noltei*	Medium
11	Palace Quay Shore	No	Mud/sand	Recovery by nature	None
12	Jacques Bay	Yes	Mud/sand	Restore *noltei*	Medium
13	Julie's House	Yes	Mud	Recovery by nature	None
14	Wharf Farm Seawall	No	Mud	Restore *noltei*	Low
15	Copperas Wood Farm	No	Mud	Recovery by nature	None
16	Johnny All Alone	No	Mud/sand	Restore *noltei*	Low
Orwell Estuary					
1	Nacton Foreshore	Yes	Mud/sand	Restore *marina*	High
2	Deer Park Lodge	Yes	Mud/sand	Recovery by nature	None
3	Orwell Park House	Yes	Mud/sand	Recovery by nature	None
4	Bridge Wood	Yes	Mud/sand	Recovery by nature	None

Site Number	Estuary / Site name	*Sporobolus* within 10m	Substrate	Restoration options	Priority
5	Woolverstone Cliff	Yes	Mud/sand	Recovery by nature	None
6	Orwell Deer Park	Yes	Mud	Recovery by nature	None
7	Orwell Observatory	Yes	Mud	Restore *marina*	High
8	Orwell Oyster Beds	Yes	Mud/sand	Recovery by nature	None
9	Woolverstone *Marina*	No	Mud	Recovery by nature	None
10	Pond Ooze	Yes	Mud/sand	Recovery by nature	None
11	Polly's Cottage	Yes	Mud/sand	Recovery by nature	None
12	Nacton Quay	Yes	Mud/sand	Recovery by nature	None
13	Freston Park	Yes	Mud	Recovery by nature	None
14	Priory Park	Yes	Mud/sand	Recovery by nature	None
15	Stoke Sailing Club	Yes	Mud	Recovery by nature	None
16	Piper's Vale	Yes	Mud	Recovery by nature	None

Site Number	Estuary / Site name	*Sporobolus* within 10m	Substrate	Restoration options	Priority
17	Monkey Lodge	No	Mud	Recovery by nature	None
18	Gun Towers	Yes	Mud	Recovery by nature	None
19	Freston Tower	No	Mud	Recovery by nature	None
20	Butterman's Bay	Yes	Mud/sand	Restore *noltei*	Medium
21	Pin Mill	Yes	Mud/sand	Restore *noltei*	Medium
22	Home Wood	No	Mud/sand	Recovery by nature	None
23	Mansbrook Grove	Yes	Mud	Recovery by nature	None
24	Mulberry Middle	No	Mud/sand	Recovery by nature	None

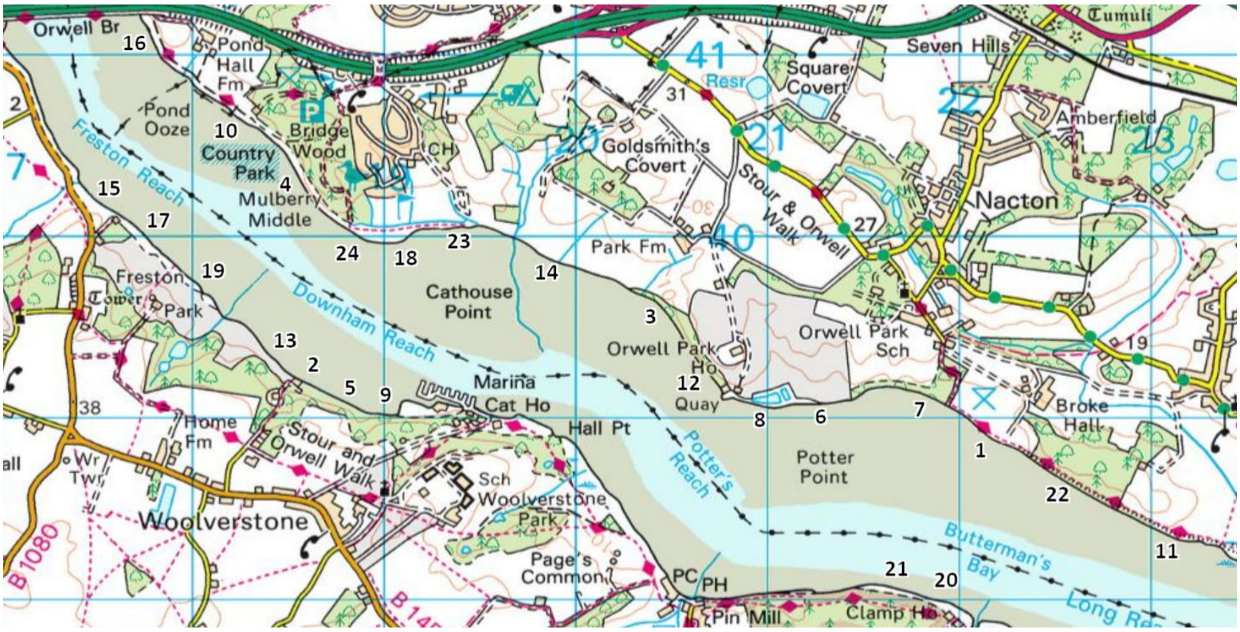

Figure 6. Orwell estuary eelgrass monitoring site locations 1 to 24, see Table 1 for more information about each site and Table 5 for restoration options and priority for Orwell eelgrass sites, with habitat characteristics. Contains OS data © Crown Copyright and database right 2021.

Figure 7. Stour estuary eelgrass monitoring site locations 1 to 16 see Table 1 for more information about each site and Table 5 for restoration options and priority for Stour eelgrass sites, with habitat characteristics. Contains OS data © Crown Copyright and database right 2021

List of Figures and Tables

Appendix I

These Unmanned Aerial Vehicle (UAV) or drone images and digital surface elevation models are credited to Jim Pullen. Copyright permission has been fully granted. All drone surveys were subject to permission of access and all legal notices.

Copperas Bay

Figure 8. This aerial image taken by drone shows Copperas Bay, Stour estuary observable over an area of 24,220 m2. The red line in the image shows the outline of the area in which Zostera was recorded.

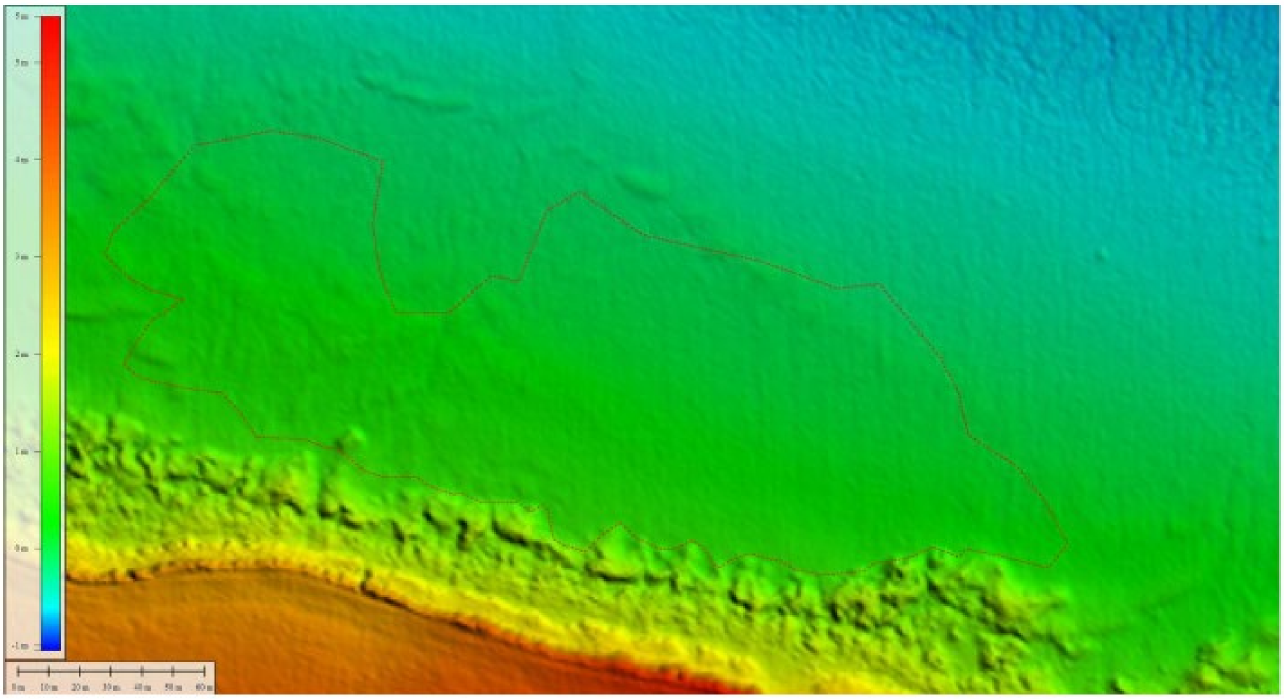

Figure 9. This digital surface model shows the Zostera area at Copperas Bay (with the red line boundary) superimposed on the coastal elevation data (height Above Ordnance Datum (m)). The Zostera area is at a depth of less than 1 metre.

Harkstead

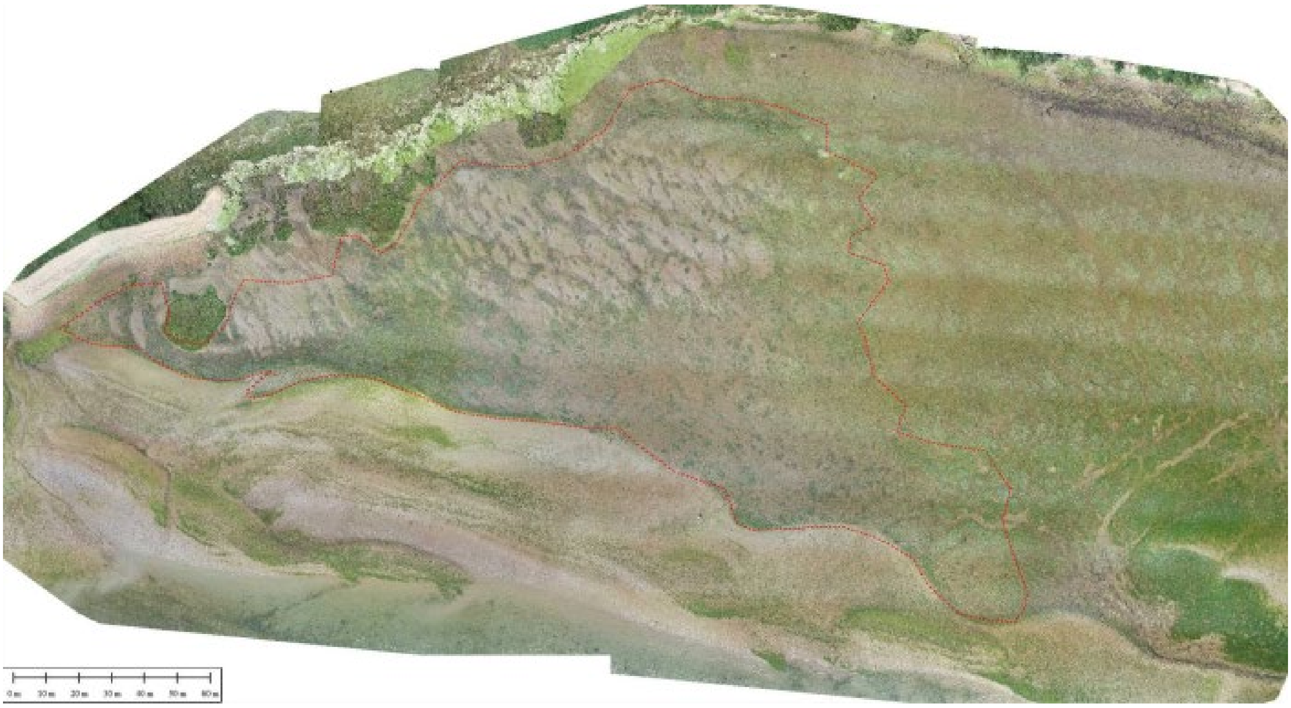

Figure 10. This aerial image taken by drone shows Harkstead, Stour estuary observable over an area of 18,724 m2. The red line shows the outline of the area in which Zostera was recorded.

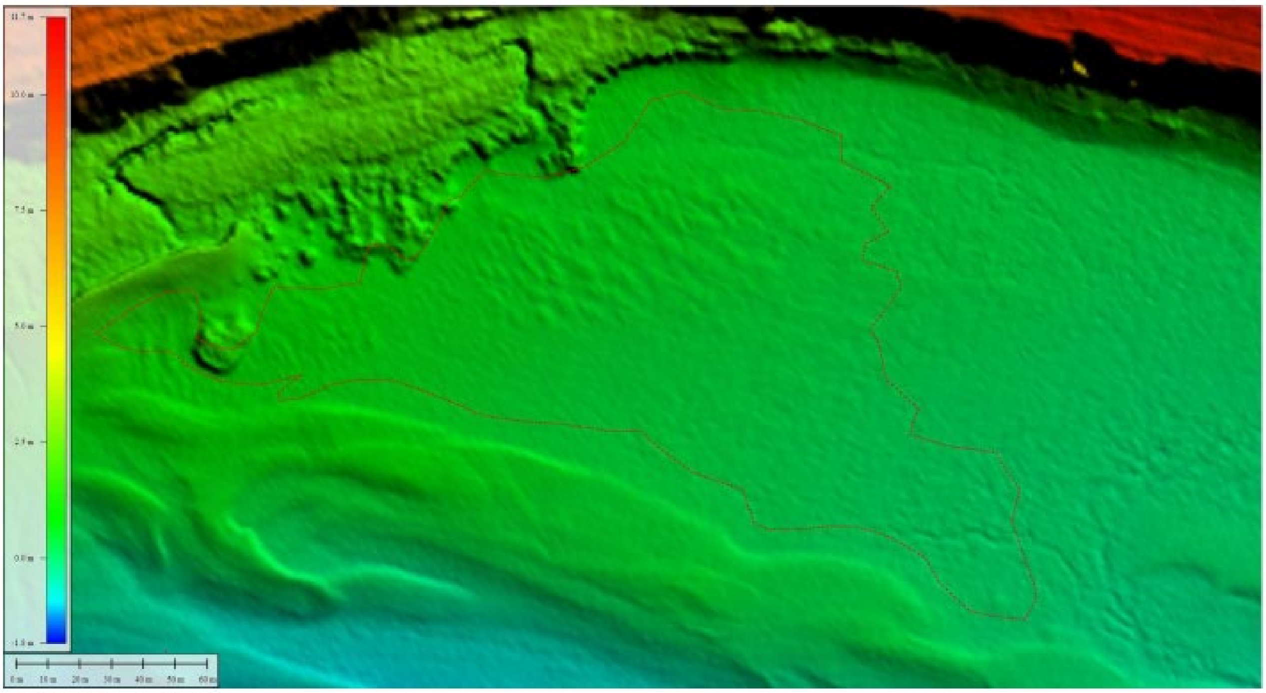

Figure 11. This digital surface model shows the Zostera area at Harkstead (with the red line boundary) superimposed on the coastal elevation data (height Above Ordnance Datum (m)). The Zostera area is at a depth of less than 2 metres.

Goldhanger

Figure 12. This aerial image taken by drone shows Goldhanger, Blackwater estuary observable over an area of 4,540 m2. The red line in the image shows the outline of the area in which Ruppia was recorded.

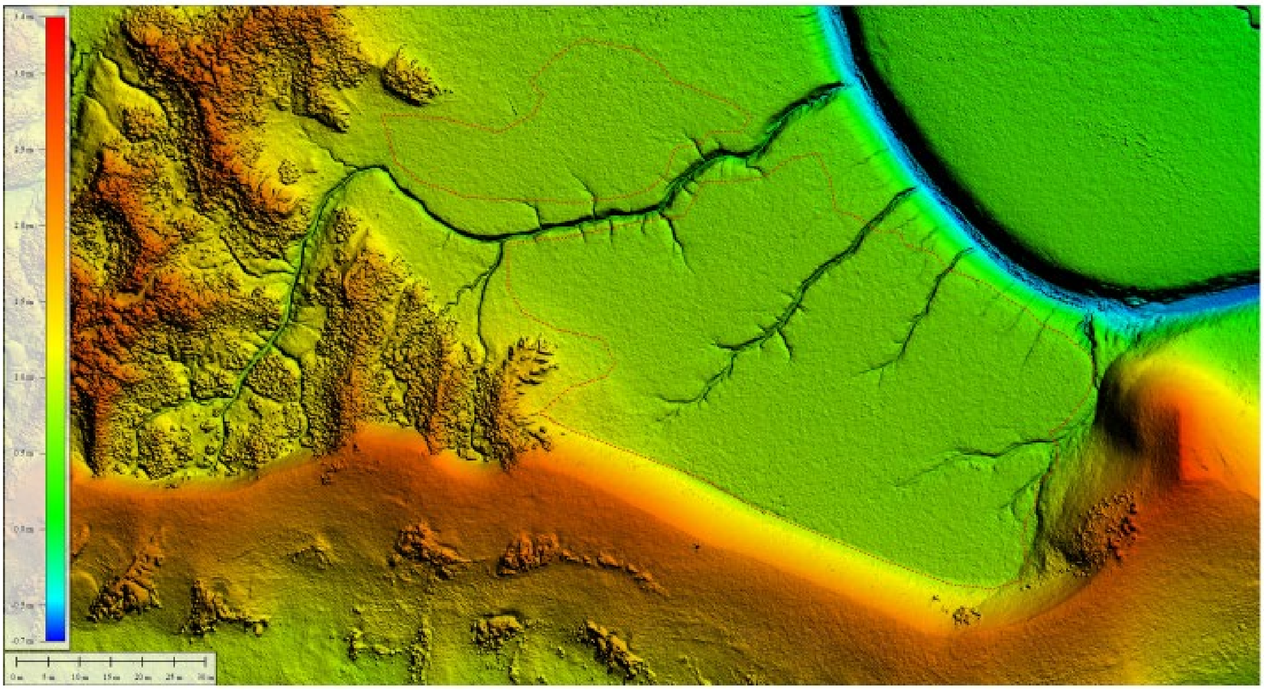

Figure 13. This digital surface model shows the Ruppia area at Goldhanger (with the red line boundary) superimposed on the coastal elevation data (height Above Ordnance Datum (m)).The Ruppia area is at a depth between 0.5 to 1 metre.

St. Lawrence

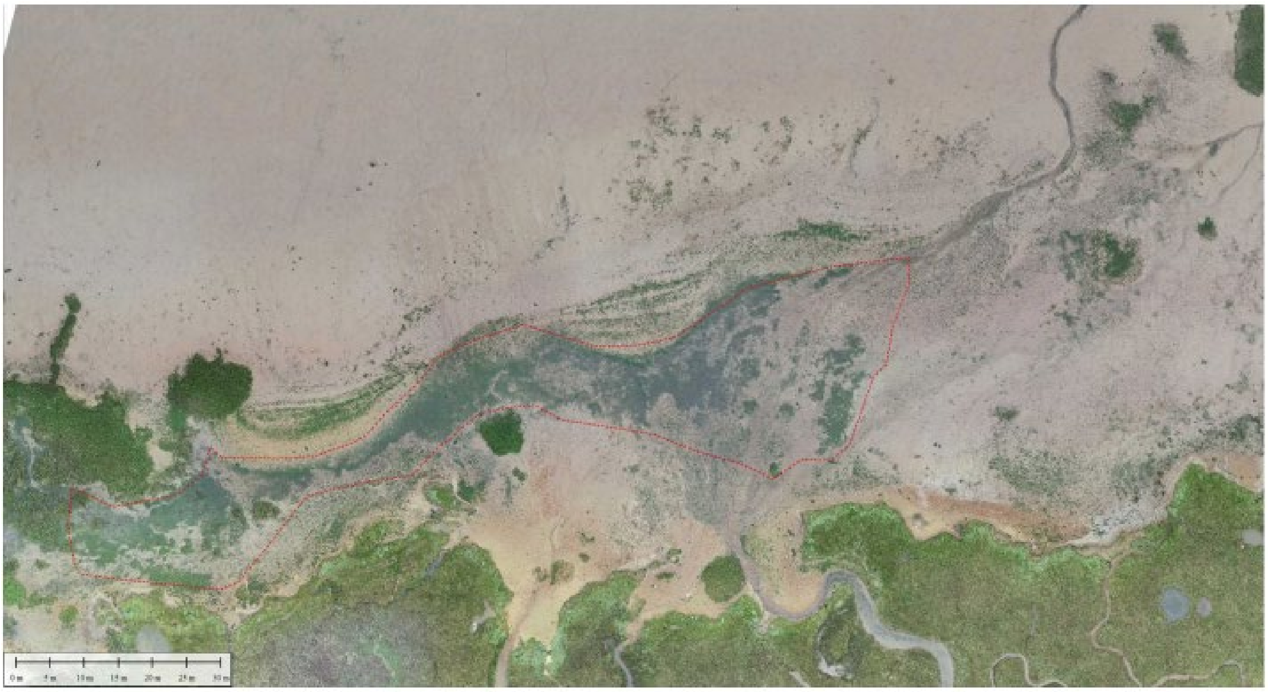

Figure 14. This aerial image taken by drone shows St. Lawrence, Blackwater estuary observable over an area of 1,916 m2. The red line in the image shows the outline of the area in which Zostera was recorded.

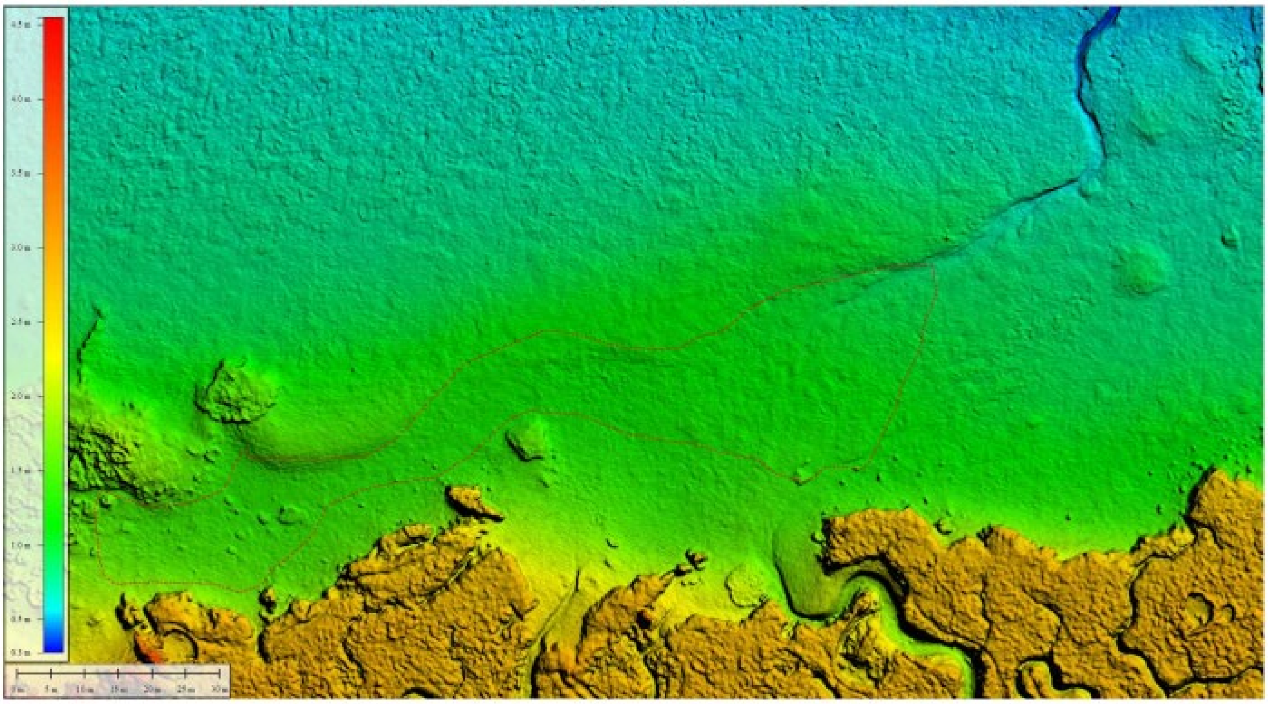

Figure 15. This digital surface model shows the Zostera area at St. Lawrence (with the red line boundary) superimposed on the coastal elevation data (height Above Ordnance Datum (m)). The Zostera area is at a depth between 1 to 1.5 metres.

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